An exploration of the life course determinants of oral health in the United Kingdom

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Abstract

Poor oral health has a substantial impact at both an individual and societal level and develops across the life course. This research explored the life course determinants of oral health in the UK, addressing an existing lack of research in this field.

This mixed-methods research utilised an existing longitudinal prospective birth cohort study – the Newcastle Thousand Families Study – which recruited 1,142 babies born in Newcastle upon Tyne in 1947. Twenty in-depth interviews were conducted with participants at age 67, to explore what influenced how they looked after their oral health across the life course. The broader life course determinants of age 63 tooth retention in this cohort were subsequently modelled using path analysis techniques.

The interviews revealed that a range of factors influenced oral health behaviours, centring around four sources: the dental profession, wider society (e.g. schools, peers, the media), family members and the individuals themselves. Determinants varied to some extent between different behaviours and also across the life course. Parents were reportedly the predominant influencers in childhood, whilst individual-level and peer influences played a major role during the transition to independent adulthood. Throughout independent adulthood, influences were diverse, although, notably, family influences transferred from parents to spouses and children, especially the former.

The path analysis demonstrated that multiple factors across the life course influenced age 63 tooth retention, including smoking and dental attendance, socio-economic determinants, dental anxiety, sex and parental encouragement. However, the potential influence of unmeasured factors (specifically sugar consumption) could not be established due to data limitations.

Subject to potential differences between this 1947 cohort and contemporary generations, this research suggests that oral health interventions should target an array of behavioural, social and psychological factors at the level of individuals, families, society and the dental profession, prioritising the most appropriate determinants at each life course stage.

Dedication

This thesis is dedicated to the memory of Professor Jimmy Steele, an inspiring mentor and friend.

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Chapter 1: Introduction

1.1: The problem

Oral health has been defined as "the ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and without pain, discomfort and disease of the craniofacial complex" (Glick et al. 2016). Such diseases and disorders of the craniofacial complex affecting oral health can be wide-ranging, including, but not limited to, caries, periodontal disease, tooth loss, head and neck cancer, temporomandibular disorders and other soft tissue and bony diseases and disorders (WHO 2020a).

Oral health is important on an individual level, due to the significant impact it can have on quality of life (Sischo and Broder 2011) and also the impact it can have on general health (Dorfer et al. 2017). In addition, it also has a huge economic impact at a societal level, due to the extensive costs of treating dental disease but also due to economic productivity losses mainly incurred by absenteeism from work (Listl et al. 2015).

Unfortunately, poor oral health is epidemic worldwide. According to the 2015 Global Burden of Disease Study, untreated dental caries in permanent teeth was estimated to be the most prevalent disease globally, whilst oral diseases were estimated to affect almost half of the world's population (Kassebaum et al. 2017). The prevalence of oral disease is equally a public health problem in the UK. The 2009 UK Adult Dental Health Survey (ADHS) estimated that 6% of the adult population were edentulous (Fuller et al. 2011), 31% had obvious tooth decay (White et al. 2011) and 9% reported current pain related to their teeth (Steele et al. 2011).

If the burden of poor oral health is to be successfully addressed, researchers must thoroughly understand the origins and determinants of oral health, so that actions and interventions can be targeted towards these factors. Unfortunately, the determinants of oral health are far from straightforward, involving a complex interplay between biological, behavioural, environmental, psychological and social mechanisms (Watt et al. 2015). Moreover, a review of existing knowledge and literature conducted as part of this research highlighted significant gaps in two key research areas relating to the determinants of oral health in the UK: 1) qualitative investigations exploring in depth the psychological and social processes across the life course which influence oral health, and 2) quantitative research comprehensively investigating the contributions of determinant factors across the whole life course to oral health.

1.2: Research aims and overview

This research aimed to further understand the life course determinants of oral health in the UK. This was achieved via two specific objectives: 1) to explore the factors across the life course which influence how and why people look after their oral health, and 2) to quantitatively model the contributions of determinant factors across the life course on individuals' oral health.

The above objectives were achieved via two methods, both utilising data from a North-East England 1947 birth cohort, the Newcastle Thousand Families Study (NTFS) cohort (Pearce et al. 2009b). The first utilised qualitative interviews with twenty participants to explore the factors influencing how and why they looked after their oral health across their life course. The second utilised quantitative path analysis techniques to model pathways between predictor variables across the whole life course and tooth retention at age 63 in this cohort.

To the author's knowledge, this research was the first to qualitatively explore the factors influencing people's oral health behaviours (OHBs) from a life course perspective in the UK, and the first worldwide to quantitatively model the life course determinants of oral health past early adulthood, using prospective birth cohort data and appropriate causal modelling techniques. Such novel evidence is critical for the design of appropriate and effective oral health interventions.

1.3: Thesis organisation

This thesis is split into seven chapters. Following this first introductory chapter, Chapter 2 reviews the existing knowledge and literature relating to the determinants of oral health. Chapter 3 documents the overall methodology and methods pertaining to this research. Chapters 4 and 5, respectively, document the results of the qualitative and quantitative analyses conducted in this research. Chapter 6 subsequently discusses the findings of this research in the context of its strengths and limitations, and within the context of existing knowledge and the current policy and practice environment. Finally, Chapter 7 provides a succinct summary of final conclusions and recommendations.

Chapter 2: Literature Review

This chapter firstly outlines why poor oral health is a major concern affecting society and why it is important for researchers and decision makers to have a clear understanding of the determinants of oral health. The majority of this chapter is then dedicated to reviewing the current evidence base regarding the determinants of oral health, with a particular focus on oral health in the UK. At the end of this chapter, a summary of current knowledge and evidence gaps is provided and the aims and objectives of this research outlined.

2.1: Search Strategy

This literature review is not a systematic review. In Sections 2.2 to 2.9, the intention is to provide an overview of a large body of evidence relating to the extent and impact of poor oral health, the importance of understanding the determinants of oral health and, subsequently, the biological, behavioural, environmental, psychological and social determinants of oral health. However, a comprehensive review of all of these topics would be beyond the scope of a PhD. In Sections 2.10 to 2.14, although still not a systematic review, the intent is to provide a more comprehensive review of the literature exploring the determinants of oral health using particular approaches, specifically quantitative life course approaches (particularly those using causal pathways modelling techniques) and qualitative approaches, especially in relation to the UK. These topics are of particular relevance to the focused objectives of this research and, therefore, it is important that all relevant previous research on these topics is identified.

The strategy that was used to identify the relevant literature for this review involved primarily using MEDLINE® and PubMed® to identify peer-reviewed literature. Secondarily, additional peer-reviewed literature, books and other grey literature were identified using the author's existing knowledge, reference lists in identified literature, the supervisory team's knowledge and internet searches. Table 1 provides an overview of the search terms used, which were utilised in various combinations. Column 1 lists the main terms used to explore key topics of relevance, whilst Column 2 provides examples of subsequent search terms used to explore more focused topics.

Literature from any time frame was potentially relevant to this review and, hence, no time limitations were set for the searches. Nevertheless, this review does intend to be a contemporary review of the literature and, hence, the most up-to-date evidence was included where possible. The literature was continuously reviewed throughout the PhD study period up until the end of November 2020 (shortly before re-submission). Any relevant new evidence published prior to this date is, therefore, included in this thesis.

Main search terms	**Subsequent search terms**
Oral health* Life course Determinants Aetiology United Kingdom* Qualitative research* Structural equation modelling Path analysis Causal pathways Birth cohort Cohort studies* Longitudinal studies* Prospective studies* Tooth loss* Dental caries* Periodontal diseases*	Genetics* Dental plaque* Systemic diseases Obesity* Oral hygiene* Tooth brushing* Smoking* Diet* Sugars* Dental anxiety* Dental attendance Fluoridation* Knowledge* Culture* Attitude* Stress Psychology* Social determinants of health* Socioeconomic factors* Social class* Education* Health care systems Public health*

Table 1: Overview of search terms used to aid the literature review.
**MeSH terms*

2.2: The extent and impact of poor oral health

Poor oral health is a major public health concern both globally and in the UK. According to the 2015 Global Burden of Disease Study, 48% of people were affected by oral conditions (Kassebaum et al. 2017), with dental caries, periodontal disease and tooth loss being the most common conditions (Dye 2017). Specifically, untreated dental caries in permanent teeth was estimated to affect 34.1% of the world's population (Kassebaum et al. 2017), with figures for severe periodontitis and severe tooth loss being 7.8% and 4.1% respectively (Kassebaum et al. 2017). Studies also show that non-carious tooth surface loss is highly prevalent in many countries, with the global prevalence of severe tooth surface loss estimated to increase from around 3% in early adulthood to around 20% in later adulthood (Van't Spijker et al. 2009).

In the UK, the prevalence of oral conditions is equally problematic. The 2009 ADHS estimated that 6% of the population were edentulous (Fuller et al. 2011), 31% of dentate adults had obvious tooth decay (White et al. 2011), 45% had levels of periodontal pocketing associated with disease (White et al. 2011), and 17% exhibited moderate or severe tooth surface loss in their anterior teeth (White et al. 2011). The 2013 UK Child Dental Health Survey additionally found that 46% of fifteen year-olds and 31% of five year-olds had obvious decay in their permanent teeth and primary teeth respectively (Health and Social Care Information Centre 2013).

The prevalence of some oral conditions is reducing over time, whereas, for others, the prevalence is remaining stable or even increasing (Marcenes et al. 2013; Steele et al. 2012; White et al. 2012). For example, the prevalence of edentulism in adults in England has reduced from 20% in 1988 (Todd and Lader 1991) to 14% in 1998 (Kelly et al. 2000) and, finally, to 6% in 2009 (Chenery 2011). However, the overall prevalence of tooth surface loss in dentate adults in England has increased from 66% in 1998 to 76% in 2009 (White et al. 2011).

All sections of the population are also affected by oral diseases. Although the prevalence of some diseases, such as total tooth loss, predominantly affects older adults (Fuller et al. 2011), other diseases, such as untreated caries, are prevalent across all age groups (White et al. 2011). Equally, all socio-economic groups are affected, even if the risk of some diseases increases in the lower socio-economic class groups (Fuller et al. 2011; White et al. 2011).

The impact of oral conditions and diseases is significant. On an individual basis, there is an extensive body of literature supporting the substantial impact oral conditions can have on quality of life and daily activities (O'Dowd et al. 2010; Rousseau et al. 2014; Sischo and Broder 2011). According to the 2009 UK ADHS, 21% of adults reported having difficulty eating and 15% difficulty smiling due to oral impacts (Nuttall et al. 2011b). There is also now a growing body of evidence regarding the systemic impact of oral health problems (Dorfer et al. 2017; Linden et al. 2013; Simpson et al. 2015). For example, the presence of periodontitis has a very clinically relevant impact on diabetes control (Simpson et al. 2015), whilst strong evidence suggests that periodontitis increases future risk for cardiovascular disease (Tonetti and Van Dyke 2013).

At the societal level, oral conditions are costly and place a large demand on resources. Conservative estimates found the global economic impact of dental diseases in 2010 to be US $442 billion, comprising US $298 billion due to direct treatment costs (an average of 4.6% of global health expenditure) and US $144 billion due to economic productivity losses (Listl et al. 2015). In the UK, the NHS in England alone spends around £3.4 billion on dental services per year (NHS England 2014), and this does not take into account additional costs resulting from productivity losses or the impact of oral conditions on systemic health.

2.3: The importance of understanding the determinants of oral health

Accepting that oral conditions present a significant problem to individuals and society, improving oral health has been identified as an urgent priority both globally and in the UK (DoH 2005; WHO 2003). However, an essential prerequisite to the effective improvement of oral health is a thorough, in-depth understanding of its complex causes and determinants. Only by understanding the pathways to poor oral health can effective interventions be devised. This concept that the determinants of poor oral health must be thoroughly understood provides the basis for this research project.

2.4: Determinants of oral health - current evidence

In recent years there has been a significant shift in beliefs about the determinants of oral health. It has been increasingly recognised that determinants of oral health are not limited to conventional biological factors (such as genetics and microbiological factors) or behavioural factors (such as smoking and oral hygiene behaviours), but that determinants of oral health include a much wider array of social, political, economic and environmental factors, collectively known as the social determinants of health (DoH 2005; Marmot and Bell 2011; Watt et al. 2015; Watt 2007). This modern view is illustrated in Figure 1, whereby upstream social factors influence the more downstream, proximal determinants of health. This shift in perspective has accompanied similar increasing recognition of the wider, social determinants of general health over the past few decades (Commission on Social Determinants of Health 2008; Marmot 2010).

Additionally, it is now recognised that life course models are applicable in the development of the majority of oral diseases (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015), that oral diseases develop via complex pathways, which cannot be modelled by simple statistical methods but require more complex causal modelling techniques (Crall and Forrest 2018; Newton and Bower 2005; Nicolau et al. 2007b), and that qualitative research methods are paramount if the underlying psycho-social processes influencing oral health and behaviours are to be understood (Bower and Scambler 2007; Newton 2001; Newton and Bower 2005).

Therefore, this literature review will firstly detail the evidence regarding the determinants of oral health from biological, behavioural, environmental, psychological and social perspectives. Secondly, it will review the evidence utilising a life course approach, the use of causal pathways modelling techniques and the use of qualitative evidence to explore the determinants of oral health.

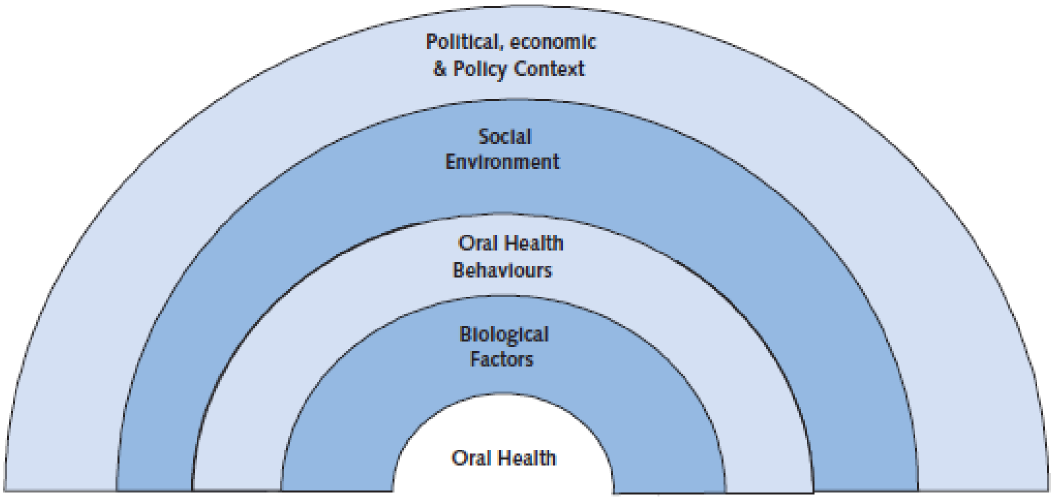

Figure 1: The underlying causes of oral health. Reproduced from (DoH 2005).

2.5: Biological determinants

Biological determinants of oral diseases include microbiological and host factors (Bartold and Van Dyke 2013; Selwitz et al. 2007), the latter including factors such as genetics (Loos and Chin 2017; Opal et al. 2015), systemic diseases (Albandar et al. 2018; Nascimento et al. 2018), anthropometrics (Keller et al. 2015) and age (Lopez et al. 2017). Research into the biological determinants of oral diseases is extensive (Bartold and Van Dyke 2013; D'Aiuto et al. 2017; Loos and Chin 2017; Takahashi and Nyvad 2011). In some areas, understanding is now quite comprehensive (Preshaw and Bissett 2019; Smith et al. 2017). However, in other areas, significant uncertainties exist (Loos and Chin 2017; Opal et al. 2015).

It has long been known that micro-organisms play a key role in many oral diseases (Gibbons and van Houte 1975). Specifically, it is undisputed that plaque bacteria are essential in the development of dental caries (Selwitz et al. 2007) and periodontal disease (Bartold and Van Dyke 2013), and that fungi (Farah et al. 2010) and viruses (Clarkson et al. 2017) are responsible for several oral infections. With regards to plaque and the development of caries, the microbiological process is complex. Numerous bacteria are known to be involved, but the exact mechanism and role of different bacteria is not exactly clear, most likely changing with the conditions of the surrounding biofilm and between individuals (Peterson et al. 2011; Takahashi and Nyvad 2011). For periodontal disease, although it is accepted that bacteria are required to initiate and progress periodontitis, the key determinant of disease progression is the host response to the microbial challenge, not the type of bacteria (Bartold and Van Dyke 2013). In the case of oral cancer, evidence supports a significant role of viruses, including the human papillomavirus (HPV) and Epstein-Barr virus (Hettmann et al. 2016). A recent global meta-analysis found that over 70% of oro-pharyngeal cancers contained HPV, although the prevalence was much lower in non oro-pharyngeal head and neck cancers (Mehanna et al. 2013).

Although micro-organisms play a key role in many oral diseases, they are certainly not the sole biological determinants of disease development. Host factors, including the host immune response (Cekici et al. 2014), salivary flow and composition (De Almeida Pdel et al. 2008), and enamel formation and development (Costa et al. 2017) are also key determinants of oral disease. Such factors are, in turn, influenced by aspects such as genetics (Laine et al. 2012; Werneck et al. 2010), systemic diseases (Cartee et al. 2015), anthropometrics (Martinez-Herrera et al. 2017; Milner and Beck 2012) and age (Preshaw et al. 2017).

Genetics plays a role in the development of many oral diseases, ranging from simple inherited disorders – such as amelogenesis imperfecta – to complex hereditary conditions, like periodontal disease and temporomandibular disorders (Melis and Di Giosia 2016; Wright and Hart 2002). However, the extent of this genetic role varies, as does the extent of our understanding of this role, depending on the disease in question. For simple inherited disorders, genetics can account completely for disease inheritance and understanding is fairly advanced (Smith et al. 2017). However, for more complex inherited disorders, the extent and role of genetics is less clear. Evidence has suggested that genetics may account for up to 50% of causal factors in severe types of periodontitis in young patients, but the evidence is uncertain and the contribution is likely to be lower for less severe forms and in older patients (Loos and Chin 2017; Meng et al. 2011; Torres de Heens et al. 2010). Although many specific genes have been identified, it is also suspected that many gene determinants for periodontitis remain unknown (Laine et al. 2012; Loos and Chin 2017). Similarly, substantial evidence supports a genetic contribution to caries susceptibility, but estimates of the extent of this contribution vary significantly (Boraas et al. 1988; Bretz et al. 2005a; Bretz et al. 2005b; Liu et al. 1998; Opal et al. 2015). Studies have focused mainly on genes influencing saliva composition, enamel formation, the immune response to cariogenic bacteria and dietary preferences (Bretz et al. 2005b; Shuler 2001; Werneck et al. 2010), but a lack of studies, little reproducibility between study findings and the limited number of genes investigated to date means understanding is still limited (Opal et al. 2015; Werneck et al. 2010).

Relationships between systemic diseases and oral diseases have also been the focus of a substantial body of research in recent years (Albandar et al. 2018; D'Aiuto et al. 2017; Dietrich et al. 2013; Kocher et al. 2018; Monsarrat et al. 2016; Nascimento et al. 2018; Picos et al. 2018). Although substantial uncertainties still remain, there is unequivocal evidence that systemic diseases can be substantial risk factors for oral diseases (Albandar et al. 2018; D'Aiuto et al. 2017; Picos et al. 2018). In the case of periodontitis, there is strong evidence that rare conditions (such as Papillon Lefevre Syndrome, leucocyte adhesion deficiency and hypophosphatasia) and common conditions (such as diabetes) are significant risk factors (D'Aiuto et al. 2017; Jepsen et al. 2018). For example, a recent meta-analysis suggested that diabetes increased the risk of periodontitis occurring or progressing by 86% (Nascimento et al. 2018), whilst severe periodontitis and early loss of both primary and permanent dentitions are universal in Papillon Lefevre Syndrome (Sreeramulu et al. 2015). Similarly, multiple systemic conditions – such as cerebral palsy, nutritional deficiencies, immune disorders (e.g. Sjogren's syndrome) and metabolic disorders (e.g. hypocalcemia) – are known risk factors for caries (Mathews et al. 2008; Salanitri and Seow 2013). Systemic diseases are also implicated in the development of other oral diseases, for example, the established role of gastrointestinal disorders in tooth erosion (Pace et al. 2008; Picos et al. 2018).

With regards to anthropometrics, substantial research has investigated the role of obesity in the development of various oral diseases (Keller et al. 2015; Shivakumar et al. 2018). The best evidence relates to periodontal disease, whereby there is modest evidence that obesity acts as a risk factor (Keller et al. 2015). The estimated extent of increased risk varies depending upon study methodologies, but longitudinal studies have suggested that obesity could increase the risk of periodontitis development by up to threefold (Keller et al. 2015; Morita et al. 2011). Research has also investigated low birth weight as a risk factor for caries, although findings have been contradictory (Nicolau et al. 2003a; Saraiva et al. 2007; Tanaka and Miyake 2014).

Finally, age may act as a risk factor for certain oral diseases. For example, there is evidence that biological changes in ageing increase susceptibility to caries and, potentially, to periodontal diseases (Lopez et al. 2017).

To summarise, biological factors, including microbiological and host factors, play a significant role in the development of oral disease. However, the extent and nature of this contribution remains uncertain for many diseases.

2.6: Behavioural and environmental determinants

Prior to the 1980s, a biomedical model of oral disease development dominated, focusing on biological determinants of disease (Watt 2012). However, throughout the 1980s and 1990s, behavioural and environmental factors – such as oral hygiene, smoking, dietary practices, dental attendance, alcohol consumption, water fluoridation and consumption of medicines – gained increasing recognition as key determinants of oral health (Rugg-Gunn and Do 2012; Watt 2012). The importance of such 'lifestyle factors' in the development of oral health is now well established (Ciancio 2004; Moynihan and Kelly 2014; Warnakulasuriya et al. 2010; Watt 2012).

Regarding oral hygiene, it is accepted that dental plaque is an essential component for the development of caries and periodontal disease, as previously discussed (Bartold and Van Dyke 2013; Selwitz et al. 2007). Furthermore, evidence confirms that the amount of dental plaque biofilm is often associated with disease progression (Broadbent et al. 2011; Crocombe et al. 2012). In turn, studies have demonstrated that better oral hygiene behaviours are associated with improved oral health outcomes (Broadbent et al. 2016; Chankanka et al. 2011), although such findings are not unanimous (Peres et al. 2009). However, the latter disagreement is likely due to the inconsistent relationship between measures of oral hygiene and effectiveness of plaque control.

Regarding smoking, it is well accepted as a significant risk factor for periodontal disease, oral cancer and tooth loss (Warnakulasuriya et al. 2010). A review of the evidence suggests that smokers increase their risk of experiencing periodontal disease by between 1.4 and 5 fold

(Warnakulasuriya et al. 2010). In addition, research from Australia, the US and New Zealand has estimated that around one to two thirds of periodontal disease in their populations may have been attributable to smoking (Do et al. 2008; Thomson et al. 2007; Tomar and Asma 2000). Studies have also found an increased risk of tooth loss in smokers (Pearce et al. 2004; Ylostalo et al. 2004). For example, after accounting for confounders, a Finnish study found that those who smoked six to ten pack-years before the age of 26 were twice as likely to lose six or more teeth by the age of 31, compared to those who had never smoked (Ylostalo et al. 2004). A meta-analysis of global case-control studies also estimated that the odds for smoking in relation to oral cancer was 4.65 (Sadri and Mahjub 2007).

There is strong evidence that diet plays a key role in the development of oral diseases, particularly caries (Moynihan and Kelly 2014) and dental erosion (Salas et al. 2015) but also oral cancer (Lucenteforte et al. 2009), developmental defects (Salanitri and Seow 2013) and periodontal disease (Genco and Borgnakke 2013). A recent systematic review calculated the risk ratio for caries prevalence between higher and lower sugar intake groups to be around 7:1 (Moynihan and Kelly 2014). Additionally, a contemporary meta-analysis concluded that the odds of children and adolescents exhibiting dental erosion in permanent teeth were significantly increased with higher consumption of carbonated drinks (OR = 1.61), acidic snacks or sweets (OR = 2.24), and acidic fruit juices (OR = 1.20) (Salas et al. 2015).

Alcohol also has an effect upon oral health, the greatest oral health risk being its effect upon oral cancer (Grocock 2018). In a recent meta-analysis, the risk of oral and pharyngeal cancer increased fivefold in those drinking at least four alcoholic drinks per day, compared to non or occasional drinkers (Tramacere et al. 2010).

With regards to dental attendance, significant evidence supports the importance of regular attendance in maintaining oral health (Fuller et al. 2011; Lu et al. 2011; Thomson et al. 2010). Some of the best longitudinal evidence comes from the Dunedin birth cohort study in New Zealand, which has shown that age 32 DMFS (decayed, missing and filled surfaces), missing teeth due to caries, and Oral Health Impact Profile (OHIP) scores were on average 4, 0.7 and 2 units greater for those who were ‘opportunist dental attenders’ between the ages of 15 and 32, compared to regular dental attenders (Crocombe et al. 2012). Data from the Dunedin study has also demonstrated that improved oral health outcomes are often associated with the length of periods of regular dental attendance and the recentness of these periods (Thomson et al. 2010).

Regarding fluoride, a wealth of evidence supports its beneficial effects on oral health, specifically caries development (Iheozor-Ejiofor et al. 2015; Marinho et al. 2003a; Marinho et al. 2013; Marinho et al. 2003b; Rugg-Gunn and Do 2012; Rugg-Gunn et al. 2016). For example, a Cochrane review and meta-analysis of 70 randomised controlled trials concluded that the use of fluoridated toothpaste in children resulted, on average, in a 24% reduction in caries experience (Marinho et al. 2003a). A Cochrane review of 22 trials also concluded that fluoride varnish applied two to four times yearly reduced caries experience in children by 43% in permanent teeth and 37% in primary teeth (Marinho et al. 2013). Furthermore, a global review of studies conducted between 1990 and 2000 concluded that average caries reductions associated with artificial water fluoridation were between 30% and 59% in primary teeth and 40% and 49% in permanent teeth (Rugg-Gunn and Do 2012).

Finally, medications can also affect oral disease susceptibility via multiple pathways (Ciancio 2004). Sugar-containing medicines or medications predisposing to dry mouth contribute to caries experience (Shaw and Glenwright 1989), whilst specific medications associated with drug-induced gingival overgrowth (namely cyclosporin, anticonvulsant medications and calcium-channel blockers) act as risk factors for periodontitis (Ciancio 2004). Certain medications, particularly bisphosphonates, can also increase the risk of jaw osteonecrosis (Kuroshima et al. 2019). Additionally, problems such as ulceration, taste disturbance and fungal infections are other common side effects of various medications (Ciancio 2004).

2.7: Psychological determinants

In recent years there has been a much greater appreciation of the role of psychological factors in oral disease causation (Gomaa et al. 2016; Sheiham and Nicolau 2005). Research has shown that such factors can influence oral health outcomes via their influence on OHBs or via biological mechanisms (Gomaa et al. 2016).

One area of particular relevance is dental anxiety. A recent systematic review demonstrated that dental anxiety or dental phobia are usually associated with poorer oral health outcomes (Kisely et al. 2016). For example, in a national survey of over 5,000 Australian adults, those who were extremely afraid of going to the dentist had 186.3% more decayed teeth and 39.6% more missing teeth than those with no fear of going to the dentist (Armfield et al. 2009). Many relevant studies have been cross-sectional and, therefore, prevent inference of causal relationships (Armfield et al. 2009; Nuttall et al. 2011a). However, a few longitudinal studies have investigated the causal nature of this relationship and have shown that higher dental anxiety acts as a predictor for poorer oral health outcomes (Jamieson et al. 2010b; Kruger et al. 1998). This is likely explained by the association between higher dental anxiety and engagement with dental services (Crocombe et al. 2011). The role of dental fear as a barrier to dental attendance is also supported by qualitative studies (Gregory et al. 2012; Hill et al. 2003).

Knowledge, beliefs and attitudes are also recognised as key determinants of OHBs and oral health outcomes (Asimakopoulou and Newton 2015; Hollister and Anema 2004). Such aspects were the focus of traditional health behaviour theories, which dominated over the latter half of the twentieth century, such as the Health Belief Model and the Theory of Planned Behaviour (Ajzen 1991; Rosenstock 1974). However, these factors are also recognised in contemporary psychological approaches to the understanding of health behaviours, such as the related Theoretical Domains Framework and COM-B (capability, opportunity, motivation, behaviour) model (Cane et al. 2012; Michie et al. 2011). The difference in these dominant contemporary models is that, as well as recognising that a person must possess the psychological ability and motivation to change behaviour, they also advocate that a person must possess the physical capability and be provided with the appropriate physical and social environment to change behaviour (Asimakopoulou and Newton 2015; Cane et al. 2012; Michie et al. 2011). In line with the above theories, empirical evidence does suggest that knowledge, beliefs and attitudes play a role in determining oral health behaviours and oral health outcomes (Broadbent et al. 2006; Broadbent et al. 2016; Gao et al. 2010). For example, the longitudinal Dunedin Study found that beliefs about the importance of OHBs in adolescence and early adulthood were associated with oral health outcomes up to the age of 38 (Broadbent et al. 2006; Broadbent et al. 2016). However, the literature does recognise the limits of knowledge and beliefs on influencing OHBs, in the context of competing physical, social, political and environmental factors (Stokes et al. 2006; Watt 2002).

Furthermore, stress is an emerging risk factor for oral disease (Akcali et al. 2013; Xie et al. 2015). It is known that stress can alter immune responses, which can increase the risk of oral disease, such as periodontal disease (Akcali et al. 2013). For example, stress has been demonstrated to affect the balance of the immune response, resulting in increased levels of inflammatory markers in gingival crevicular fluid, increased loads of pathogenic bacteria and poorer clinical periodontal outcomes (Giannopoulou et al. 2003; Johannsen et al. 2007). Studies have also demonstrated that stress is linked to periodontal outcomes via behaviours, as stress increases the risk of negative OHBs, such as smoking and oral hygiene behaviours (Aleksejuniene et al. 2002a). Beyond periodontal diseases, evidence also suggests that stress may act as a risk factor for other oral diseases, such as oral cancer (Xie et al. 2015) and temporomandibular disorders (Berger et al. 2015).

Many longitudinal and cross-sectional studies have also implicated other psychological conditions and traits, such as depression, negative emotionality, sense of coherence and self-esteem, in subjective and objective oral health outcomes (Baker et al. 2010; Nascimento et al. 2019; Okoro et al. 2012; Thomson et al. 2011). A recent systematic review confirmed that poorer oral health outcomes are consistently found in people with anxiety and depression (Kisely et al. 2016). It is proposed that the relationship between personality and oral health may be mediated via three factors: parafunctional habits, OHBs and perceptions of clinical oral health (Thomson et al. 2011).

2.8: Social determinants

As discussed, it is now accepted that the determinants of health extend far beyond traditional biological and behavioural factors and include broader social, political, cultural and economic determinants, known as the 'social determinants of health' (Marmot and Bell 2011; Watt et al. 2015). Emerging in the 1970s and 1980s (Black 1980; WHO 1978), momentum for the social determinants of health has increased globally over the last few decades (Acheson 1998; Commission on Social Determinants of Health 2008; Marmot 2010). In terms of oral health, social determinants have become the focus of a substantial body of research and discussion (Marmot and Bell 2011; Watt 2007; 2012) and the social determinants of oral health are high on international oral health agendas (Sgan-Cohen et al. 2013; Watt et al. 2015).

Regarding measures of socio-economic position, such as social class, income, education, employment and deprivation, there is extensive evidence on a global scale that substantial oral health inequalities are related to these factors (Dye and Thornton-Evans 2010; Peres et al. 2018a; Steele et al. 2014; Thomson 2012). National data from the UK show that, in 2009, rates of edentulism were five times greater in adults from routine and manual occupation households, compared to managerial and professional occupation households (Fuller et al.

2011). In addition, the prevalence of caries was 37% versus 26% in these groups, respectively, and the prevalence of deep periodontal pocketing (6mm+) was 11% versus 7% (White et al. 2011). A smaller social gradient was noted for tooth surface loss, with the prevalence of moderate or severe tooth surface loss being 18% versus 16% in these groups, respectively (White et al. 2011). Recent evidence also shows substantial inequalities by deprivation for oral cancer rates in the UK (Oral Health Foundation 2020b). There is accumulating evidence that such socio-economic inequalities are mediated by both OHBs and biological factors (Gomaa et al. 2016). For example, studies have demonstrated that socio-economic position influences OHBs, including dental attendance, tooth brushing and dietary behaviours (Broadbent et al. 2016; Castaneda et al. 2010; Hamasha et al. 2006; Torriani et al. 2014), but also influences biological factors, such as cortisol levels, salivary immunoglobulins and the immune response (Buchwald et al. 2013; Gomaa et al. 2016). In turn, these biological factors can affect enamel development, bacterial loads and susceptibility to inflammation (Buchwald et al. 2013; Gomaa et al. 2016).

Social networks and relationships have also been shown to play a role in oral health (Kettle et al. 2019; Rouxel et al. 2015b). Substantial evidence supports the role of parents in determining children's OHBs and oral health outcomes (Castilho et al. 2013; Hall-Scullin et al. 2015; Stokes et al. 2006), whilst a role for other family members has also been identified (Duijster et al. 2015; Gill et al. 2011). Evidence also suggests that wider social networks may influence oral health outcomes, including tooth loss, caries, periodontal disease and oral health-related quality of life (OHRQoL) (Rouxel et al. 2015b). For example, studies have found that participation in social activities is associated with improved tooth retention (Takeuchi et al. 2013). Furthermore, qualitative research studies have highlighted the perceived importance of friends and peers in influencing individuals' oral health beliefs, expectations and behaviours (Brondani et al. 2007; Duijster et al. 2015; Jensen et al. 2011; Ostberg et al. 2002).

Multiple elements of culture, which refers to the social norms, behaviours, beliefs, values and customs of a human society, also influence oral health (Butani et al. 2008; Smith et al. 2013). A classic example of a culturally-related behaviour relevant to oral health is tobacco usage (Anwar and Williams 2008) which, as discussed, is a well-accepted risk factor for periodontal disease, oral cancer and tooth loss (Warnakulasuriya et al. 2010). World Health Organisation estimates of current tobacco smoking prevalence range from 8.9% in Ethiopia to 76.2% in Indonesia (WHO 2020b). For smokeless tobacco, over two-thirds of its global consumption occurs in South and South East Asia (Sinha et al. 2015). Research has also explored and demonstrated cultural variation in behaviours such as dental care-seeking behaviours (Hilton et al. 2007), oral hygiene practices (Zhu et al. 2005) and food consumption (Mullan et al. 2006). Cultural factors which often influence such behaviours include cultural beliefs about the value of oral health (Hilton et al. 2007; Smith et al. 2013), the causes of oral disease (Butani et al. 2008; Smith et al. 2013), the effectiveness of modern medicine (Butani et al. 2008; Smith et al. 2013), the motivations and trustworthiness of dentists (Hilton et al. 2007; Newton et al. 2001), religion (Smith et al. 2013) and language barriers (Newton et al. 2001). For example, a qualitative study exploring cultural barriers to accessing oral health care in children from four minority ethnic groups in the USA identified cultural differences in dental anxiety (often stemming from experiences of older generations in their home country), beliefs about the trustworthiness of the dental profession and views on the need for preventive dental care (Hilton et al. 2007). Research has also highlighted the strong influence of traditional health beliefs and traditional medicine on oral health outcomes in some cultures, such as inaccurate beliefs about 'tooth worms' as a cause of caries and a reliance on herbal remedies for the management of dental problems in Chinese cultures (Smith et al. 2013).

Further upstream, factors such as healthcare systems (Garbin Neumann and Quinonez 2014; Hosseinpoor et al. 2012), public health systems (Rugg-Gunn and Do 2012), education systems (FDI 2019; Steele et al. 2014), food availability (Sreebny 1982), transport (McKernan et al. 2017), employment opportunities (Al-Sudani et al. 2017), welfare arrangements and taxation (Guarnizo-Herreno et al. 2014), amongst other things, all have the potential to influence the oral health of individuals and populations. In turn, these factors themselves are governed by broader factors, including politics, economics and the environment. A recent cross-national review of the effect of four key structural determinants (governance, macroeconomic policy, public policy, and social policy) on children's oral health concluded that the type of political regime, gross domestic product (GDP) per capita, employment ratio, income inequality, type of welfare regime and government expenditure on health, amongst other factors, were all associated with children's clinical and subjective oral health and accounted for between 5% and 21% of the variance in children's OHRQoL scores (Baker et al. 2018). For example, children in countries with high GDP per capita (e.g. Germany) had significantly lower decayed, missing and filled teeth (DMFT) scores and better self-rated OHRQoL than in low GDP countries (e.g. Cambodia, Thailand) (Baker et al. 2018).

Regarding oral healthcare systems, these vary considerably around the world. For example, there is great variation in the ratio of dental professionals to population size (Gallagher and Hutchinson 2018; Petersen 2014; Sinclair et al. 2019), the nature and type of treatments available (Adeniyi et al. 2012; Kandelman et al. 2012) and the extent to which services are publically or privately funded (ADA 2017b; Biggs 2012; Kandelman et al. 2012; NHS.UK 2017; Sinclair et al. 2019). Specifically, population coverage for oral health care ranges from an average of 35% in low-income countries to 82% in high-income countries (Hosseinpoor et al. 2012). Furthermore, in many low-income countries, services often provide only basic or emergency dental treatment (Adeniyi et al. 2012; Kandelman et al. 2012). Regarding public funding for oral health, the United Kingdom funds most treatment for children, pregnant or new mothers and low-income groups (as well as subsidises treatment costs for the general population) (NHS.UK 2017). However, levels of public funding vary considerably across other countries (Biggs 2012; Kandelman et al. 2012; Sinclair et al. 2019).

Evidence shows that such variation in healthcare systems can impact upon dental attendance and population oral health outcomes (ADA 2017a; BDA 2019a; Devaux and Looper 2012; Garbin Neumann and Quinonez 2014). For example, comparisons between the UK, USA, Brazil, Canada and France demonstrated that dental visiting behaviours, twelve year-old DMFT rates and unmet oral health care needs were worse in countries with lower public funding for oral health care (Garbin Neumann and Quinonez 2014). Furthermore, there is evidence that the insufficient availability of NHS dental services in some areas of the UK currently is impacting upon access for patients; recent figures from England showed that around a quarter of new patients were unable to secure NHS dental appointments (BDA 2019a; Owen et al. 2019).

Finally, public health measures can have a significant impact upon population oral health (Colchero et al. 2017; PHE 2015a; Rugg-Gunn and Do 2012). As previously discussed, substantial caries reductions can be achieved by artificial water fluoridation (Rugg-Gunn and Do 2012), although only around 5% of the world's population and 10% of the UK population receives artificially fluoridated water (BFS 2013). The effectiveness of national tobacco control policies on smoking prevalence and cessation rates is also well established (Joossens 2004), and 136 countries now implement at least one key tobacco control policy intervention (WHO 2019). Public health sugar reduction measures, with the potential to reduce caries prevalence, can also include a range of strategies, such as taxation policies, reformulation strategies, labelling standards, marketing and promotion regulations and education campaigns (PHE 2015a). For example, taxes on sugar-sweetened beverages have now been implemented in around 60 countries (World Cancer Research Fund International 2018) and evidence supports their effectiveness in reducing sugar consumption (Colchero et al. 2017; PHE 2015b). Following their introduction in the UK in 2018, the average sugar content of affected drinks decreased by almost a third due to reformulation efforts (PHE 2019b). Furthermore, a small number of countries also operate minimum pricing regulations for alcohol, with Scotland being the first country to implement a national minimum unit price in 2018 (Katikireddi et al. 2019). The immediate effect of this legislation in Scotland was a 7.6% reduction in purchases of alcohol (O'Donnell et al. 2019). Modelling studies predict that minimum unit pricing will significantly reduce chronic conditions related to alcohol, which includes many oral cancers (Holmes et al. 2014).

2.9: Variation in determinants between oral health outcomes

Sections 2.4 to 2.8 detail the evidence regarding the determinants of oral health from biological, behavioural, environmental, psychological and social perspectives, highlighting throughout where different determinants may relate to specific oral health outcomes. As there can be substantial variation between the determinants of different oral health outcomes (Genco and Borgnakke 2013; Selwitz et al. 2007), this section will now provide a brief summary of this variation from the perspectives of the most common oral diseases globally and in the UK, for clarity. These diseases include caries, periodontal diseases, tooth loss and non-carious tooth surface loss (Dye 2017; Fuller et al. 2011; Van't Spijker et al. 2009; White et al. 2011).

In the case of caries, it is well accepted that a combination of plaque bacteria, sugar, tooth substrate and time are the essential requirements for caries development (Selwitz et al. 2007). As discussed, research has shown that caries prevalence is around seven times greater in higher than lower sugar intake groups (Moynihan and Kelly 2014), and that following a high rather than low plaque trajectory from early childhood to age 32 increases caries risk by 40% (Broadbent et al. 2011). However, the contributions of biological, environmental, psychological and social factors have also been recognised (Selwitz et al. 2007). Genetic contributions to caries are thought to be significant, although the precise extent is currently uncertain (Bretz et al. 2005b; Opal et al. 2015). Furthermore, fluoride exposure has been shown to decrease caries experience by around a third or more (Marinho et al. 2003a; Marinho et al. 2013; Rugg-Gunn and Do 2012). Psychological and social factors have also been strongly related to caries experience (Kisely et al. 2016; Thomson et al. 2011; White et al. 2011), affecting OHBs (Hamasha et al. 2006; Hilton et al. 2007; Hosseinpoor et al. 2012) and caries-related physiology, such as enamel development, saliva flow and saliva composition (Gomaa et al. 2016).

In the case of periodontal disease, it is well accepted that disease develops if there is a disruption in host-microbial homeostasis (Bartold and Van Dyke 2013), and evidence suggests that the most relevant risk factors are genetics, smoking, systemic diseases and plaque control behaviours (Genco and Borgnakke 2013). As discussed, research has shown that genetics may account for up to 50% of causal factors in periodontitis (Loos and Chin 2017; Meng et al. 2011; Torres de Heens et al. 2010), smoking increases periodontitis risk by one- to five-fold (Warnakulasuriya et al. 2010) and poorer plaque control has been consistently associated with poorer periodontal outcomes (Broadbent et al. 2011). In addition, systemic diseases, particularly diabetes and various rare disorders, are accepted as major risk factors (Albandar et al. 2018; Genco and Borgnakke 2013), with a recent meta-analysis finding that diabetes increased the risk of periodontitis occurring or progressing by 86% (Nascimento et al. 2018). Furthermore, as with caries, psychological and social factors have also been related to periodontitis (Nascimento et al. 2019; White et al. 2011), affecting OHBs (Gao et al. 2010; Gomaa et al. 2016; Hamasha et al. 2006) and periodontitis-related physiology, such as the immune response (Giannopoulou et al. 2003; Gomaa et al. 2016; Johannsen et al. 2007).

Regarding tooth loss, research across several countries over the last few decades (Anand et al. 2010; Jafarian and Etebarian 2013; Murray et al. 1997), including within the UK (Hull et al. 1997; McCaul et al. 2001; Richards et al. 2005), has evidenced that the main reasons for dental extractions are caries and periodontal disease. Other reasons for extractions less commonly include orthodontic treatment, trauma and impaction. For example, a study of General Dental Practices in Greater Manchester in 1991 showed 37%, 29% and 12% of teeth were extracted due to caries, periodontal disease and trauma, respectively (Hull et al. 1997), whilst a study in General Dental Practices in South Wales in 2002 found that 58%, 29% and 6% of teeth, respectively, were extracted due to caries, periodontal disease and orthodontics (Richards et al. 2005). It therefore follows that the determinants of tooth loss should particularly reflect the determinants of caries and periodontal disease. Certainly, evidence supports an association between tooth loss and the following behavioural and environmental determinants of caries and periodontal disease: sugar consumption (Kim et al. 2017), plaque control (Broadbent et al. 2011), smoking (Arora et al. 2010; Simila and Virtanen 2015) and fluoride exposure (Neidell et al. 2010). Furthermore, evidence also supports a role of the psychological and social determinants of caries and periodontal disease in tooth loss, for example: dental anxiety (Thomson et al. 2000), psychological disorders (Kisely et al. 2016; Okoro et al. 2012) and socio-economic factors (Pearce et al. 2009a; Ramsay et al. 2018; Steele et al. 2014).

Finally, in relation to non-carious tooth surface loss, the key determinants depend upon the type of surface loss. Erosion is the loss of tooth surface due to acid attack and is caused by either the consumption of acidic foods or stomach acids entering the mouth as a result of various systemic conditions, such as gastric reflux or bulimia (Yule and Barclay 2015). A recent meta-analysis found that the odds of exhibiting dental erosion in permanent teeth were increased by up to twofold in individuals consuming high rather than low rates of acidic food and drink (Salas et al. 2015). In contrast, abrasion is the physical removal of tooth substrate by an external agent, and is usually caused by inappropriate brushing techniques (Yule and Barclay 2015). Lastly, attrition is the loss of tooth substrate as a result of tooth to tooth contacts and is exacerbated by bruxism (Yule and Barclay 2015). In addition to the direct causative agents above, there is evidence that biological factors, such as genetics, enamel composition, saliva flow and saliva composition, influence the development of tooth surface loss, by changing the susceptibility of tooth structure and the favourability of the local environment (Hara and Zero 2014; Yule and Barclay 2015). Furthermore, psychological and social factors can exacerbate key causative behaviours, such as the consumption of acidic foods and drinks, gastric conditions, tooth brushing habits and bruxism (Ahmed 2013; Jansson et al. 2007).

2.10: A life course approach to chronic disease causation

Sections 2.4 to 2.9 provide an overview of the body of evidence to date regarding the determinants of oral health from biological, behavioural, environmental, psychological and social perspectives. Advancing this knowledge regarding the determinants of oral health, it has also been accepted in recent years that oral health develops across the whole life course, with oral diseases frequently being chronic and cumulative in nature (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015). Sections 2.10 to 2.13 now provide an overview of current knowledge regarding the life course determinants of oral health. Section 2.10 first provides a general introduction to the life course approach to chronic disease causation, discussing the evolution of this approach, conceptual models of life course disease causation, study design in life course epidemiology and applications of a life course approach to general health topics. Section 2.11 subsequently discusses the applicability of a life course approach to the determinants of oral health and provides an overview of longitudinal studies with oral health data in existence, which facilitate the application of this approach. The findings of these longitudinal studies are subsequently discussed in Section 2.13, following a discussion of the statistical analysis methods applicable to longitudinal data (Section 2.12).

2.10.1: Evolution and definition of a life course approach to chronic disease causation

Theories to explain the aetiology of chronic diseases have evolved over time (Kuh and Ben-Shlomo 2004; Susser and Susser 1996), from the 'germ theory' (which dominated in the first half of the twentieth century (Susser and Susser 1996)), to the adult lifestyle theory (which focused on the role of adult lifestyle risk factors in the post-war period (Dawber et al. 1959; Doll and Hill 1964)), to the early origins of adult disease theory (in which there was particular interest in the late twentieth century (Barker 1995; 2001; Barker et al. 1993; Eriksson et al. 1999; Osmond et al. 1993)). Elements of these theories are still supported today, but, in recent years, increasing evidence has begun to support a life course approach to adult disease causation (Halfon et al. 2018; Kuh and Ben-Shlomo 2004). Such an approach has been defined as 'the study of long-term effects on chronic disease risk of physical and social exposures during gestation, childhood, adolescence, young adulthood and later adult life' (Kuh and Ben-Shlomo 2004). It includes studies of the biological, behavioural and psycho-social pathways that operate across an individual's life course, as well as across generations, to influence the development of chronic diseases (Kuh and Ben-Shlomo 2004).

2.10.2: Conceptual models in life course epidemiology

There are a myriad of pathways by which factors across the life course could contribute to chronic disease. The most commonly used theoretical models were proposed by Ben-Shlomo and Kuh (2002) and, in their simplest form, are outlined in Table 2. The 'critical period model' refers to an exposure having a permanent effect on the structure or function of the body during a specific period, which is not modified in a significant way in later life (Ben-Shlomo and Kuh 2002). An example would be maternal exposure to thalidomide in pregnancy and limb development (Ben-Shlomo and Kuh 2002; Vargesson 2019). The second model extends the 'critical period model' to account for subsequent exposures that may modify the effect of the initial critical period exposure (Ben-Shlomo and Kuh 2002). An example would be the detrimental effect that being overweight in adulthood has on the development of insulin resistance in small birthweight babies (Ben-Shlomo and Kuh 2002; Lithell et al. 1996). The third model refers to disease caused by the cumulative effect of multiple unrelated exposures, such as the cumulative effect of an accidental skin burn and excessive exposure to sunlight on the risk of developing skin cancer (Ben-Shlomo and Kuh 2002). The fourth model is similar in that it refers to the accumulation of risk, but this model refers to the accumulation of risk due to related factors. These factors could be clustered, such as risk factors associated with socio-economic status, or they could be linked in pathways or chains, e.g. one factor predisposes to another factor which, in turn, increases disease risk (Ben-Shlomo and Kuh 2002). These theoretical models are not intended to be mutually exclusive, and chronic disease development may involve more than one, or possibly all, of these theoretical pathways (Ben-Shlomo and Kuh 2002).

The critical period model
The critical period model with later effect modifiers
Accumulation of risk with independent and uncorrelated insults
Accumulation of risk with correlated insults (clustering, chains or pathways of risk)

Table 2: Conceptual models of disease causation in life course epidemiology. (Ben-Shlomo and Kuh 2002; WHO 2000)

2.10.3: Study design in life course epidemiology

The ideal study design for implementing a life course approach to chronic disease causation is the prospective birth cohort study (Burton-Jeangros et al. 2016; Halfon et al. 2018). Such studies involve the prospective measurement of potential determinants and disease outcomes from birth (or the prenatal period) and across the life course. The key benefit of such a study design is that it maximises the potential to obtain detailed, accurate and reliable data by controlling the measurement of outcomes and exposures (Kuh and Ben-Shlomo 2004) and takes into consideration the whole life course. However, the conduct of such studies is challenging in many ways: there can be a substantial time lag between instigating a study and realising its benefits; such studies are extremely costly and resource intensive; and loss to follow-up and resultant sample bias is often a problem (Halfon et al. 2018; Kuh and Ben-Shlomo 2004).

Beyond the prospective birth cohort study, prospective cohort studies starting after birth can provide an alternative opportunity to apply a partial life course approach to the study of chronic disease causation (Halfon et al. 2018). However, the severe disadvantage of such studies is that they do not include information about the part of the life course preceding the study's start point. This can be a significant drawback, given the importance of birth and early life in the development of many chronic diseases (Barr 2017; Knop et al. 2018).

Beyond the above prospective studies, retrospective life course studies can be utilised (Halfon et al. 2018; Kuh and Ben-Shlomo 2004). Such studies are conducted at a single point in time but life course data is collected retrospectively from individuals. These studies are quicker and easier to conduct than prospective studies, generating more timely results at lower resource costs. However, retrospective data collection can be significantly limited by memory loss, recall bias and the inability to collect certain data retrospectively. Such limitations can result in a loss of detail, inaccurate and unreliable data (Halfon et al. 2018; Kuh and Ben-Shlomo 2004).

For all longitudinal studies, an additional challenge is managing changes in the understanding, measurement and classification of exposures and outcomes over time. This results in a conflict between maintaining consistency throughout a study and keeping up-to-date with contemporary developments (Kuh and Ben-Shlomo 2004).

2.10.4: The application of a life course approach in the field of general health

Over the past few decades, life course approaches have been applied to the study of general health and disease with increasing frequency (Ben-Shlomo et al. 2016; Pratt and Frost 2016). The most common general health conditions studied include obesity, malnutrition, frailty, cognitive function, mental health, cardiovascular diseases, musculoskeletal conditions and general aging (Pratt and Frost 2016).

Across a range of general health conditions, evidence has demonstrated the importance of maternal, pre- and perinatal factors in offspring disease risk (Knop et al. 2018; Lebold et al. 2020), for example, the impact of birth weight (Rolland-Cachera et al. 2006) and maternal obesity, diabetes and diet (Barbour 2014a) on future metabolic risk. The importance of childhood conditions has also been established for many health outcomes (Armenian et al. 2018; Barr 2017), particularly the importance of childhood in shaping psychological development (Dube et al. 2003; Kuh and Ben-Shlomo 2004; Teicher et al. 2016) and the role of childhood socio-economic adversity in health inequalities in adulthood (Marmot 2010). Furthermore, there is strong evidence for the contribution of factors across adulthood to chronic disease risk, particularly the effects of adult lifestyle factors (such as smoking, alcohol and diet) on major non-communicable diseases, including cardiovascular disease, cancer, chronic respiratory disease and diabetes (Banks et al. 2019; Bowen et al. 2018; Connor 2017; Pan et al. 2019; Piano 2017; Taylor 2019). Research has explored the applicability of the four conceptual models of life course disease causation (Ben-Shlomo and Kuh 2002) to general health and has established support for all four models, with pathways varying by health and disease outcomes (Burton-Jeangros et al. 2016; Halfon et al. 2018; Pratt and Frost 2016).

To provide more detail and context from the field of general health, the case of cardiovascular disease is discussed by way of example. Substantial evidence from epidemiological and animal studies supports the role of the maternal environment (Blackmore and Ozanne 2015) – including undernutrition (Painter et al. 2006), overnutrition (Reynolds et al. 2013) and diabetes (Wichi et al. 2005) – in offspring future cardiovascular risk. Low birth weight has also been consistently associated with future cardiovascular disease risk (Hardy et al. 2015), including coronary heart disease (Huxley et al. 2007) and high blood pressure (Huxley et al. 2002), although there is limited research disentangling the effects of younger gestational age from restricted fetal growth rate within the above relationships (Hardy et al. 2015). In terms of childhood effects, there is a consistent body of evidence supporting associations between childhood obesity and cardiovascular outcomes in adulthood (Park et al. 2012), although further research is needed to establish the independence of these effects from adulthood body mass index (Hardy et al. 2015). A substantial body of evidence also establishes the adverse effects of childhood socio-economic status on cardiovascular outcomes, independent of adult socio-economic position (Galobardes et al. 2008; Hardy et al. 2015). Finally, the most established evidence and greatest risk relates to the role of adult lifestyle risk factors in the development of cardiovascular disease, namely tobacco use, diet and obesity, physical inactivity and alcohol

(Appelman et al. 2015; Elisaf 2001; Flora and Nayak 2019; Lamont et al. 2000). Although there is still much more to be elucidated in the case of cardiovascular disease (Blackmore and Ozanne 2015; Hardy et al. 2015), the above evidence establishes that its development is a life course process, involving interactions of risk factors across the life course via complex pathways (Aboderin et al. 2002).

In terms of key longitudinal studies, which have contributed extensive evidence to the field of life course health and disease development, a large number of multidisciplinary prospective birth cohort studies are now in existence (Batty et al. 2007; MRC 2021). Some of the most notable are from the UK and include the 1946 British National Survey of Health and Development (Wadsworth et al. 2006), the 1958 British National Child Development Study (Power and Elliott 2006), the 1970 British Cohort Study (Elliott and Shepherd 2006) and the British Millennium Cohort Study (Connelly and Platt 2014). Outside of the UK, some of the most notable include the Dunedin Multidisciplinary Health and Development Study (New Zealand, 1972/73) (Poulton et al. 2015), the Pelotas Birth Cohorts (Brazil, 1982/1993/2004) (Santos et al. 2011; Victora and Barros 2006; Victora et al. 2008), the Northern Finland Birth Cohorts (1966/1986) (Miettunen et al. 2019; Rantakallio 1988), the National Collaborative Perinatal Project (US, 1959-66) (Martin et al. 2004) and the South Africa Birth to Twenty Cohort (1990) (Richter et al. 2007).

Other key longitudinal studies include prospective cohort studies starting after birth, such as: the Framingham Heart Study, which has followed over 5,000 adults from Framingham in the USA since 1948, to study the determinants of cardiovascular disease (Tsao and Vasan 2015); the UK Biobank, which has followed 500,000 adults since 2006 to study a wide range of serious and life-threatening illnesses (Sudlow et al. 2015); and three generations of the Nurses' Health Study, which have followed over 280,000 nurses from the USA from 1976 and beyond to study the risk factors of major chronic diseases in women (Nurses' Health Study 2020).

Finally, examples of key retrospective cohort studies are the Lothian Birth Cohorts of 1921 and 1936. Within these studies, retrospective data was collected from 550 and 1,091 adults living in Edinburgh and the Lothians, who were born in 1921 and 1936 respectively. Subsequently, mainly cognitive, but also other psycho-social and medical, outcomes have been studied (Deary et al. 2011).

2.11: A life course approach to oral health

2.11.1: The applicability of a life course approach to oral health

It is accepted that life course models are applicable to the development of oral health and disease, as oral diseases are frequently chronic and cumulative in nature, particularly the major oral diseases of caries, periodontal disease, oral cancer, tooth loss and non-carious tooth surface loss (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015).

As in the field of general health, evidence has supported the applicability of all four theoretical models of life course chronic disease causation to oral health (Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015). Accordingly, Heilmann et al. (2015) have proposed a theoretical life course framework for oral health, which takes into account biological, psychological, behavioural and social determinants of oral health and involves elements of all theoretical models of life course disease causation (Figure 2).

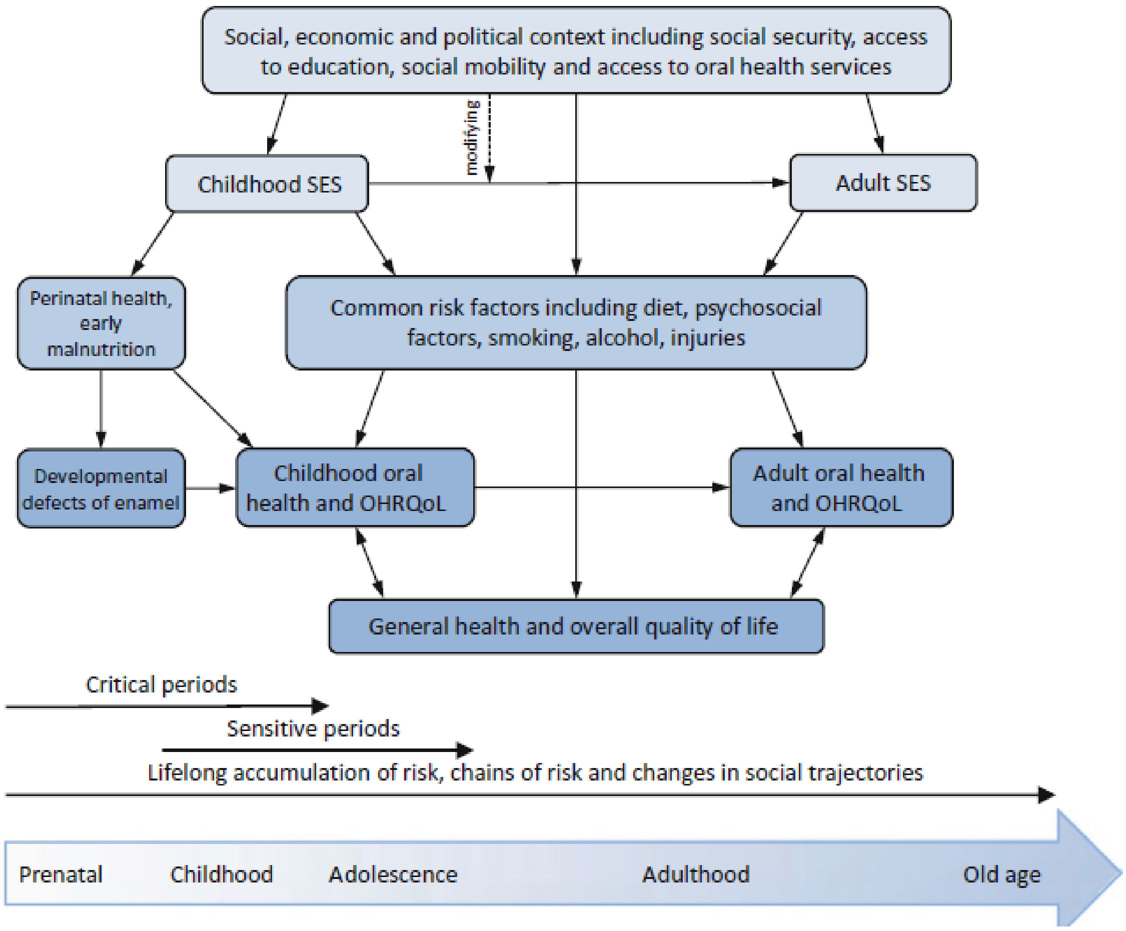

Figure 2: A proposed theoretical life course framework for oral health. Reproduced from (Heilmann et al. 2015).

However, although the number of published studies adopting a life course approach to the development of oral health is steadily increasing, the overall body of evidence is still far from extensive (Heilmann et al. 2015). Primarily, this is because longitudinal datasets facilitating the use of such an approach in the field of oral health are limited in number (Heilmann et al. 2015). The following sub-sections (2.11.2 and 2.11.3) provide an overview of the key longitudinal oral health studies in existence. Sections 2.11.4 and 2.13 subsequently discuss the oral health findings from these studies.

2.11.2: Prospective birth cohort studies with oral health data

As previously discussed, the ideal study design for exploring the life course determinants of chronic diseases is the prospective birth cohort study (Halfon et al. 2018; Kuh and Ben-Shlomo 2004). To the author's knowledge, sixteen prospective birth cohort studies to date have included data on oral health outcomes, eleven from outside the UK (Table 3) and five from within the UK (Table 4).

The longest running and most comprehensive of the non-UK studies is the Dunedin Multidisciplinary Health and Development study, which began with 1,037 babies born in Dunedin, New Zealand, in 1972/1973 (Poulton et al. 2015). Second to this, the most useful studies are the oral health sub-studies of three Pelotas (Brazil) Birth Cohorts (Peres et al. 2017; Peres et al. 2010; Peres et al. 2016), the Iowa Fluoride Study in the USA (Levy et al. 1998) and the Australian Aboriginal Birth Cohort (ABC) study (Sayers et al. 2017). These latter cohorts are younger than the Dunedin study; the three Pelotas cohorts began in 1982, 1993 and 2004, whilst the Iowa Fluoride and ABC studies began in 1992 and 1987, respectively. However, these cohorts are not dissimilar in size to the Dunedin study; the Pelotas oral health sub-studies included 900, 359 and 1,129 individuals, whilst the Iowa and ABC studies included 1,072 and 686 babies, respectively. The above cohorts have all undergone regular detailed dental examinations, focusing on a range of oral health outcomes (apart from the Iowa study, which has focused purely on caries and fluorosis). Extensive information about a broad array of potential determinant factors, including socio-demographic, biological, lifestyle and health factors, has also been regularly collected across the life course in all studies (Broadbent et al. 2011; Broadbent et al. 2016; Curtis et al. 2018a; Jamieson et al. 2010c; Peres et al. 2017; Peres et al. 2010; Peres et al. 2016; Poulton et al. 2015; Sayers et al. 2017; Thomson et al. 2000; Warren et al. 2006). Retention rates in the above cohorts are variable, but are notably higher in the Dunedin study, in which 89% of original participants were dentally examined at age 38 (Broadbent et al. 2013).

Beyond the above studies, five other non-UK prospective birth cohort studies with dental data also exist but are in their relative infancy. The VicGeneration (VicGen) Study and the Study of Mothers' and Infants' Life Events Affecting Oral Health (SMILE) recruited 466 babies from disadvantaged areas in Victoria, Australia, in 2008, and 2,112 babies from Adelaide, Australia, in 2013/2014, respectively (Do et al. 2014; Johnson et al. 2017). Both studies have conducted dental examinations at regular intervals (the former examining caries only and the latter a broad range of clinical dental outcomes). A sub-study (n=340) from a 2001/2002 birth cohort from Sao Leopoldo, Brazil, also involved the collection of clinical data regarding caries and traumatic dental injuries up to the age of four (Feldens et al. 2010), whilst the Gudaga Study has included information on the OHBs of a cohort of 149 Aboriginal babies born in the Campbelltown region of Australia from 2005 to 2007 (George et al. 2018). Lastly, the Longitudinal Study of Australian Children (LSAC) recruited 5,107 babies from across Australia in 2003 and 2004, but measured oral health outcomes have been limited to self-reported clinical dental outcomes (reported by carers) (Stormon et al. 2019).

Table 3 summarises the key characteristics of the above non-UK prospective life course studies, alongside their main strengths and weaknesses.

Study name	Country	Start date	Cohort characteristics	Dental outcomes	Key strengths and weaknesses
Dunedin Multidisciplinary Health and Development Study (Poulton et al. 2015)	New Zealand	1972/1973	1,037 babies born in Dunedin	Ages 5, 9, 11, 13, 15, 18, 21, 26, 32, 38 and 45. Detailed assessments of: - caries - periodontal disease - tooth loss - enamel defects - plaque control - malocclusion - OHRQoL	Substantial and detailed dental and potential determinants data. Retention rates extremely high. Oldest non-UK prospective birth cohort with dental data.
Pelotas Birth Cohorts (dental sub-studies) (Peres et al. 2017; Peres et al. 2011a; Peres et al. 2010)	Brazil	1982 1993 2004	900 babies born in Pelotas 359 (as above) 1,129 (as above)	Ages 15, 24 and 31. Ages 6, 12 and 18. Age 5. Detailed assessments of: - caries - periodontal disease - malocclusions - soft tissues - posterior restorations - prostheses use - trauma - fluorosis	Substantial and detailed dental and potential determinants data.
Iowa Fluoride Study (Levy et al. 1998)	USA	1992 to 1995	1,072 babies born in Iowa	Ages 5, 9, 13, 17 and 23. Detailed assessments of: - caries - fluorosis	Detailed dental and potential determinants data.
Aboriginal Birth Cohort (ABC) Study (Sayers et al. 2017)	Australia	1987 to 1990	686 babies born to Aboriginal mothers in Darwin	Ages 18 and 24. Detailed assessments of: - caries - periodontal disease - tooth loss - soft tissue lesions	Detailed dental and potential determinants data. Focus on Aboriginal community may affect generalisability.
VicGeneration (VicGen) Study (Johnson et al. 2017)	Australia	2008	466 babies born to disadvantaged mothers in Victoria	Approximately yearly detailed caries assessments.	Detailed dental and potential determinants data. Focus on disadvantaged communities may affect generalisability.

Study of Mothers' and Infants' Life Events Affecting Oral Health (SMILE) (Do et al. 2014)	Australia	2013/2014	2,012 babies born in Adelaide	Age 2 (and currently at school age). Detailed assessments of: - caries - development defects - gingival health	Detailed dental and potential determinants data.
Sao Leopoldo Birth Cohort (Feldens et al. 2010)	Brazil	2001/2002	340 babies born in Sao Leopoldo	Caries and traumatic dental injuries up to age of four.	Detailed dental and potential determinants data. Short dental follow-up.
Gudaga Study (George et al. 2018)	Australia	2005 to 2007	149 babies born to Aboriginal mothers in the Campbelltown region	Oral health behaviours.	No data on oral health outcomes, purely behaviours. Small sample size. Focus on Aboriginal community may affect generalisability.
Longitudinal Study of Australian Children (LSAC) (Stormon et al. 2019)	Australia	2003/2004	5,107 babies across Australia	Self-reported (by carers): - caries experience - injuries - dental treatment - oral health behaviours	Only self-reported (by carers) oral health outcomes.

Table 3: Summary characteristics of non-UK prospective birth cohort studies with dental data.

In addition to the above studies from outside of the UK, five prospective birth cohort studies with dental data also exist within the UK (Table 4). The longest running is the Newcastle Thousand Families Study (NTFS), which began in 1947 with 1,142 babies born in Newcastle upon Tyne (Pearce et al. 2009b). Detailed information about birth, socio-demographic, biological, lifestyle and health factors has been collected from participants across the life course, whilst clinical dental examinations (measuring self-reported and clinical outcomes) were undertaken at ages 50 (n=337) and 63 (n=343) (Pearce et al. 2009b). Although this study is the longest prospective birth cohort with dental data in existence, the dental examination data is reasonably limited compared to other seminal studies, such as the Dunedin (Poulton et al. 2015) and Pelotas birth cohorts (Peres et al. 2017; Peres et al. 2011a; Peres et al. 2010). Additionally, due to the abeyance of this study (other than a few small scale sub-studies) between the ages of 18 and 50, life course data between these ages was collected retrospectively (Pearce et al. 2009b), and the loss to follow-up rate at the age 50 and 63 dental examinations was high (around 70% at both) (Pearce et al. 2004). Other studies include: the Millennium Cohort Study (n=18,827) (Connelly and Platt 2014) and the National Child Development Study (NCDS) (n=17,416) (Delgado-Angulo and Bernabe 2015b), which recruited babies from across the UK; the Avon Longitudinal Study of Parents and Children (ALSPAC) (n=14,061 live births), based in Bristol (Dudding et al. 2018); and one of the Growing Up in Scotland (GUS) birth cohorts (n=5,217) (Skafida and Chambers 2018). The NCDS is nearly as old as the NTFS cohort, beginning in 1958, whereas the other studies are more recent, beginning in 2000, 1991/92 and 2004/05 respectively. Other than the NTFS, all of these UK studies, however, have only obtained self-reported, rather than clinically measured, oral health outcomes (apart from a sub-study in the ALSPAC cohort which obtained clinical data up until the age of seven) (Connelly and Platt 2014; Delgado-Angulo and Bernabe 2015a; Dudding et al. 2018; Fitzsimons 2020; Skafida and Chambers 2018).

Study name	Start date	Cohort characteristics	Dental outcomes	Key strengths and weaknesses
Newcastle Thousand Families Study (Pearce et al. 2009b)	1947	1,142 babies born in Newcastle upon Tyne	Ages 50 and 63. Assessment of: - tooth retention - denture use - mobile teeth - grossly broken teeth - occluding pairs - dental pain - OHRQoL	Oldest prospective birth cohort with dental data in existence. Detailed data on potential determinants but age 18 to 50 data collected retrospectively. Dental examination data reasonably limited. Significant loss to follow-up (70% by age 50 and 63 dental examinations).
Millennium Cohort Study (Connelly and Platt 2014)	2000	18,827 babies from across the UK	Self-reported dental health at age 14	Dental health outcomes self-reported and only at age 14.
National Child Development Study (NCDS) (Delgado-Angulo and Bernabe 2015b)	1958	17,416 babies from across the UK	Self-reported problems with gums or mouth at age 33	Limited dental health outcomes self-reported at age 33 only.
Avon Longitudinal Study of Parents and Children (ALSPAC) (Dudding et al. 2018)	1991/1992	14,061 babies born in Bristol	Ages 7, 10, 17 and 23. Self-reported data on: - dental treatment - dental visiting - wisdom teeth - mouth ulcers (10% sub-study: additional age 5 caries examinations)	Dental health outcomes limited and self-reported (other than sub-study caries data at age 5).
Growing Up in Scotland (GUS) Birth Cohort 1 (Skafida and Chambers 2018)	2004/2005	5,217 babies from across Scotland	Age 5: Self-reported (by mothers) dental treatment experience	Dental health outcomes limited and self-reported (by mothers).

Table 4: Summary of UK prospective birth cohort studies with dental data.

2.11.3: Prospective cohort studies starting after birth and retrospective studies

As discussed, second to prospective birth cohort studies, prospective cohort studies starting after birth and retrospective life course studies provide the next best evidence regarding the life course determinants of oral health (Halfon et al. 2018; Kuh and Ben-Shlomo 2004). Multiple studies utilising these two designs and including oral health data exist, the most relevant of which are summarised in Tables 5 and 6 and discussed in the following paragraphs.

Regarding prospective cohort studies starting after birth (Table 5), key UK studies include the British Regional Heart Study (BRHS) and the English Longitudinal Study of Ageing (ELSA). The former has regularly followed 7,735 men aged 40 to 59 from across Britain since the late 1970s (Lennon et al. 2015). The study was initially set up to focus on cardiovascular disease, but subjects underwent dental examinations for the first time between 2010 and 2012 when they were 71-92 years old (Ramsay et al. 2015). Of note, this study focuses only on men, which may affect its generalisability to women. The ELSA has followed 11,391 participants over 50 years of age from across England every two years since 2002/03 (Steptoe et al. 2013). The study focuses on the dynamics of health, social, wellbeing and economic circumstances and has collected self-reported oral health data every four years (Kang et al. 2019; Rouxel et al. 2015a; Steptoe et al. 2013).

Outside of the UK, some of the most useful prospective studies include the Veterans Affairs Dental Longitudinal Study (Kapur et al. 1972) and the Florida Longitudinal Dental Care Study (Gilbert et al. 2003; University of Florida Health 2020). The former has followed a cohort of 1,231 male veterans, originally aged 21-84, from Massachusetts (USA) since 1969, and conducted detailed dental examinations every three to five years. The latter followed 873 adults aged 45 and over from Florida from 1994, collecting detailed clinical and self-reported oral health data at least every two years. The former, however, recruited only 'medically healthy' male veterans, affecting the generalisability of this study, whilst the latter involved a relatively short follow-up period of only six years. Further studies include: the 1942 Swedish Birth Cohort Study, which followed over 6,000 fifty year-olds for twenty years between 1992 and 2012, collecting self-reported oral health data at five yearly intervals (Astrom et al. 2015; Astrom et al. 2011a); the Pro-Saude Study, which followed up 4,030 university staff (aged 22-67) from Rio de Janeiro, Brazil, from 1999, collecting self-reported oral health information after thirteen years (Faerstein et al. 2005; Vettore et al. 2016); a longitudinal study of 671 one year-olds from Sweden in 1988, who have been followed up until fifteen years of age and participated in regular detailed caries assessments (Alm et al. 2008; Wendt et al. 1994); and a longitudinal study of 638 twelve year-olds from Hong Kong in 2001, who were followed up at ages 15 and 18 years of age and in whom detailed caries and periodontal examinations were conducted (Lu et al. 2011). Notably, the follow-up periods of these latter four studies were all time limited (between six and twenty years). Furthermore, the 1942 Swedish Birth Cohort Study and the Pro-Saude study are limited by their reliance on self-reported oral health outcomes (Table 5).

Study name	Start date	Cohort characteristics	Dental outcomes	Key strengths and weaknesses
UK studies				
British Regional Heart Study (BRHS) (Lennon et al. 2015; Ramsay et al. 2015)	1978-80	7,734 men aged 40-59 from across Britain	Single assessment aged 71-92: - tooth retention - periodontal disease - OHRQoL - self-rated oral health - xerostomia	Detailed dental assessment (although no caries data). Focus on dental outcomes only latterly (initial focus was on cardiovascular disease) so lack of early data on certain oral health-specific determinants. Limited to men only. Follow-up only from middle age.
English Longitudinal Study of Ageing (ELSA) (Kang et al. 2019; Rouxel et al. 2015a; Steptoe et al. 2013)	2002/03	11,391 adults age 50+ from across England	Approximately every 4 years: - self-reported number of teeth - self-rated oral health status - OHRQoL	Only self-reported oral health outcomes. Follow-up only from middle or older age.
Non-UK studies				
Florida Longitudinal Dental Care Study (Gilbert et al. 2003; University of Florida Health 2020)	1994	873 adults aged 45+ from Florida, USA	Detailed assessments every 2 years (for 6 years): - caries - periodontal disease - tooth retention - self-reported outcomes	Detailed potential determinant and outcome data (although no dietary data). Follow up only for 6 years from middle or older age.
The Veterans Affairs Dental Longitudinal Study (Kapur et al. 1972)	1969	1,231 medically healthy men aged 21-84 from Greater Boston area, Massachusetts, USA	Detailed examinations every 3 to 5 years: - caries - periodontal disease - tooth retention - filled teeth - self-rated oral health	Detailed potential determinant and dental data. Focus on medically healthy male veterans affects generalisability. Follow-up only from young, middle or older adulthood.
1942 Swedish Birth Cohort Study (Astrom et al. 2015; Astrom et al. 2011a)	1992	6,346 adults aged 50 from Sweden	Self-reported outcomes every 5 years (for 20 years): - number of teeth - OHRQoL	Outcomes self-reported and limited. Limitations in potential determinant data, e.g. lack of dietary data. Follow up only for 20 years from middle age.

Pro-Saude Study (Faerstein et al. 2005; Vettore et al. 2016)	1999	4,030 university staff (aged 22-67) in Rio de Janeiro, Brazil	Self-reported measures of tooth loss and self-rated oral health 13 years after baseline.	Outcomes limited and self-reported. Follow up only for 13 years from young or mid adulthood.
Longitudinal study of one year-olds in Jonkoping, Sweden (no official title) (Alm et al. 2008; Wendt et al. 1994)	1988	671 one-year olds from Jonkoping, Sweden	Regular detailed caries examinations between ages 1 and 15.	Detailed clinical caries examinations. Detailed potential determinant data, apart from dietary data. Only 14 year follow up.
Longitudinal study of 12 year-olds in Hong Kong (no official title) (Lu et al. 2011)	2001	638 12 year-olds from Hong Kong	Dental assessments at age 12, 15 and 18: - caries - periodontal disease	Detailed caries examinations. Detailed potential determinant data. Follow-up only for 6 years from 12 years of age.

Table 5: Summary of key prospective cohort studies starting after birth with dental data.

Finally, with respect to purely retrospective studies (Table 6), some of the most relevant findings come from studies such as the Finnish Health 2000 Survey (Bernabe et al. 2011), the Survey of Health, Ageing and Retirement in Europe (SHARE) (Listl et al. 2018; Listl et al. 2014), the Norwegian Trondelag Studies (Holst and Schuller 2012; Schuller and Holst 1998) and studies of Brazilian thirteen year olds and their mothers (Nicolau et al. 2003a; Nicolau et al. 2007a). The former three studies are large scale, cross-sectional population health surveys of adults from Finland, fourteen European countries and Norway, respectively, which have collected contemporaneous dental outcome measures and retrospective information about potential determinants across the life course. The Finnish and Norwegian studies include detailed clinical examination data, whereas the SHARE study includes only limited self-reported oral health outcomes. The Brazilian cohorts included a cross-sectional study of 652 thirteen year-olds and 305 of their mothers in 1999, involving detailed dental examinations and the collection of retrospective life course data.

Study name	Start date	Cohort characteristics	Dental outcomes	Key strengths and weaknesses
Finnish Health 2000 Survey (Bernabe et al. 2011)	2000/2001	7,112 adults aged 30+ across Finland	Single assessment of: - caries - periodontal disease - tooth retention - perceived oral health	Detailed dental data. Retrospective collection of determinant variables.
Survey of Health, Ageing and Retirement in Europe (SHARE) (Listl et al. 2018; Listl et al. 2014)	7 waves from 2004-2017	Adults aged 50+ from 14 European countries and Israel (16,624 in SHARE wave 2, 41,560 in wave 5)	Self-reported chewing ability (wave 2). Self-reported number of teeth (wave 5)	Limited and self-reported dental outcomes. Retrospective collection of determinant variables.
The Trondelag Study (Holst and Schuller 2012; Schuller and Holst 1998)	Three cross-sectional waves in 1984, 1997 and 2006.	Adults in Trondelag, Norway (3,869 in 1983, 3,493 in 1997 and 700 in 2006).	Single dental assessment of: - caries - filled teeth - missing teeth	Detailed dental data. Retrospective collection of determinant variables.
Study of Brazilian children and mothers (no official title) (Nicolau et al. 2003a; Nicolau et al. 2007a)	1999	652 thirteen year-olds from Cianorte, Brazil. 305 mothers of above children.	Single assessment (in children) of: - caries - gingival bleeding - traumatic dental injuries Single assessment (in mothers) of periodontal disease.	Detailed dental data. Retrospective collection of determinant variables. Focus only on part of life course up to early motherhood.

Table 6: Summary of key retrospective life course studies with dental data.

2.11.4: Contributions of longitudinal oral health studies

In terms of the contributions of each of the above longitudinal oral health studies to knowledge regarding the determinants of oral health, a substantial amount of research has been based on the Dunedin (Broadbent et al. 2011; Broadbent et al. 2016; Crocombe et al. 2012; Thomson 2012; Thomson et al. 2007; Thomson et al. 2000; Thomson et al. 2010), Pelotas (Peres et al. 2017; Peres et al. 2009; Peres et al. 2018a; Peres et al. 2018b; Peres et al. 2007; Peres et al. 2016; Schuch et al. 2018) and Iowa (Broffitt et al. 2013; Chankanka et al. 2016; Curtis et al. 2018a; Levy et al. 2003; Wang et al. 2012) prospective birth cohort studies, plus the prospective Florida Longitudinal Dental Care study (starting after birth) (Dolan et al. 2001; Fisher et al. 2004; Gilbert et al. 2003; Gilbert et al. 2000; Riley and Gilbert 2005). A more modest amount of evidence has been based upon most of the other studies to date (Alm et al. 2008; Astrom et al. 2011b; Delgado-Angulo and Bernabe 2015a; 2015b; Feldens et al. 2010; Ha and Do 2018; Jamieson et al. 2010b; 2010c; Kang et al. 2019; Kay et al. 2010; Krall et al. 2006; Lu et al. 2011; Pearce et al. 2004; Pearce et al. 2009a; Ramsay et al. 2018; Rouxel et al. 2015a; Skafida and Chambers 2018; Tsakos et al. 2011; Vettore et al. 2016). To the author's knowledge, no published analyses regarding the determinants of oral health have been based upon the VicGen, LSAC, Gudaga and Millennium prospective birth cohort studies.

An overview of these findings will be provided in Section 2.13. However, firstly, it is necessary to discuss the statistical techniques appropriate for the analysis of longitudinal data, as these significantly influence the interpretation of such findings.

2.12: Causal pathways modelling in life course research

2.12.1: An introduction

It is recognised that research utilising a life course approach to study the development of health and disease must utilise specialised statistical techniques that permit the longitudinal modelling of causal pathways of disease development across the whole life course (Bub and Ferretti 2014; Burton-Jeangros et al. 2016; Halfon et al. 2018). Traditional multivariable regression analyses are insufficient as they treat distal and proximal determinants of disease as being equally distant to the outcome and presume the effects of determinants on outcomes are direct (Figure 3a) (Weitkunat and Wildner 2002). Such methods do not allow complex pathways of causation to be modelled, whereby some determinants may not have a direct effect on an outcome but may exert indirect effects via mediator variables (Victora et al. 1997; Weitkunat and Wildner 2002). The result of this is that the effects of more distal determinants on an outcome are often underestimated (Newton and Bower 2005; Weitkunat and Wildner 2002).

It is therefore recommended that hierarchical regression modelling is used as a minimum in life course epidemiology but, ideally, more contemporary techniques, such as structural equation modelling (SEM) and path analysis (Bub and Ferretti 2014; Newton and Bower 2005; Victora et al. 1997). Hierarchical regression modelling involves grouping potential determinants by levels, such as life course stages, in a conceptual framework (Figure 3b) and running a series of multivariable regression models, incorporating successive levels each time (i.e. starting with only those determinants in level one, then including determinants in levels one and two and so forth) (Victora et al. 1997). By comparing results between the above models, this allows the direct and indirect effects of each level of predictor variables to be elucidated (Victora et al. 1997).

A disadvantage of hierarchical regression, however, is that detailed causal pathways between individual variables cannot be elucidated (Newton and Bower 2005). For this reason, path analysis is preferred, which is a more sophisticated extension of multivariable regression analysis, whereby multiple regression coefficients are estimated simultaneously for each path in a previously specified path diagram of causal relations between multiple *individual* variables (Figure 3c) (Newton and Bower 2005; Shipley 2016). This allows both direct and indirect paths between all variables to be modelled (Shipley 2016). SEM is a further extension of path analysis, whereby latent variables are also included in the model, in addition to observed variables (Lei and Wu 2007). Latent variables are variables that cannot be measured directly but can be estimated by a number of other observable variables (Lei and Wu 2007).

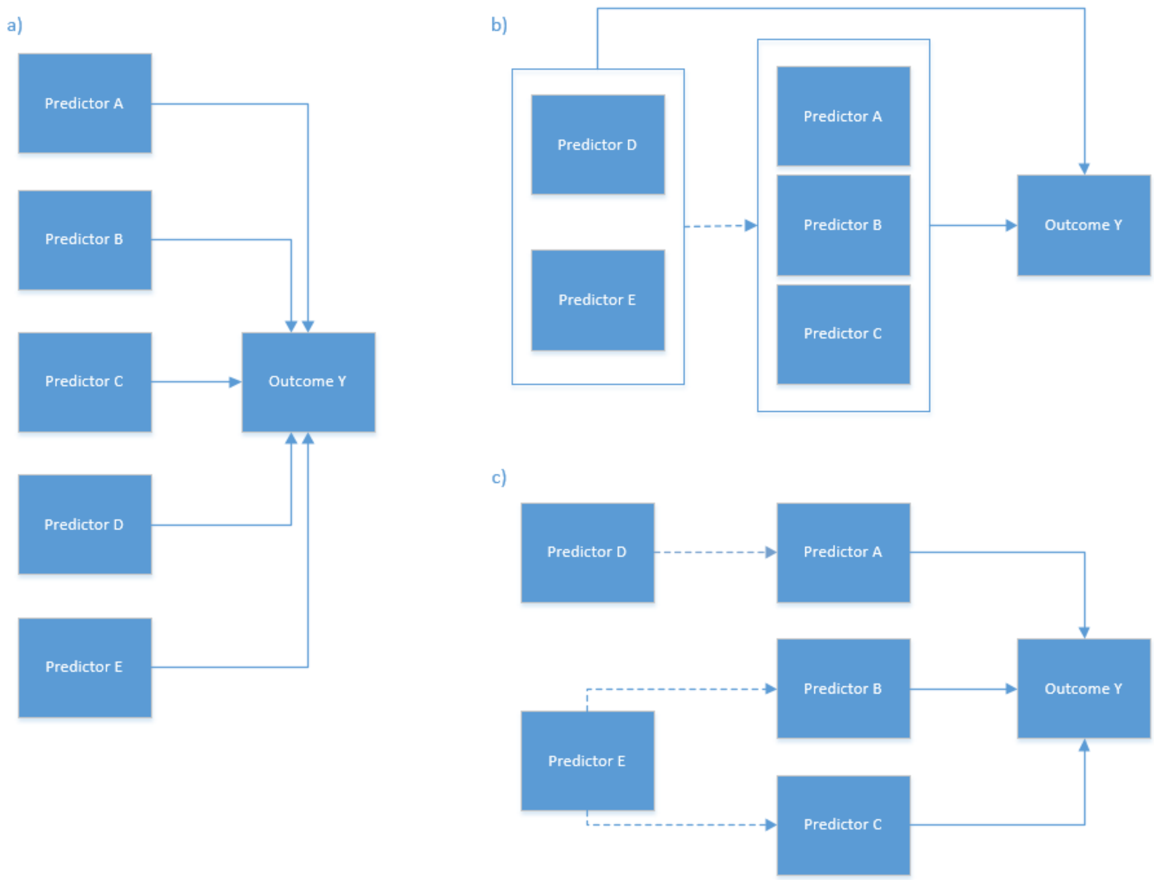

Figure 3: Diagrammatic comparison of a) multivariable regression, b) hierarchical multivariable regression, c) path analysis.
a) identifies only direct paths between predictor and outcome variables, b) identifies direct and indirect paths between levels of predictor variables, c) identifies direct and indirect paths

between individual variables. Direct and indirect paths are represented by solid and dotted lines respectively.

2.12.2: Applications in the field of general health

Hierarchical regression models and SEM, including path analyses, have been utilised in health research mainly over the past three decades (Beran and Violato 2010; Lei and Wu 2007; Victora et al. 1997). Although their applications in medical research and epidemiology are growing, there is still scope for much wider application of these techniques however (Beran and Violato 2010; Tu 2009).

Studies on a range of topics have incorporated hierarchical regression modelling techniques, to distinguish the effects of risk factors acting at different levels on health outcomes (Duncan et al. 1999; Nascimento et al. 2004; Nonterah et al. 2018; Parker et al. 2003; Pearce et al. 2006). For example, such techniques have been used to separate the effects of more upstream determinants from more proximal determinants (Nonterah et al. 2018; Parker et al. 2003; Pearce et al. 2006), such as the effects of different stages of the life course on disease outcomes (Parker et al. 2003; Pearce et al. 2006; Pearce et al. 2005) or the effects of different levels of risk factors on outcomes, such as neighbourhood, family and individual effects (Duncan et al. 1999; Reading et al. 1999).

In the case of more advanced SEM and path analysis techniques, a range of health outcomes have also been explored, for example, in the fields of psychiatry (Loberg et al. 2006), cardiovascular health (Dahly et al. 2009; Pearce et al. 2012), reproduction (Islam et al. 2016; Sheppard et al. 2016) and respiratory function (Shook-Sa et al. 2017; Tennant et al. 2008). Using the 1947 NTFS prospective birth cohort study as an example, path analysis has been used to explore the overall, direct and indirect contributions of factors across the whole life course on reproduction patterns (Sheppard et al. 2016), adulthood physical activity (Mann et al. 2013), adult respiratory function (Tennant et al. 2008), adulthood blood pressure (Mann et al. 2011) and adulthood fibrinogen levels (Pearce et al. 2012). For example, in a study of blood pressure, Mann and colleagues (2011) demonstrated that adulthood factors and birth factors were both important in determining age 50 blood pressure. Specifically, adulthood body mass index then sex were of greatest overall importance, followed by birth factors (including social class at birth and standardised birth weight), then adulthood physical activity. In contrast, adulthood smoking status and social class were of least importance

(Figure 4) (Mann et al. 2011). Furthermore, this analysis demonstrated the pathways of influence between the above variables (Figure 4) (Mann et al. 2011). The use of path analysis modelling techniques in this research significantly enhanced its reliability and usefulness compared to previous examples in this field (Cheung et al. 2000; Martyn et al. 1995), as it allowed causal pathways between individual factors to be modelled and relative contributions of early life factors to be elucidated, despite effects being mediated through later life variables.

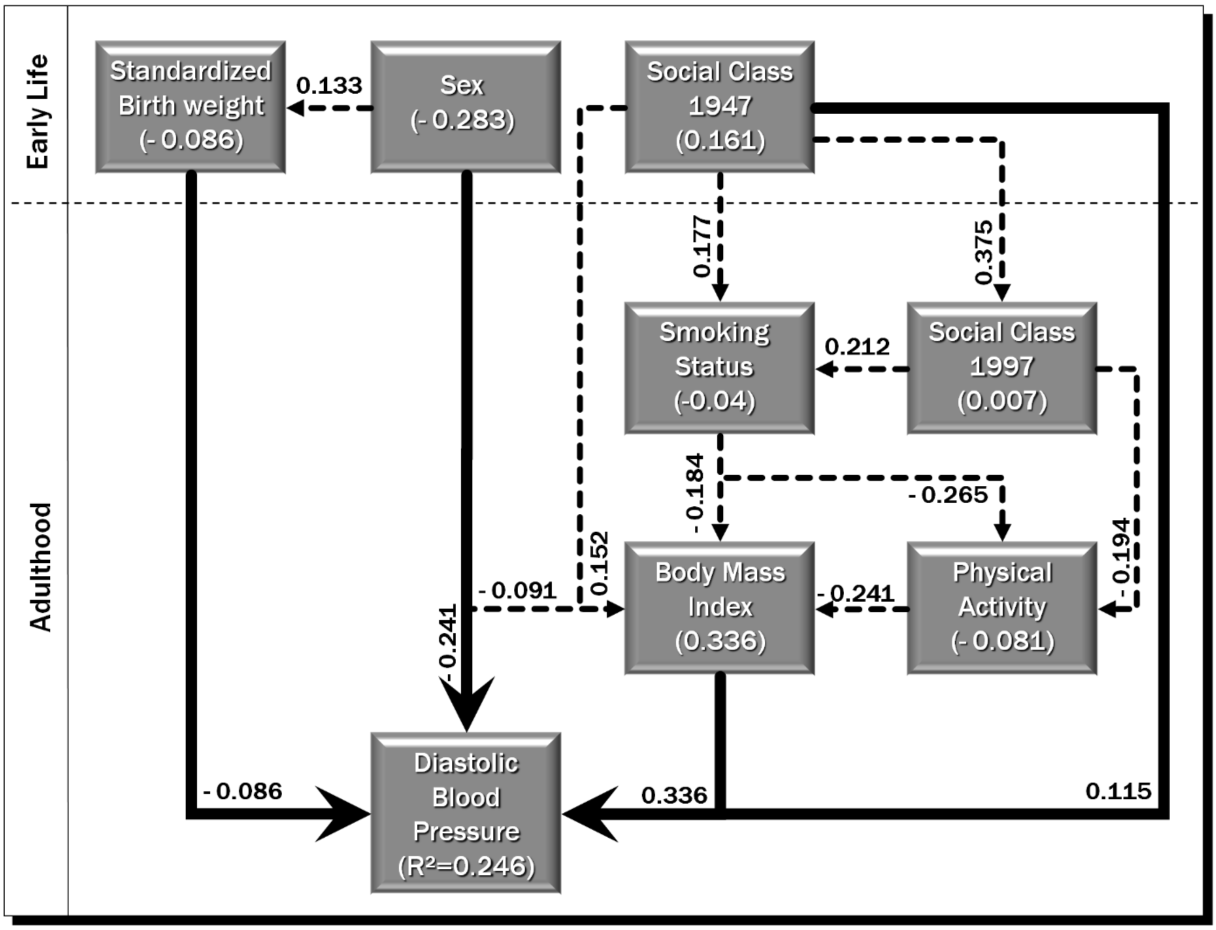

Figure 4: Path diagram showing the direct and indirect predictors of diastolic blood pressure at age 50 years in the NTFS, according to an analysis by (Mann et al. 2011). Significant effects (p<0.05) are represented by arrows and are labelled with standardised coefficients (β). Direct and indirect effects are represented by solid and dashed arrows respectively. The standardised total effect for each variable is the sum of the direct and indirect effects and is shown underneath the variable name.

2.12.3: Applications in the field of oral health

Analogous to the field of general health research, researchers within oral health epidemiology also recognise that research investigating the causes of oral health and disease needs to move beyond using simple statistical methods (i.e. traditional multivariable regression) and utilise techniques which permit the modelling of complex causal pathways of disease development (i.e. hierarchical regression modelling and SEM) (Crall and Forrest 2018; Newton and Bower 2005; Nicolau et al. 2007b). Historically, analyses investigating the determinants of oral disease have not utilised such techniques (Crall and Forrest 2018; Newton and Bower 2005) but, in recent years, a substantial number of studies have begun to apply such approaches (Aleksejuniene et al. 2002a; Aleksejuniene et al. 2002b; Bernabe et al. 2009; Broadbent et al. 2016; Curtis et al. 2018a; Donaldson et al. 2008; Duijster et al. 2014; Gao et al. 2010; Gururatana et al. 2014; Ho et al. 2019; Kumar et al. 2017; Lu et al. 2011; Mason et al. 2006; Newton and Bower 2005; Pearce et al. 2004; Peres et al. 2018b; Sfreddo et al. 2019; Silva et al. 2020; Tolvanen et al. 2012; Vendrame et al. 2018; Vettore et al. 2016). The majority of studies have utilised SEM (Broadbent et al. 2016; Curtis et al. 2018a; Vettore et al. 2016) or path analysis (Goettems et al. 2018; Lu et al. 2011), although some analyses have used hierarchical regression modelling techniques (Mason et al. 2006; Pearce et al. 2004).

Many of the above applications of causal pathways modelling techniques have been applied to cross-sectional data (Aleksejuniene et al. 2002a; Aleksejuniene et al. 2002b; Behbahanirad et al. 2017; Bernabe et al. 2009; Donaldson et al. 2008; Duijster et al. 2014; Ho et al. 2019; Kojima et al. 2013; Kumar et al. 2017; Polk et al. 2010; Tolvanen et al. 2012) or longitudinal data with very short follow-up periods, e.g. of around one year (Gao et al. 2010; Gururatana et al. 2014; Silva et al. 2020). Such studies are very useful in providing evidence about the pathways existing between different determinants of oral health at a single point in time, but do not provide any evidence regarding determinants across the life course.

With regards to the application of causal pathways modelling approaches to longitudinal data to explore the determinants of oral health, the number of studies is reasonably limited. Studies primarily relate to: the Dunedin (Broadbent et al. 2016), Pelotas (Goettems et al. 2018; Peres et al. 2018b), Iowa (Curtis et al. 2018a) and NTFS (Mason et al. 2006; Pearce et al. 2004) prospective birth cohorts; two prospective longitudinal studies starting after birth – the Pro-Saude Study (Vettore et al. 2016) and the six-year follow up of twelve year-olds in Hong Kong (Lu et al. 2011); and two retrospective life course studies – the Finnish Health 2000 Survey (Bernabe et al. 2012) and a retrospective study of adults aged eighteen years or over in Brazil (Vendrame et al. 2018). These longitudinal studies have primarily explored the determinants of clinical oral health outcomes in both adults (Bernabe et al. 2011; Broadbent et al. 2016; Pearce et al. 2004; Vendrame et al. 2018; Vettore et al. 2016) and children (Curtis et al. 2018a; Goettems et al. 2018; Lu et al. 2011; Peres et al. 2018b), primarily focusing on caries (Broadbent et al. 2016; Curtis et al. 2018a; Goettems et al. 2018; Lu et al. 2011), periodontal (Lu et al. 2011; Peres et al. 2018b) and tooth loss outcomes (Broadbent et al. 2016; Pearce et al. 2004; Vendrame et al. 2018; Vettore et al. 2016), but have also explored the determinants of OHRQoL (Gururatana et al. 2014; Mason et al. 2006). Two of these studies have utilised hierarchical regression modelling (Mason et al. 2006; Pearce et al. 2004), but the others have used path analysis (Goettems et al. 2018; Lu et al. 2011; Peres et al. 2018b) or SEM techniques (Bernabe et al. 2012; Broadbent et al. 2016; Curtis et al. 2018a; Vendrame et al. 2018; Vettore et al. 2016). Due to the small number of studies and the narrow focus of several studies (Goettems et al. 2018; Lu et al. 2011; Peres et al. 2018b), the contribution of this evidence to our understanding of the life course determinants of oral health is fairly limited, and the potential to increase the amount of evidence in this field is significant.

The findings of the above studies will be discussed in the following section (Section 2.13), where they will be discussed in the context of the whole body of evidence exploring the life course determinants of oral health.

2.13: Key findings from life course oral health studies

Building on the information provided in Sections 2.11 and 2.12, this section now reviews the contribution of existing longitudinal studies to knowledge about the life course determinants of oral health, particularly those using causal pathways modelling approaches. Sub-section 2.13.1 firstly discusses studies which have focussed in particular on the association between life course socio-economic trajectories and oral health outcomes, as this has been one particular focus of research. Sub-sections 2.13.2 to 2.13.4 subsequently discuss key findings relating to the broader determinants of dental caries, periodontal disease and tooth loss as, pertaining to the most common clinical dental diseases (Dye 2017), these areas have been the other main focus of research.

2.13.1: Life course socio-economic trajectories and oral health outcomes

The relationship between life course socio-economic trajectories and adulthood oral health outcomes has been the specific focus of a number of analyses utilising data from longitudinal oral health studies. Such analyses relate to a range of studies, predominantly: the Pelotas

(Peres et al. 2018a; Peres et al. 2011b; Schuch et al. 2018), Dunedin (Poulton et al. 2002; Thomson et al. 2004), NTFS (Pearce et al. 2009a) and NCDS (Delgado-Angulo and Bernabe 2015a; 2015b) prospective birth cohorts; two prospective longitudinal studies starting after birth – the UK BRHS (Ramsay et al. 2018) and the 1942 Swedish Birth Cohort (Astrom et al. 2015); and three retrospective life course studies – the Finnish Health 2000 survey (Bernabe et al. 2011; Bernabe et al. 2009; Bernabe et al. 2012) and two studies of Brazilian adults (Andrade et al. 2018; Vendrame et al. 2018). The key studies and their findings relating to caries, periodontal disease and tooth loss are detailed in Table 7.

In summary, studies have focused on trajectories based on several socio-economic measures, particularly social class (Pearce et al. 2009a; Poulton et al. 2002; Ramsay et al. 2018; Thomson et al. 2004), income (Peres et al. 2011b; Schuch et al. 2018) and educational attainment (Bernabe et al. 2011). They have investigated outcomes across all of adulthood but particularly early adulthood in the case of caries (Peres et al. 2011b; Poulton et al. 2002; Thomson et al. 2004) and particularly middle and older adulthood in the case of tooth loss (Astrom et al. 2015; Pearce et al. 2009a; Ramsay et al. 2018). The majority of studies have demonstrated that oral health outcomes were best in high socio-economic trajectory groups, worst in low trajectory groups and in the middle of these two points for upwardly and downwardly mobile groups (Astrom et al. 2015; Bernabe et al. 2011; Pearce et al. 2009a; Peres et al. 2011b; Poulton et al. 2002; Schuch et al. 2018; Thomson et al. 2004). However, there were conflicting results regarding which of these latter two trajectories was most beneficial (Astrom et al. 2015; Bernabe et al. 2011; Pearce et al. 2009a; Peres et al. 2011b; Poulton et al. 2002; Schuch et al. 2018; Thomson et al. 2004). These studies therefore support the importance of both childhood and adulthood socio-economic conditions in determining adulthood oral health outcomes, although they conflict over the relative importance of these life course stages.

Several of the above studies also explicitly tested support for various life course models of oral health development (Bernabe et al. 2011; Ramsay et al. 2018). Bernabe et al.'s (2011) study of caries development across all adult ages in Finland found support for a critical period model in childhood, an accumulation of risk model across the whole life course and a social trajectories model – a special case of the accumulation model whereby there is a gradient of outcomes across progressive trajectory groups. Ramsay et al.'s (2018) study of tooth loss in older British men also found support for various life course models, although support for the critical period model in middle age was greatest.

Although the majority of studies found relationships between life course socio-economic trajectories and adulthood oral health outcomes, it is worth noting that such conclusions were not unanimous. According to data from the NTFS study, associations between life course social class trajectories and adult tooth loss were only present for women, not for men (Pearce et al. 2009a), which was in contrast to Ramsay et al.'s (2018) study. In addition, Ramsay et al.'s (2018) study found little association between any life course model of social class and deprivation and periodontal disease outcomes in older British men, which contrasted with findings from younger cohorts (Poulton et al. 2002; Thomson et al. 2004)(Schuch et al. 2018)(Bernabe et al. 2011). It is postulated that this may have been the result of the healthy survivor effect. Specifically, there would have been an increased likelihood of periodontally compromised teeth being lost by the age of 71-92. In addition, participants experiencing the worst socio-economic conditions and periodontal disease may have been more likely to die prematurely due to shared risk factors such as smoking (Ramsay et al. 2018).

Outcomes	Key studies (and relationships explored)	Key findings
Caries	Dunedin study: life course social class trajectories and outcomes at age 26 (Poulton et al. 2002; Thomson et al. 2004).	Worse outcomes progressively demonstrated across persistently high, upwardly mobile, downwardly mobile and persistently low social class trajectory groups.
	1982 Pelotas Birth Cohort: life course family income trajectories and outcomes at age 18 (Peres et al. 2011b).	Stable high income groups generally had the lowest caries experience, followed by the upward, stable low and downwardly mobile groups.
	Finnish Health 2000 Survey: parental and own education trajectories and outcomes across adulthood (Bernabe et al. 2011)	Worse outcomes progressively demonstrated across persistently high, upwardly mobile, downwardly mobile and persistently low trajectory groups.
Periodontal disease	Dunedin study: life course social class trajectories and age 26 outcomes (Poulton et al. 2002; Thomson et al. 2004).	A linear increase in periodontal disease was demonstrated across persistently high, downwardly mobile, upwardly mobile, and persistently low social class trajectory groups.
	1982 Pelotas Birth Cohort: life course family income trajectories and age 31 outcomes (Schuch et al. 2018).	Outcomes were better in persistent high, then persistent middle, then low and variable life course family income trajectory groups.
	Finish Health 2000 Survey: parental and own education trajectories and outcomes across adulthood (Bernabe et al. 2011).	Outcomes progressively worsened across persistently high, upwardly mobile, downwardly mobile and persistently low trajectory groups.
	UK BRHS: life course trajectories of social class and deprivation and outcomes in men at age 71-92 (Ramsay et al. 2018).	Little association between any life course model and periodontal disease outcomes at ages 71-92.
Tooth loss	NTFS Study: social class trajectories age 0 to 50, 25 to 50 and 0 to 25 and functional dentition age 50 (Pearce et al. 2009a).	For women, persistently low trajectories always associated with worse outcomes than persistently high trajectories. Inconsistent findings for upward and downward mobility groups but frequently worse outcomes than persistently high trajectory groups. No associations for men.
	UK BRHS: life course trajectories of social class and deprivation and complete tooth loss/functional dentition in men at age 71-92 (Ramsay et al. 2018).	Assessed applicability of sensitive period, accumulation and social trajectory models. Support for various models but greatest support for sensitive period model in middle age.
	Finnish Health 2000 survey: parental and own education trajectories and edentulism across adulthood (Bernabe et al. 2011).	Worse outcomes demonstrated progressively across persistently high, upwardly mobile, downwardly mobile and persistently low trajectory groups.
	1942 Swedish Birth Cohort: age 50 to 65 marital status and employment trajectories, and tooth retention at ages 65 and 70 (Astrom et al. 2015).	Stable low trajectories always associated with worse outcomes than stable high trajectories. Upwardly mobile trajectories only occasionally worse outcomes than stable high trajectories. Downwardly mobile trajectories usually worse outcomes than stable high trajectories.

Table 7: Key findings from studies exploring the relationship between life course socio-economic trajectories and oral health outcomes.

__2.13.2: Determinants of dental caries-broader findings__

Many analyses have used longitudinal oral health studies to explore the determinants of caries from a broader perspective than purely life course socio-economic trajectories. The key studies and their findings on this topic are summarised in Table 8.

The majority of analyses focus on caries outcomes in children and adolescents, with very few addressing caries outcomes in adults (Broadbent et al. 2016; Holst and Schuller 2012). The studies in children and adolescents are based mainly on the Pelotas (Goettems et al. 2018; Peres et al. 2009; Peres et al. 2005) and Iowa (Broffitt et al. 2013; Chankanka et al. 2011; Chankanka et al. 2016; Curtis et al. 2018a; Curtis et al. 2018b; Levy et al. 2003; Wang et al. 2012) prospective birth cohort studies, although minimal evidence is also available from other prospective birth cohorts (the Australian ABC and Scottish GUS cohorts (Jamieson et al. 2010b; Skafida and Chambers 2018)) and other types of longitudinal studies (Lu et al. 2011; Nicolau et al. 2003a).

As an overview, the studies in children have generally found that factors such as socio-economic position (Broffitt et al. 2013; Chankanka et al. 2011; Peres et al. 2005; Skafida and Chambers 2018), parental factors (such as parental oral health and beliefs) (Alm et al. 2008; Broadbent et al. 2016), sugar consumption (Chankanka et al. 2016; Jamieson et al. 2010b; Peres et al. 2005; Skafida and Chambers 2018), tooth brushing habits (Broffitt et al. 2013; Curtis et al. 2018a; Peres et al. 2009; Skafida and Chambers 2018), plaque control (Broadbent et al. 2011), dental attendance (Crocombe et al. 2012; Thomson et al. 2010) and fluoride exposure (Levy et al. 2003; Wendt et al. 1994) were associated with caries outcomes. The majority of studies, however, have utilised traditional multivariable regression analysis techniques, so the relative contributions of factors is difficult to reliably establish.

Only three studies have utilised causal pathways modelling techniques to explore caries outcomes in childhood and adolescents (Curtis et al. 2018a; Goettems et al. 2018; Lu et al. 2011). One study, based on data from the Iowa Fluoride Study (Curtis et al. 2018a), used SEM techniques to investigate the determinants of caries experience in the permanent dentition in adolescence. This study found that neither socio-economic position at birth, nor in adolescence, had a significant overall effect on the outcome. However, the combined effects of adolescent dental attendance and tooth brushing frequency were almost double the effect of sex (with females having worse outcomes than males) and over double the effects of adolescent sugar-sweetened beverage intake and adolescent frequency of eating events per day. However, this study did not distinguish the effects of dental attendance from those of tooth brushing. Furthermore, the two additional studies (Goettems et al. 2018; Lu et al. 2011) provide little information about the relative contributions of determinants to caries outcomes, focusing only on pathways of mediation between parental factors and children's caries experiences.

Regarding the longitudinal studies of caries outcomes in adults, these are very limited (Broadbent et al. 2016; Holst and Schuller 2012) (Table 8). Norwegian birth cohort data have demonstrated that childhood OHBs were associated with caries outcomes in adulthood, independent of adulthood OHBs and socio-economic position, but did not use causal pathways modelling techniques (Holst and Schuller 2012). Advancing on this study, Broadbent and colleagues (2016) used SEM approaches to model the pathways linking life course socio-economic position, oral health beliefs, dental attendance and tooth brushing behaviours to age 38 caries outcomes. However, although this study demonstrated a variety of direct pathways between variables, it did not calculate indirect or total effects of variables on caries outcomes and, hence, provides little further information about the overall contributions of determinants.

Age group	Studies NOT using causal pathways modelling approaches		Studies using causal pathways modelling approaches	
	Key studies	**Key findings**	**Key studies**	**Key findings**
Children and adolescents	Numerous studies. Majority relate to Pelotas (Peres et al. 2009; Peres et al. 2005) and Iowa (Broffitt et al. 2013; Chankanka et al. 2011; Chankanka et al. 2016; Curtis et al. 2018b; Levy et al. 2003; Wang et al. 2012) prospective birth cohorts. Minimal evidence from other prospective birth cohorts (ABC study (Jamieson et al. 2010b) and GUS cohort (Skafida and Chambers 2018)) and other types of longitudinal studies (Nicolau et al. 2003a).	Childhood and adolescent socio-economic factors, parental factors, sugar consumption, tooth brushing habits, plaque control, dental attendance and fluoride exposure repeatedly associated with caries outcomes.	Limited to two analyses relating to the Iowa study (Curtis et al. 2018a; Goettems et al. 2018) and one longitudinal study of Hong Kong children as they aged between 12 and 18 (Lu et al. 2011).	Neither socio-economic position at birth nor in adolescence had a significant overall effect on caries experience in adolescence. However, oral health behaviours in adolescence (including dental attendance, tooth brushing habits and dietary habits) and sex all had a significant overall effect (Curtis et al. 2018a). Pathways of influence between parental socio-economic factors, parental oral health behaviours and childrens' caries experiences are mediated by children's oral health behaviours (Goettems et al. 2018; Lu et al. 2011).
Adults	Limited studies (Holst and Schuller 2012). No prospective birth cohort studies.	Age 10 oral health behaviours, adulthood oral health behaviours and socio-economic factors associated with adulthood caries outcomes (Holst and Schuller 2012).	Limited to one analysis relating to the Dunedin Study (Broadbent et al. 2016).	Adult SES, tooth brushing frequency and dental visiting behaviours influenced caries experience at age 38. Childhood SES influenced adult SES and adolescent and adult oral health-related beliefs. Adolescent and adult oral health-related beliefs, in turn, influenced adult tooth brushing frequency and dental visiting behaviours. However, only direct effects, not indirect or total effects, calculated.

Table 8: Key findings from longitudinal studies exploring the determinants of caries.
SES = Socio-economic status

2.13.3: Determinants of periodontal disease-broader findings

Several longitudinal studies have investigated the determinants of periodontal disease from a broader perspective than purely socio-economic trajectories. These primarily include the Pelotas (De Castilhos et al. 2012; Nascimento et al. 2017; Peres et al. 2018b) and Dunedin (Broadbent et al. 2011; Broadbent et al. 2006; Thomson et al. 2007; Zeng et al. 2014) prospective birth cohort studies. In addition, a few analyses have also been based on other types of longitudinal studies, such as the prospective cohort study following children in Hong Kong between the ages of twelve and eighteen (Lu et al. 2011) and the retrospective life course studies of children and mothers in Brazil (Nicolau et al. 2003b; Nicolau et al. 2007a) (Table 9).

Studies exploring outcomes prior to adulthood have been very limited (Lu et al. 2011; Nicolau et al. 2003b; Peres et al. 2018b), but associations have been demonstrated between socio-economic factors (Lu et al. 2011; Nicolau et al. 2003b; Peres et al. 2018b), family environment (Nicolau et al. 2003b), plaque control (Nicolau et al. 2003b) and gingival health outcomes in adolescence. However, such analyses provide little evidence regarding the overall contributions of life course factors to periodontal health outcomes, as they either rely solely on traditional multivariable regression analyses (Nicolau et al. 2003b) or, where complex causal pathways modelling approaches have been used, focus only on very specific relationships (Table 9) (Lu et al. 2011; Peres et al. 2018b).

Studies in adults have been more extensive and have mainly focused on the contributions of smoking (Albandar et al. 2000; Thomson et al. 2007; Zeng et al. 2014), plaque control (Broadbent et al. 2011) and obesity (De Castilhos et al. 2012; Nascimento et al. 2017) to periodontal health outcomes in early adulthood. Studies based on the Dunedin cohort found that life course smoking and plaque trajectories were of greatest importance in determining periodontal health outcomes up to the age of 38 (Thomson et al. 2007; Zeng et al. 2014), whilst studies based on the Pelotas birth cohorts also demonstrated a key role of obesity in age 31 periodontal outcomes (Nascimento et al. 2017). However, none of these studies utilised causal pathways modelling approaches.

Age group	Studies NOT using causal pathways modelling approaches		Studies using causal pathways modelling approaches	
	Key studies	**Key findings**	**Key studies**	**Key findings**
Children and adolescents	Limited research, such as a retrospective life course study of thirteen year old children in Brazil (Nicolau et al. 2003b)	Socio-economic factors, family environment and plaque control from birth to age 13 associated with gingival health outcomes (Nicolau et al. 2003b).	Limited to two analyses, one from the 1993 Pelotas Birth Cohort Study (Peres et al. 2018b) and one from a longitudinal study of Hong Kong children as they aged between 12 and 18 (Lu et al. 2011).	Peres and colleagues (2018b) explored only pathways mediating the effects of maternal schooling on gingival health at age 13. Lu and colleagues (2011) explored only the pathways mediating the effects of parental socio-economic factors on periodontal outcomes in adolescence.
Adults	Several studies, particularly based upon the Dunedin and Pelotas prospective birth cohorts, have examined the effects of various determinants across the life course on periodontal health outcomes in adulthood, particularly early adulthood (Albandar et al. 2000; Broadbent et al. 2011; Broadbent et al. 2006; De Castilhos et al. 2012; Nascimento et al. 2017; Nicolau et al. 2007a; Thomson et al. 2007; Zeng et al. 2014).	Studies based on the Dunedin cohort have demonstrated that life course smoking and plaque trajectories were of greatest importance in determining periodontal health outcomes in adulthood (up to the age of 38) (Thomson et al. 2007; Zeng et al. 2014). Studies based on the Pelotas Birth Cohorts have also demonstrated a role of obesity of similar importance to that of smoking (up to the age of 31) (Nascimento et al. 2017).	None identified.	

Table 9: Key findings from longitudinal studies exploring the determinants of periodontal outcomes
SES = Socio-economic status

2.13.4: Determinants of tooth loss-broader findings

A broad range of longitudinal oral health studies have explored the determinants of tooth loss from a broader perspective than purely socio-economic trajectories. Studies include: the NTFS (Pearce et al. 2004) and Dunedin (Crocombe et al. 2012; Thomson et al. 2000) prospective birth cohorts; several prospective cohort studies starting after birth, such as the ELSA (Kang et al. 2019; Rouxel et al. 2015a; Tsakos et al. 2011), Pro-Saúde (Vettore et al. 2016), Florida Longitudinal Dental Care (Gilbert et al. 2003) and Veterans Affairs Dental Longitudinal (Krall et al. 2006) studies; and a small number of retrospective studies, such as the SHARE survey (Listl et al. 2018) (Table 10). Studies have universally focused on tooth loss outcomes in adulthood, but outcomes across the whole of adult life have been studied, including young adulthood (Crocombe et al. 2012; Thomson et al. 2000), middle age (Astrom et al. 2011b; Pearce et al. 2004; Simila and Virtanen 2015) and older age (Gülcan et al. 2015; Thorstensson and Johansson 2010).

The vast majority of analyses have not utilised causal pathways modelling techniques and, therefore, provide limited information about the relative contributions of determinant factors across the life course on tooth loss, or potential pathways of influence. However, such analyses have demonstrated the independent effects of various predictors on future tooth loss, including: socio-economic factors across the whole life course (Astrom et al. 2011b; Gülcan et al. 2015; Listl et al. 2018; Tsakos et al. 2011); dental visiting in early (Crocombe et al. 2012; Thomson et al. 2000; Thomson et al. 2010), as well as later, adulthood (Astrom et al. 2011b; Listl et al. 2018); plaque trajectories (Broadbent et al. 2011); dental anxiety (Thomson et al. 2000); general health (Listl et al. 2018); and later adulthood social capital (Rouxel et al. 2015a) and cognitive function (Kang et al. 2019). Many studies have also focused on the effects of smoking on tooth loss and collectively suggest that smoking across all stages of the life course can influence future tooth loss (Albandar et al. 2000; Arora et al. 2010; Astrom et al. 2011b; Krall et al. 2006; Simila and Virtanen 2015; Thorstensson and Johansson 2010; Yanagisawa et al. 2009). Moreover, studies suggest that it is the extent and duration of smoking and the time since cessation, rather than the life course stage at which smoking occurs, which particularly influence tooth loss outcomes (Albandar et al. 2000; Arora et al. 2010; Krall et al. 2006; Simila and Virtanen 2015; Yanagisawa et al. 2009). As tooth loss is primarily the result of two main diseases – caries and periodontal disease (Anand et al. 2010; Hull et al. 1997; Jafarian and Etebarian 2013;

McCaul et al. 2001; Murray et al. 1997; Richards et al. 2005) – it is not surprising that many of the above determinants overlap those related to caries and periodontal disease (sub-sections 2.13.2 and 2.13.3).

With regards to the use of causal pathways modelling approaches to explore determinants of tooth loss, studies are scarce (Table 10) (Broadbent et al. 2016; Pearce et al. 2004; Vendrame et al. 2018; Vettore et al. 2016). One analysis of UK NTFS data suggested that the overall effects of adult lifestyle factors on tooth loss were around double the combined overall effects of birth and childhood factors (Table 10) (Pearce et al. 2004). However, this study did not include information on several potentially key determinants, such as life course dental attendance or oral hygiene practices, nor sugar consumption in childhood. In addition, relying on hierarchical regression modelling, this study was unable to unpick the separate effects of individual determinants at each life course stage. Two further studies from Brazil used SEM approaches to explore the determinants of tooth loss across adulthood (Vendrame et al. 2018; Vettore et al. 2016). These studies supported a substantial contribution of socio-economic position across the whole life course to future tooth loss outcomes and suggested that the overall effects of childhood and adulthood socio-economic status were similar (Vendrame et al. 2018; Vettore et al. 2016). Vendrame at al.'s study (2018) also demonstrated an equal importance of the role of gender but a minor role of adulthood stress and social ties by comparison. However, both studies lacked information on several key potential determinants, particularly dietary and oral hygiene practices (Vendrame et al. 2018; Vettore et al. 2016). Finally, as previously discussed in relation to caries outcomes (sub-section 2.13.2), Broadbent et al. (2016) used SEM approaches to model the pathways between life course socio-economic factors, oral health behaviours and beliefs and tooth retention, but only calculated direct and not indirect or total effects.

Age group	Studies NOT using causal pathways modelling approaches		Studies using causal pathways modelling approaches	
	Key studies	**Key findings**	**Key studies**	**Key findings**
Adults	Multiple studies have examined the effects of various determinants across the life course on tooth loss across the whole of adulthood. These include the Dunedin birth cohort study (Broadbent et al. 2016; Crocombe et al. 2012; Thomson et al. 2000; Thomson et al. 2010), non-birth prospective cohort studies from the UK (Kang et al. 2019; Rouxel et al. 2015a; Tsakos et al. 2011) and elsewhere (Gilbert et al. 2003; Krall et al. 2006), and a small number of retrospective studies (Listl et al. 2018).	Independent effects of a variety of predictors on future tooth loss have been demonstrated, including socio-economic factors across the whole life course (Astrom et al. 2011b; Gülcan et al. 2015; Listl et al. 2018; Tsakos et al. 2011), dental visiting in early (Crocombe et al. 2012; Thomson et al. 2000; Thomson et al. 2010) and later adulthood (Astrom et al. 2011b; Listl et al. 2018), plaque trajectories (Broadbent et al. 2011), dental anxiety (Thomson et al. 2000), general health (Listl et al. 2018), later adulthood social capital (Rouxel et al. 2015a), later adulthood cognitive function (Kang et al. 2019) and smoking across the life course (Albandar et al. 2000; Arora et al. 2010; Krall et al. 2006; Simila and Virtanen 2015; Yanagisawa et al. 2009).	Limited to four analyses related to the NTFS (Pearce et al. 2004) and Dunedin (Broadbent et al. 2016) prospective birth cohorts, the Brazilian Pro-Saude thirteen year prospective cohort study (Vettore et al. 2016) and a retrospective study of adults in Southern Brazil (Vendrame et al. 2018).	The overall effects of adult lifestyle factors (including smoking, alcohol consumption, sugar consumption and social class) on age 50 tooth loss were around double the combined effects of birth and childhood factors (including socio-economic conditions, birth weight and breastfeeding practices) according to hierarchical regression modelling (Pearce et al. 2004). The total effect of baseline SES on tooth loss thirteen years later (in adults of all ages) was more than five times that of the total effect of current smoking. By comparison, the effects of baseline stress and social ties were very minor. No significant effects were associated with the frequency of dental visiting and having health insurance at baseline (Vettore et al. 2016). The overall effects of childhood and adulthood SES and gender on adult tooth loss were similar, but the effects of current smoking and current chronic disease experience were not significant (Vendrame et al. 2018). Pathways modelled between life course socio-economic factors, oral health beliefs and oral health practices and age 38 tooth loss. However, no indirect or total effects calculated (Broadbent et al. 2016).

Table 10: Key findings from longitudinal studies exploring the determinants of tooth loss.
SES = Socio-economic status

2.13.5: Applicability of findings to UK population

Whilst reviewing the global evidence from longitudinal studies regarding the life course determinants of oral health, it is important to consider how applicable this body of research is to the UK population, the focus of the present research study. As discussed, only a very small number of longitudinal studies with oral health data exist within the UK (Tables 4 and 5), whilst the majority originate from elsewhere.

Even within the UK studies, there are issues of representativeness. For example, the NTFS and ALSPAC cohorts are comprised of individuals born in Newcastle upon Tyne (Pearce et al. 2009b) and Bristol (Dudding et al. 2018), respectively, whilst the GUS (Skafida and Chambers 2018) and ELSA cohorts (Steptoe et al. 2013) are representative of Scotland and England respectively. The demographics and characteristics of these different areas differ in some respects. For example, compared to England overall, the socio-economic environment is generally similar, if not slightly better, in South-West England (where Bristol resides) (PHE 2020c), generally poorer in North-East England (the region including Newcastle upon Tyne) (PHE 2020c) and reasonably similar, in general, in Scotland (Abel et al. 2016). Furthermore, only around 10% of the UK's population receives optimally fluoridated water, including Newcastle upon Tyne and limited other areas of England, but not Bristol (O'Hora and Wilkinson 2006). There are also many differences in NHS dental care between England and Scotland. For example, a new system of NHS dental charges introduced in England in 2006 has resulted in many differences in patient charges, not least that dental check-ups are free on the NHS in Scotland but cost £23.80 currently in England (NHS.UK 2020b; Scottish Dental 2021).

Furthermore, other specific characteristics of the UK studies, beyond their location, may also limit the generalisability of their findings. For example, the UK BRHS includes only male and not female participants (Lennon et al. 2015), which is a concern given evidence of gender differences in oral disease susceptibility and experience (Russell et al. 2013).

Outside of the UK, the majority of evidence from longitudinal studies, regarding the life course determinants of oral health, originates from the Dunedin, Pelotas and Iowa birth cohorts, and the non-birth Florida Longitudinal Dental prospective cohorts (see sub-section 2.11.4). The Dunedin, Iowa and Florida cohorts may be considered not dissimilar to UK cohorts in many ways, in that they originate from regions of developed countries with reasonably comparable socio-economic profiles to the UK (OECD 2021). That said, unlike in the UK, water fluoridation has been widespread in Dunedin and the whole of New Zealand for several decades (Moore et al. 2017; Peres et al. 2011c), as it has been in the states of Iowa and Florida and the rest of the USA (Allukian et al. 2018; Florida Health 2020; Maurer 2005). Furthermore, there are notable differences in oral health care systems in these countries. In the UK, the entire adult population is entitled to publically subsidised oral health care (NHS.UK 2020b), whereas in New Zealand and the USA the majority of adults have to pay for their dental care on a completely private basis (HHS.Gov 2017; New Zealand Government 2020). In the USA, many children also have to pay for dental treatment (HHS.Gov 2017), unlike in the UK and New Zealand (New Zealand Government 2020; NHS.UK 2020b). Furthermore, in New Zealand, a universal and free school-based dental service exists, which results in the vast majority of children and adolescents receiving regular dental care up to the age of 15 (Thomson et al. 2010), which is above and beyond what is achieved in the UK (Tsakos et al. 2015).

Regarding the Pelotas studies, the differences between these cohorts and UK populations may be even greater. Brazil is still considered a developing nation whose socio-economic environment, health resources and health outcomes are significantly lower than those of the UK (OECD 2021). In terms of oral health care, this has supposedly been available free of charge to all throughout most of the lives of the Pelotas cohorts (a unified health system was introduced in 1988) (Nascimento et al. 2013), but, in reality, evidence suggests inequalities in access to care are persistent across Brazil (Nascimento et al. 2013). Furthermore, Pelotas has received fluoridated water since 1961 (Peres et al. 2011c).

Beyond the above cohorts, the evidence regarding the life course determinants of oral health originating from other cohorts is more modest, and issues of applicability to the UK are variable. Evidence from the ABC (Jamieson et al. 2010b; 2010c) and SMILE (Ha and Do 2018) Australian cohorts is important, given these cohorts are prospective birth cohorts. In general, Australia is relatively comparable to the UK, in terms of socio-economic conditions (OECD 2021). However, funding for dental care is very different, with most adults and even children having to pay for dental care on a private basis (Healthdirect 2020). In addition, unlike in the UK, water fluoridation across the whole of Australia is widespread (SA Health 2020). Furthermore, the ABC study is based upon babies born to Aboriginal mothers, in whose communities socio-economic conditions are very poor, access to dental care is limited and sugar consumption, smoking and alcohol rates are particularly high (Jamieson et al. 2010a).

Many other relevant studies are based in Nordic countries (Tables 5 & 6), including Sweden (Alm et al. 2008; Astrom et al. 2011b), Finland (Bernabe et al. 2011) and Norway (Holst and Schuller 2012). In terms of similarities to the UK, oral healthcare is free for children in these countries (Niiranen et al. 2008; Palvarinne et al. 2018; Widstrom et al. 2005) and artificial water fluoridation has remained minimal (Mullen 2005; Wang et al. 1997). However, socio-economic conditions are generally better in these countries than those in the UK (Grunfelder et al. 2018; OECD 2021). Furthermore, adult care has been subsidised for many years in Sweden and Finland (Niiranen et al. 2008; Palvarinne et al. 2018; Widström et al. 2019), as in the UK (NHS.UK 2017), but levels of subsidisation and oral health outcomes are much better in Sweden (Saekel 2018; Sinclair et al. 2019). In contrast, most adults pay privately for oral healthcare in Norway (Widstrom et al. 2005).

Finally, for the entirety of the longitudinal oral health studies in existence (Tables 3, 4, 5 & 6), it is important to consider how applicable findings are to other generations, both older and younger, than those included within each study. For example, the oldest prospective birth cohort study with dental data – the NTFS – follows a 1947 birth cohort (Pearce et al. 2009b), whilst the most recent – the SMILE study – follows a cohort from 2013/14 (Do et al. 2014). As economic, cultural, social, and healthcare environments will vary across time, period variations will exist in the determinants of oral health.

2.14: A qualitative approach

Over recent decades, it has become accepted that qualitative research methods are paramount to understanding many issues within the field of oral health, including the determinants of oral health (Bower and Scambler 2007; Newton 2001; Newton and Bower 2005). Qualitative research provides a deeper understanding of social processes, using the accounts and explanations of those involved, and answers the ‘how’ and ‘why’ of a phenomenon, which often cannot be explained by quantitative research methods alone (Barbour 2014b; Green and Thorogood 2018; Pope and Mays 2006). In relation to the determinants of oral health, qualitative research can explain topics such as why individuals perform certain OHBs or the barriers or motivating factors behind the engagement of individuals with dental professionals. Given its importance, this section will review the contribution of qualitative research to our understanding of the determinants of oral health.

Focusing firstly on research originating from the UK, a modest amount of such evidence exists (Amos and Bostock 2008; Borreani et al. 2010; Chadwick et al. 2018; Daly et al. 2010; Davies et al. 2017; Delaney et al. 2018; Gibson et al. 2019; Gill et al. 2011; Gregory et al. 2007; Hall-Scullin et al. 2015; Hill et al. 2003; Kerr et al. 2006; Kettle et al. 2019; Kwan and Holmes 1999; Lin et al. 2017; Marshman et al. 2016; Muirhead et al. 2017; Newton et al. 2001; Rawahi et al. 2018; Scambler et al. 2010; Stokes et al. 2006; Tombor et al. 2017; Uppal et al. 2013). Studies have mainly focused on children and adolescents (Amos and Bostock 2008; Daly et al. 2010; Gill et al. 2011; Hall-Scullin et al. 2015; Marshman et al. 2016; Stokes et al. 2006), elderly populations (Bloom et al. 2017; Borreani et al. 2010; Kerr et al. 2006; Whitelock and Ensaff 2018) or small minority groups, such as foster children, cleft patients or minority ethnic groups (Chadwick et al. 2018; Davies et al. 2017; Kwan and Holmes 1999; Lin et al. 2017; Muirhead et al. 2017; Newton et al. 2001; Scambler et al. 2010). However, some studies have also focused on mainstream adult populations (Gregory et al. 2007; Hill et al. 2003; Rawahi et al. 2018; Tombor et al. 2017; Uppal et al. 2013). One project has also utilised a life course approach to explore older people's views about the development of their oral health (Gibson et al. 2019; Kettle et al. 2019). In terms of the topics studied, many studies have focused on the determinants of specific OHBs, such as tooth brushing (Gill et al. 2011; Lin et al. 2017; Marshman et al. 2016), dental attendance (Borreani et al. 2010; Gregory et al. 2007; Hill et al. 2003; Newton et al. 2001), smoking (Amos and Bostock 2008; Kerr et al. 2006; Tombor et al. 2017; Uppal et al. 2013) and sugar consumption (Rawahi et al. 2018), although several studies have also focused on the determinants of oral health more generally (Daly et al. 2010; Davies et al. 2017; Hall-Scullin et al. 2015; Kwan and Holmes 1999; Muirhead et al. 2017; Stokes et al. 2006).

In relation to the findings of such studies, those focusing on mainstream groups of children and adolescents have suggested influences of oral health and OHBs are very diverse. Parental influences and the importance of routines and habits have been frequently identified as key determinants of behaviours (Gill et al. 2011; Hall-Scullin et al. 2015; Marshman et al. 2016; Stokes et al. 2006). In addition, influences such as grandparents, peers, social settings (e.g. schools and shopping environments), children's personal preferences and behavioural issues have also repeatedly emerged (Amos and Bostock 2008;

Gill et al. 2011; Hall-Scullin et al. 2015; Marshman et al. 2016; Stokes et al. 2006). Perhaps expectedly, variations in predominant influences have been evident depending upon the behaviour in question and the life course stage. For example, peer influences have reportedly been particularly critical during adolescence, especially for behaviours with a social element, such as smoking and dietary practices (Amos and Bostock 2008; Stead et al. 2011). Children and adolescents have reportedly demonstrated a mixed understanding of the aetiology and prevention of oral disease (Gill et al. 2011; Hall-Scullin et al. 2015; Stokes et al. 2006) and some recognition of the importance of oral health (Gill et al. 2011; Hall-Scullin et al. 2015), especially in relation to appearance in adolescence (Stokes et al. 2006). However, the influence of such knowledge and beliefs on behaviours has often been limited (Gill et al. 2011; Hall-Scullin et al. 2015; Stokes et al. 2006).

In relation to studies in mainstream adult and elderly populations, emerging determinants have been similarly diverse. The lasting effects of earlier life factors have frequently been identified alongside many contemporary influences, such as spousal and peer relationships, social and consumer environments, influences of healthcare professionals, beliefs and knowledge about health, dental anxiety and cost (Borreani et al. 2010; Gregory et al. 2007; Hill et al. 2003; Kerr et al. 2006; Rawahi et al. 2018; Tombor et al. 2017; Uppal et al. 2013). Again, influences have varied depending upon the outcome in question and the life course stage. For example, studies exploring smoking influences have identified different determinants (e.g. social relationships, general health concerns and enjoyment) (Tombor et al. 2017; Uppal et al. 2013) from those focusing upon dental attendance behaviours (e.g. satisfaction with dentists, the importance of oral health, access to services and dental anxiety) (Borreani et al. 2010; Gregory et al. 2007; Hill et al. 2003). Several influences have also been particularly associated with older age, such as reduced physical and psychological capabilities, bereavement and social isolation (Bloom et al. 2017; Whitelock and Ensaff 2018).

Research focusing particularly on small minority groups has also identified similar determinant factors to a certain extent to the above studies involving mainstream groups (Davies et al. 2017; Kwan and Holmes 1999; Muirhead et al. 2017; Newton et al. 2001; Scambler et al. 2010). However, additional influencing factors pertaining to specific groups have also been identified, such as language and communication difficulties acting as barriers to dental care in ethnic groups (Kwan and Holmes 1999; Newton et al. 2001) and anatomical factors and post-surgical pain acting as barriers to tooth brushing in children born with a cleft lip and/or palate (Lin et al. 2017).

As mentioned, only one qualitative study has explicitly used a life course approach to explore the development of oral health in a UK population (Gibson et al. 2019). This study involved interviews with adults aged 65 to 91 from Sheffield and Edinburgh (n=43) and the use of grounded theory to explore emergent views. One topic identified related to the life course determinants of oral health (Gibson et al. 2019; Kettle et al. 2019), although the comprehensive findings on this topic area have not yet been published in full (Gibson et al. 2019). Nevertheless, evidence presented to date has revealed how individuals viewed their oral health as a 'life course project', and the degree to which they could participate was influenced by both individual and social factors (Gibson et al. 2019). The 'social world of dentistry' was reportedly crucial, whereby parents, family, friends, dental care environments, schools and consumer environments contributed to people's OHBs and oral health outcomes (Gibson et al. 2019). For example, parents reportedly influenced dental attendance and treatment decisions, especially in childhood, but also as individuals aged (Kettle et al. 2019), whilst schools determined access to dentists, dental education and tooth brushing programmes (Gibson et al. 2019). Access to consumer products, such as toothpastes and mouthwashes, was determined by their availability within society but also within families (Gibson et al. 2019).

In addition to the importance of accessing this 'social world of dentistry', the importance of other factors, such as valuing oral health, experiences of having work done and experiences of oral health outcomes, were also identified. Gibson and colleagues (2019) reported that engaging in oral care was dependent upon valuing oral health, that past experiences of dental work shaped expectations and decisions around future work and dental attendance, and that oral care efforts were driven by a sense of satisfaction and achievement resulting from retaining teeth into later life.

Published findings from this project so far discuss to some extent how determinants of oral health reportedly changed across the life course (Gibson et al. 2019; Kettle et al. 2019). For example, dominant influencers in childhood focused around parents, families and schools (Gibson et al. 2019; Kettle et al. 2019). As individuals aged into their teenage years, the importance of peers was recognised (Gibson et al. 2019). Subsequently, as they aged into adulthood, the influence of individuals' own children and then grandchildren emerged

(Kettle et al. 2019), alongside the influence of individuals' own values and past experiences (Gibson et al. 2019). The improved availability of consumer dental products, improved access to dental services and more pleasant experiences of dental visits over the years was also identified (Gibson et al. 2019).

In addition to studies involving UK populations, a modest amount of qualitative research has also explored the determinants of oral health in countries outside of the UK. Like the former, studies have focused on a range of population groups, including children and adolescents (Amin and Harrison 2009; Battram et al. 2016; De Oliveira et al. 2006; Drummond and Drummond 2012; Duijster et al. 2015; Fägerstad et al. 2019; Fitzgerald et al. 2004; Naidu et al. 2012; Ostberg et al. 2002; Panday et al. 2003), the elderly (Brondani et al. 2007; Derblom et al. 2017; Gregory et al. 2012; MacEntee et al. 2019; Sussex et al. 2010), specific minority groups (Castaneda et al. 2010; Fitzgerald et al. 2015; Graham et al. 2013; Mago et al. 2018; Van Hout and Hearne 2014; Zhang 2008) and the general adult population (Block et al. 2013; Chatrchaiwiwatana et al. 2012; Jensen et al. 2011; Pourtau et al. 2019; Syrjala et al. 2001). Again, like in the UK, some studies have focused upon the determinants of specific OHBs, including oral hygiene (Ghaffari et al. 2018; Jensen et al. 2011), dental attendance (De Oliveira et al. 2006; Derblom et al. 2017; Mago et al. 2018; Zhang), smoking (Fish et al. 2020; Panday et al. 2003; Pourtau et al. 2019) and sugar consumption behaviours (Battram et al. 2016; Block et al. 2013; Graham et al. 2013), whilst others have focused on the determinants of oral health more generally (Chatrchaiwiwatana et al. 2012; Duijster et al. 2015; Ostberg et al. 2002; Syrjala et al. 2001; Van Hout and Hearne 2014). A very small number of studies have also utilised a life course approach to explore determinants relevant to oral health, although the focus of these studies has been very specific (Delaney and McCarthy 2011; MacEntee et al. 2019; Thomeer et al. 2019). Macentee and colleagues (2019) explored lifelong influences of older adults' dental experiences and beliefs in China and Hong Kong; Thomeer and colleagues (2019) investigated the effects of social connections on smoking across the life course in the USA; whilst Delaney and McCarthy (2011) focused on food choice in the South West of Ireland.

Broadly speaking, the findings of much of the above research reflects those from UK studies. For example, a study of Swedish adolescents and adults focusing on influences of fluoride and tooth brushing behaviours identified the following as key determinants of such behaviours: levels of oral health knowledge, the importance of oral health, childhood habits founded by parents, social expectations and aesthetics, cost and influences from dental professionals (Jensen et al. 2011). In another example, a study of older people in New Zealand found the following factors to be key determinants of dental attendance behaviours: trust in the dental profession, mobility and access to services, cost of dental services and dental anxiety (Gregory et al. 2012).

However, as discussed in relation to quantitative research (sub-section 2.13.5), there are limitations regarding the applicability of non-UK studies to UK populations, due to inevitable differences in economic, cultural, social, family and oral health care environments (Sinclair et al. 2019; Smith et al. 2013). For example, Macentee et al.'s (2019) life course study in China and Hong Kong reported that changing oral health experiences and beliefs over the life course were associated with many population-specific factors, such as health promotion activities, access to services, traditional health beliefs and the Cultural Revolution.

2.15: Summary of evidence and knowledge gaps

It is indisputable that poor oral health is a significant problem in the UK (as well as globally), due to the high prevalence of oral diseases and conditions (Kassebaum et al. 2017; White et al. 2011) and the substantial impact these can have at an individual and societal level (NHS England 2014; Nuttall et al. 2011b). Subsequently, it is clear that a thorough understanding of the development of poor oral health in the UK is of paramount importance if the causes and pathways to poor oral health are to be effectively addressed and oral health outcomes improved. Hence, the main aim of this literature review was to explore the current extent of knowledge regarding the determinants of poor oral health, particularly in relation to the UK.

This review demonstrated that extensive evidence to date has focussed on the causes of poor oral health and has shown that a wide array of factors contribute to oral health outcomes, including biological, behavioural, environmental, psychological and social factors. Such factors include, but are not limited to, genetics (Loos and Chin 2017), systemic diseases (Mathews et al. 2008; Nascimento et al. 2018), dietary factors (Moynihan and Kelly 2014; Salas et al. 2015), oral hygiene behaviours (Broadbent et al. 2011), smoking habits (Warnakulasuriya et al. 2010), fluoride exposure (Marinho et al. 2003b; Rugg-Gunn and Do 2012), oral health knowledge and attitudes (Asimakopoulou and Newton 2015), psychological conditions (Kisely et al. 2015; Kisely et al. 2016), socio-economic factors (Dye et al. 2012; Steele et al. 2014), social networks (Castilho et al. 2013; Rouxel et al. 2015b), culture (Butani et al. 2008), health care systems (Garbin Neumann and Quinonez 2014) and public health systems (Rugg-Gunn and Do 2012). It is also clear that key determinants vary between different oral health outcomes, such as caries, periodontal disease and non-carious tooth surface loss (Genco and Borgnakke 2013; Selwitz et al. 2007; Yule and Barclay 2015).

As well as evidencing the broad influences of oral health, this review also identifies that contemporary thinking supports the applicability of a life course approach to the development of oral health and disease, as oral diseases are frequently chronic and cumulative in nature and can be influenced by factors occurring in the pre-natal period, at birth, during childhood and across adulthood into later life (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015). Despite recognition of the appropriateness of such an approach, such research in the field of oral health is still far from extensive, although the number of studies in this area is steadily increasing (Heilmann et al. 2015). This is primarily due to a lack of appropriate studies of a longitudinal nature, which are required for the application of a life course approach, such as the prospective birth cohort study or, secondarily, prospective cohort studies starting after birth and retrospective cohort studies (Halfon et al. 2018). This literature review found that the number of such studies including oral health outcomes is reasonably limited, especially those of a prospective nature (Tables 3,4,5 & 6), most likely due to the challenges and resource intensiveness associated with conducting longitudinal studies (Halfon et al. 2018).

Furthermore, this review demonstrates that the majority of longitudinal studies with dental data originate from outside of the UK, particularly New Zealand (Poulton et al. 2015), Brazil (Faerstein et al. 2005; Peres et al. 2017; Peres et al. 2011a; Peres et al. 2010), Australia (Do et al. 2014; Jamieson et al. 2010b; Johnson et al. 2017), the USA (Kapur et al. 1972; Levy et al. 2003; University of Florida Health 2020) and Nordic countries (Astrom et al. 2015; Bernabe et al. 2011; Holst and Schuller 2012), and there are issues with generalising the results of these studies to the UK population. In terms of prospective birth cohorts with dental data, only sixteen currently exist worldwide (Tables 3 and 4), and only five of these are from the UK – the NTFS, NCDS, ALSPAC, GUS and Millennium Cohort studies (Table 4). Furthermore, the number of published analyses relating to these UK prospective birth cohorts are quite limited (Delgado-Angulo and Bernabe 2015a; 2015b; Kay et al. 2010; Mason et al. 2006; Pearce et al. 2004; Pearce et al. 2009a). Two prospective cohort studies starting after birth have also originated from the UK – the BRHS (Lennon et al. 2015) and

ELSA (Steptoe et al. 2013) studies – which have followed individuals from mid adulthood and over – but all other key prospective cohort studies starting after birth and retrospective studies have originated from outside of the UK (Tables 5 & 6).

This literature review also recognises that causal pathways modelling techniques must be applied to the analysis of longitudinal data, if indirect effects (as well as direct effects) of distal determinants earlier in the life course are to be recognised (Bub and Ferretti 2014; Burton-Jeangros et al. 2016; Halfon et al. 2018). Unfortunately, this review found that most of the above longitudinal studies have relied upon traditional multivariate regression to investigate the determinants of oral health (Alm et al. 2008; Bernabe et al. 2011; Broffitt et al. 2013; Correa et al. 2010; Jamieson et al. 2010b; Listl et al. 2018; Thomson et al. 2000).

In summary, many of these studies have focused on the relationships between life course socio-economic trajectories and oral health outcomes (Astrom et al. 2015; Bernabe et al. 2011; Pearce et al. 2009a; Peres et al. 2011b; Poulton et al. 2002; Ramsay et al. 2018; Schuch et al. 2018; Thomson et al. 2004) and have demonstrated the importance of socio-economic conditions across the whole life course. However, these studies have conflicted regarding the relative importance of early life compared to later life conditions (Astrom et al. 2015; Bernabe et al. 2011; Pearce et al. 2009a; Poulton et al. 2002; Thomson et al. 2004). In addition, many studies have demonstrated the importance of a multitude of other determinants across the life course in the development of various oral health outcomes, such as (but not limited to) the contribution of sugar consumption (Chankanka et al. 2016; Skafida and Chambers 2018), tooth brushing habits (Broffitt et al. 2013; Peres et al. 2009) and dental attendance (Crocombe et al. 2012; Thomson et al. 2010) to caries outcomes; the contribution of smoking (Albandar et al. 2000; Thomson et al. 2007), plaque control (Broadbent et al. 2011) and obesity (De Castilhos et al. 2012; Nascimento et al. 2017) to periodontal outcomes; and the contribution of smoking (Krall et al. 2006; Yanagisawa et al. 2009), plaque trajectories (Broadbent et al. 2011) and dental visiting (Crocombe et al. 2012; Thomson et al. 2010) to tooth loss outcomes. However, as said, these studies do not take into account indirect causal pathways and, hence, often significantly underestimate the contributions of more distal determinants (Weitkunat and Wildner 2002).

In contrast, only a very small number of analyses have applied causal pathways modelling techniques, such as hierarchical regression modelling (Mason et al. 2006; Pearce et al. 2004), path analyses (Goettems et al. 2018; Lu et al. 2011; Peres et al. 2018b) and SEM techniques (Bernabe et al. 2012; Broadbent et al. 2016; Curtis et al. 2018a; Vendrame et al. 2018; Vettore et al. 2016), to longitudinal oral health studies. These studies relate to: the Dunedin (Broadbent et al. 2016), Pelotas (Goettems et al. 2018; Peres et al. 2018b), Iowa (Curtis et al. 2018a) and NTFS (Mason et al. 2006; Pearce et al. 2004) prospective birth cohorts; two prospective longitudinal studies starting after birth from Brazil (Vettore et al. 2016) and Hong Kong (Lu et al. 2011); and two retrospective life course studies from Finland (Bernabe et al. 2012) and Brazil (Vendrame et al. 2018).

In particular, key findings originating from these studies include an analysis of the determinants of caries outcomes in adolescence, based on the Iowa prospective birth cohort (Curtis et al. 2018a). This study found that the combined effects of adolescent dental attendance and tooth brushing frequency on adolescent caries experience were almost double the effect of sex and over double the effects of certain adolescent sugar consumption measures, but that neither socio-economic position at birth nor in adolescence had a significant effect. However, this study did not distinguish the effects of dental attendance from those of tooth brushing and may not be completely generalisable to the UK due to inter-country differences, particularly in domains such as oral health care (HHS.Gov 2017; NHS.UK 2020b) and water fluoridation (Maurer 2005; O'Hora and Wilkinson 2006). Furthermore, three key studies provided evidence regarding the relative contributions of life course determinants to adult tooth loss (Pearce et al. 2004; Vendrame et al. 2018; Vettore et al. 2016). The UK NTFS found that the overall effects of factors occurring in adulthood were around double the combined effects of birth and childhood factors (Pearce et al. 2004), but could not elucidate the effects of individual determinants due to its reliance only on hierarchical regression modelling. Two studies in Brazil also demonstrated similar overall effects of childhood and adulthood socio-economic status on future tooth loss outcomes (Vendrame et al. 2018; Vettore et al. 2016), similar effects of gender (Vendrame et al. 2018), only minor effects of adulthood stress and social ties and no effects of dental attendance (Vettore et al. 2016). However, there was a lack of inclusion of many key variables in all of the above three studies, whilst the generalisability of the latter two studies (Vendrame et al. 2018; Vettore et al. 2016) to the UK is questionable. In summary, it is clear that the findings of these studies using causal pathways modelling approaches have been quite limited and that there is a need for further such studies.

Finally, the last section of this literature review was devoted to the qualitative evidence investigating the determinants of oral health. It is now accepted that qualitative research is paramount in aiding our understanding of the determinants of oral health (Bower and Scambler 2007; Newton and Bower 2005), and, in recent years, a reasonable body of such evidence has started to accumulate globally (Borreani et al. 2010; Brondani et al. 2007; Castaneda et al. 2010; Daly et al. 2010; Duijster et al. 2015; Fitzgerald et al. 2015; Gibson et al. 2019; Gregory et al. 2007; Gregory et al. 2012; Hall-Scullin et al. 2015; Hill et al. 2003; Jensen et al. 2011; Kettle et al. 2019; MacEntee et al. 2019; Naidu et al. 2012; Stokes et al. 2006; Syrjala et al. 2001). In summary, studies from the UK have found that factors such as parents, families, peers, schools, other social environments, and children's personal preferences and behavioural issues are dominant influences in childhood and adolescence (Amos and Bostock 2008; Gibson et al. 2019; Gill et al. 2011; Hall-Scullin et al. 2015; Kettle et al. 2019; Marshman et al. 2016; Stokes et al. 2006), and that past experiences, spouses, social and consumer environments, beliefs and knowledge about health, dental anxiety, cost, access to services and influences of dental professionals are key in adulthood (Borreani et al. 2010; Gibson et al. 2019; Gregory et al. 2007; Hill et al. 2003; Kerr et al. 2006; Kettle et al. 2019; Rawahi et al. 2018; Tombor et al. 2017; Uppal et al. 2013). However, the extent of research originating from the UK is still reasonably modest, and there are issues with generalising findings from elsewhere to UK populations.

Furthermore, although such qualitative studies collectively have focused on various stages of the life course, only one qualitative study has holistically utilised a life course approach to explore the determinants of oral health in the UK (Gibson et al. 2019). A small number of studies from elsewhere have also used such a life course approach (Delaney and McCarthy 2011; MacEntee et al. 2019; Thomeer et al. 2019). However, the breadth of these studies is limited. In some cases, cultural differences also substantially diminish their applicability to UK populations (MacEntee et al. 2019). Additionally, of note, several of these life course studies were published after the completion of this PhD research (Gibson et al. 2019; MacEntee et al. 2019; Thomeer et al. 2019).

To conclude, this literature review has explored the current extent of knowledge regarding the determinants of poor oral health, particularly in relation to the UK. It has identified a substantial body of evidence in this field but reveals two major gaps in the evidence relating to the UK. Firstly, there is a lack of quantitative evidence (limited to only two studies (Mason et al. 2006; Pearce et al. 2004)) which has used both a life course approach and causal pathways modelling techniques to explore the determinants of oral health. Secondly, there is a lack of qualitative evidence which has used a life course approach to explore the development of oral health – only one UK study has attempted this, but its focus was much broader than this topic alone (Gibson et al. 2019). In light of the accepted importance of the above two approaches in understanding the life course determinants of oral health, addressing these two major evidence gaps is critical.

2.16: Research aims and objectives

Based on the research gaps identified in the preceding literature review, the aim of this PhD research was as follows:

- **Aim**: To investigate the life course determinants of oral health in the UK.

This was achieved via two specific objectives:

- **Objective 1**: To explore the factors across the life course which influence how and why individuals look after their oral health.
- **Objective 2**: To quantitatively model the contributions of determinant factors across the life course to individuals’ oral health.

Chapter 3: Methodology and Methods

This chapter presents the methodology and methods used in this research project. It aims to present both a detailed description of the methods employed and also a discussion of the rationale and justification for these methods (the methodology). Sections 3.1 to 3.5 introduce the two studies comprising this research project – one qualitative and one quantitative – and address topics of relevance to both studies, such as the Newcastle Thousand Families Study (NTFS) (which provides the setting for this research) (Pearce et al. 2009b), mixed-methods research approaches, the philosophical underpinnings of this research and ethical approval. Section 3.6 then addresses topics specifically relating to the qualitative study, and Section 3.7 topics relating to the quantitative study.

3.1: Overview of research phases

This PhD research was a mixed-methods study based around the existing NTFS, a 1947 birth cohort from Newcastle upon Tyne (Pearce et al. 2009b). This research comprised two separate but related studies, addressed by three distinct research phases:

Qualitative study: A qualitative study of the factors which influenced how and why NTFS participants cared for their oral health over their lifetimes. This was achieved by:

- **Phase 1**: In-depth interviews with a sub-sample of NTFS participants

Quantitative study: A quantitative study of the life course determinants of oral health in the NTFS. This was achieved by:

- **Phase 2**: Devising and distributing a questionnaire to NTFS participants, to collect additional information about potential life course determinants of oral health not measured in the original study.
- **Phase 3**: Conducting a path analysis using existing life course data from the NTFS cohort, plus data from Phase 2, to model the life course determinants of tooth retention at age 63.

These two studies together address the aim of this research 'to investigate the life course determinants of oral health in the UK' (Section 2.16). The qualitative study directly addresses the first objective of this research 'to explore the factors across the life course which influence how and why people look after their oral health'. The quantitative study addresses the second objective 'to quantitatively model the contributions of determinant factors across the life course to individuals' oral health' (Section 2.16).

To clarify my personal contribution to this research, Phase 1 involved primary data collection via interviews with NTFS participants and data analysis. I conducted all of the interviews myself and was responsible for data analysis, with some support provided by my supervisors, as described in Section 3.6. Transcription support was also provided by a senior research administrator in the NTFS team (Katharine Kirton). Phase 2 also involved primary data collection via a questionnaire to NTFS participants. I was responsible for the design, testing and refinement of the questionnaire, although I received administrative support from Katharine Kirton in distributing the questionnaire and electronically inputting the received responses. Phase 3 involved secondary data analysis of existing NTFS data and the data collected in the Phase 2 questionnaire. My role included data preparation of the existing NTFS data and the new data collected in Phase 2, plus the conduction of a complex statistical life course path analysis. Statistical advice was received from Dr Kay Mann (a Research Associate in Epidemiology and Statistics in the NTFS study team), specifically regarding the use of the STATA software and path analysis techniques, but all statistical analyses were thoroughly researched, understood and conducted by myself.

3.2: The NTFS cohort

3.2.1: Justification for use

As highlighted in the preceding literature review, the NTFS is one of five prospective birth cohort studies with dental data in the UK (Pearce et al. 2009b). Beginning in 1947, it is the oldest of these cohorts, with participants now in their early seventies. It is also the only one of these cohorts to have measured dental outcomes in later life – the latest measurements being around age 60, compared to age 33 in the other studies (Delgado-Angulo and Bernabe 2015b) – and is the only cohort to have obtained clinical oral health measures (excluding the ALSPAC cohort which obtained clinical measures up to the age of seven only (Kay et al. 2010)). Therefore, this cohort study provides a unique opportunity to explore the life course determinants of oral health in the UK.

3.2.2: Overview of the existing study

Prior to my involvement in the NTFS (my PhD commenced in 2012), a large amount of data had been collected from study participants since the study's commencement in 1947. This section describes this pre-existing data collected by the wider study team. Some of this pre-existing data was used in the secondary data analysis in Phase 3 of this PhD research.

The NTFS cohort began with the recruitment of all but four of the 1,146 babies born in May and June, 1947, to mothers resident in the city of Newcastle upon Tyne. Extensive medical and social information was collected about participants and their families during their first year of life, via antenatal charts, midwives' reports, health visitors' records, medical reports, hospital records and housing assessments. Participants were subsequently followed extensively throughout their early childhood and school years, up to the age of 15, with information about medical and social factors collected from health visitors' assessments, housing surveys, school reports, doctors' assessments and medical records. Information about entry to further education and employment was collected at age 18 and height and weight at age 22. Other than a small number of sub-studies then undertaken up to the age of 32 (Miller et al. 1974; Miller et al. 1960; Pearce et al. 2009b; Spence et al. 1954), the study went into abeyance until 1997, when a large-scale attempt was made to trace all living original study members, following a surge in interest in the early origins of disease in later life (Barker 1990). Between 1997 and 1999 (age 49 to 51), those traceable were asked to complete an extensive 'Health and Lifestyle questionnaire', collecting current and retrospective information about socio-economic, medical, lifestyle and behavioural factors, and invited to attend a clinical examination, which also involved a dental examination. Between 1999 and 2009, a small number of data collection episodes were undertaken from sub-groups of participants. In 2009, a further large-scale attempt was once again made to trace all living original study members. Those responding completed a further Health and Lifestyle questionnaire, updating information about socio-economic, medical, lifestyle and behavioural factors, and attended a clinical examination, which included a dental examination. Since then, only a small number of data collection episodes have been undertaken from smaller groups of participants for sub-studies (Pearce et al. 2009b).

To describe the dental outcomes measured in more detail, the dental examinations at ages 50 and 63 were conducted in the Clinical Research Facility of the Royal Victoria Infirmary, Newcastle upon Tyne, as one component of a full day of clinical examinations covering a range of other medical assessments. Each examination was conducted by one research nurse, who was not dentally trained by background but had received specific training for the purposes of these assessments (two research nurses were involved in the 50 follow-ups and two different research nurses at the age 63 examinations). The examinations were conducted in a reclining chair using two dental mirrors and direct illumination. The examinations recorded whether or not participants wore upper and/or lower complete or partial dentures, whether each natural tooth was present or missing and, at age 50, whether each present tooth was grossly decayed/broken down or visibly loose. At the age 50 examinations, the numbers of lower premolar and molar teeth with opposing contacts were also recorded for both the right and left quadrants. A very small number of questions were also asked to participants during these examinations, such as whether participants had any loose teeth at all and how often they had experienced tooth ache over their life. In addition, previously validated and widely used 49-question (Slade and Spencer 1994) and 14-question (Slade 1997) Oral Health Impact Profile (OHIP) questionnaires were self-completed at ages 50 and 63 respectively .

Table 11 summarises the data collected and response rates at each stage of the study. Retention rates were 65% by the age of 15, 50% by the age of 50 and 38% by the age of 63. Members of the original study sample now live across the UK and wider world. Study members have continued to participate in follow-ups from as far away as Australia, South Africa and Canada.

Year	Cohort age (years)	Participants (n)	Data collected
1947	Birth	1142	Antenatal chart, midwives' report (including birthweight, gestational age and infant feeding)
1947-1962	Birth to 15	1,142, falling to 750 by age 15	Health visitors' records, doctors' reports, hospital records, housing assessments, school reports, medical assessments (including data on socio-economic factors, family circumstances, physical examinations, illnesses, behaviour & criminality, school performance, home & leisure activities)
1966	18	750	Entry to employment and further education
1969	22	442	Height and weight
1997-1999	50	574	Health & Lifestyle questionnaire (history of education, employment, earnings, housing, family circumstances, smoking, alcohol, general health, family health, current diet, exercise and social life)
		412	Clinical assessment (cardiovascular, metabolic, anthropometric, bone and respiratory tests)
		337	Dental examination (number of teeth, presence of dentures, numbers of grossly broken down/loose teeth, occluding pairs)
		309	Dental questionnaire (Oral Health Impact Profile-49, current dental attendance & treatment preferences)
2009-2011	63	434	Health & Lifestyle questionnaire (current work, income, retirement, marital status, smoking, alcohol, physical activity, diet, general health, dental health (mainly Oral Health Impact Profile-14), family health)
		354	Clinical assessment (cardiovascular, metabolic, musculoskeletal, anthropometric, cognition, hearing, respiratory tests)
		343	Dental examination (number of teeth, presence of dentures, dental attendance)

Table 11: Overview of existing data collected from the full NTFS cohort.
Adapted from (Pearce et al. 2009b).

In terms of leadership and funding, the study was initiated by the Department of Child Health, King's College, Newcastle upon Tyne, and the Health Department of the City, following concerns at the time about the high rate of infant mortality due to infections in the city (Pearce et al. 2009b; Spence et al. 1954). The study remained a joint undertaking between these two institutions during its first two decades, led by a team of paediatricians including Sir James Spence, Dr Fred Miller and Sir Donald Court (Miller et al. 1974; Miller et al. 1960). Funding over the first fifteen years was from Newcastle City Health Department, the City Health Committee and the Nuffield Foundation (Pearce et al. 2009b). Funding in early adulthood was from a variety of sources, including the Department for Health and Social Security, the Medical Research Council, the Social Science Research Council, the Joseph Rowntree Trust, the WT Grant Foundation (New York), the Newcastle Inner Cities

Fund, the Joel Joffe Trust and the Home Office (Pearce et al. 2009b). When the study was resurrected in 1997, this was led by Professor Louise Parker at Newcastle University. Since 2002, Mark Pearce, a Professor in Applied Epidemiology at Newcastle University (and supervisor of this PhD) has led the study. Funding for the age 50 follow-up was predominantly from the Wellcome Trust, but the Newcastle Healthcare Charity, the Sir James Knott Trust and the Minnie Henderson Trust Fund also contributed (Pearce et al. 2009b). The age 63 follow-up was funded via multiple sources, particularly a UK National Institute for Health Research Biomedical Research Centre for Ageing and Age-Related Disease award and funding from the JGW Patterson Foundation, Action on Hearing Loss and Breathe North (Harrison et al. 2013).

3.3: A mixed-methods approach

This PhD research utilised a mixed-methods approach, incorporating two separate but related studies answering similar, but slightly different, questions. The qualitative study examines in detail the factors influencing how and why individuals looked after their oral health across the life course, whilst the quantitative study investigates the life course determinants of oral health from a broader perspective. Both of these studies address the broad aim ‘to investigate the life course determinants of oral health in the UK’. A qualitative approach was deemed essential to achieve the first objective of this research (‘to explore the factors across the life course which influence how and why people look after their oral health’), as a qualitative approach facilitates a deeper understanding of social processes that cannot be achieved via quantitative methods (Barbour 2014b; Green and Thorogood 2018; Pope and Mays 2006). In contrast, a quantitative approach was the most appropriate method to achieve the second objective (‘to quantitatively model the contributions of determinant factors across the life course to individuals’ oral health’). This use of mixed-methods approaches as equal but separate tools for answering different questions on the same topic is commonplace in mixed-methods research (Teddlie and Tashakkori 2009).

Mixed-methods research designs can be classified into multiple typologies (NIH OBSS 2018; Tariq and Woodman 2010). This research project incorporated a multiphase design, using elements of both ‘exploratory sequential’ and ‘convergent’ designs. The qualitative study was conducted first as, in accordance with the ‘exploratory sequential’ typology, the intention was to use the qualitative findings to influence the design of the quantitative study, specifically guiding which determinant factors should be included in the quantitative path analysis. Representing elements of a ‘convergent’ design, the research findings of the qualitative and quantitative components were closely integrated at the interpretation stage to corroborate and complement each other. Integration at this stage permitted ‘expansion’ to occur, where each methodology allowed a concept to be considered from different angles, and also allowed confirmation and discordance of findings to be identified (Fetters et al. 2013). The ability of mixed-methods approaches to enhance the quality, usefulness and applicability of research, by combining the strengths of each methodology, is well-accepted in the literature (Tariq and Woodman 2010). The above methods of integrating qualitative and quantitative research adhere to best practice guidelines in mixed-methods research (NIH OBSS 2018).

3.4: Philosophical Assumptions

Philosophical assumptions, particularly pertaining to theories about the nature of reality (ontology) and the nature of knowledge (epistemology), are important considerations in research. A wide spectrum of philosophical positions are supported but, in very broad terms, can be classified under the broad categories of positivism and interpretivism (Green and Thorogood 2018; Ritchie and Lewis 2014). Positivism is a philosophy which assumes that a stable reality exists (the ontological position of realism) (Green and Thorogood 2018). Epistemologically, positivism supports the view that a stable reality can be studied and can be known accurately and that this reality is unaffected by the research process or the values of researchers or research participants (value-free inquiry) (Ritchie and Lewis 2014). Such philosophical underpinnings mean positivist approaches are often associated with research in the natural sciences (where it is believed phenomena can be objectively measured), quantitative study methods, and deductive rather than inductive methods (whereby knowledge is acquired through a ‘top-down’ process involving the generation of hypotheses which are subsequently tested against observations) (Creswell and Plano Clark 2011; Green and Thorogood 2018; Ritchie and Lewis 2014). In contrast, interpretivism is a philosophical position whose roots are more aligned to the ontological stance of idealism, which (in opposition to realism) asserts that reality is fundamentally mind-dependent and that no external reality exists independent of our beliefs and understandings (Ritchie and Lewis 2014). Epistemologically, an interpretive approach is concerned with understanding people’s experiences of the world as it is subjectively understood and supports the view that this subjective reality is affected by the research process and that value-free research is impossible (Ritchie and Lewis 2014). Accordingly, interpretivism is often associated with research in the social sciences, qualitative study methods and inductive approaches to research, the latter being a 'bottom-up' process where evidence is collected and knowledge and theories subsequently generated from this (Creswell and Plano Clark 2011; Green and Thorogood 2018; Ritchie and Lewis 2014). In between (or under) the broad stances of these two philosophical positions lie a variety of other philosophical worldviews, such as social constructionism and critical realism. The former is aligned to an interpretive perspective but focuses on the socially constructed nature of reality (Green and Thorogood 2018), whilst the latter sits between positivism and interpretivism and advocates that an external reality does exist but can only be accessed through the interpretations of individuals (Ritchie and Lewis 2014).

In mixed-methods research, some researchers have argued that the philosophical premises of qualitative and quantitative methodologies are inherently incompatible (Morse 2003), whereas others have advocated a range of philosophical underpinnings (Creswell and Plano Clark 2011; Denscombe 2008; Greene and Caracelli 1997). The philosophical paradigm of pragmatism is strongly supported in relation to mixed-methods research, in which the distinguishing belief is that an interpretation is true if it leads to actions that produce desired or predicted results (Ritchie and Lewis 2014). Pragmatism embraces diverse approaches and both subjective and objective knowledge (Creswell and Plano Clark 2011). Proponents of pragmatism argue that the forced choice dichotomy between positivism and interpretivism and concepts of truth and reality should be abandoned (Tashakkori and Teddlie 2010). In contrast to pragmatism, it has also been advocated that changing between philosophical positions during mixed-methods research is an advantage, to reveal contradictory ideas and arguments by attempting to know the world from different perspectives (Greene and Caracelli 1997), and that changing between philosophical positions is necessary and driven by the different research methods employed (Creswell and Plano Clark 2011).

The main philosophy with which I identified in relation to this research was pragmatism, whereby the aim was to uncover the factors which determine oral health, whether in a stable reality or subjective interpretations of reality. If addressed, these factors would lead to improvements in oral health. However, I believe that I inhabited more than one philosophical position during this research and, as contemporarily advocated by some authoritative researchers (Ritchie and Lewis 2014), that this was related to the nature of the research questions posed to a greater extent than to my underlying philosophical beliefs. The qualitative component of this research aimed to explore individuals' subjective accounts of psycho-social influences, which aligns with a more interpretative philosophy. The quantitative study explored both objective and subjective determinants related to the natural and social sciences, such as pack-years of smoking and parental influence respectively, and, therefore, aligned with both positivist and interpretivist positions.

3.5: Ethical approval, participant consent and data access

This PhD research required ethical approval from Newcastle University's Faculty of Medical Sciences Ethics Committee, which was requested via online submissions. Ethical approval was granted in two stages: on 2nd October 2014 for the qualitative study (Phase 1); on 25th May 2016 for the quantitative study (including both Phases 2 and 3 – questionnaire distribution to NTFS participants and secondary analysis of existing NTFS data, respectively). Such approvals are included in Appendices A and B.

Study participants received an invitation letter, a written participant information sheet and completed a written consent form prior to their involvement in the qualitative interviews (Appendix C). Prior to their completion of the dental questionnaire (Phase 2), participants also received an invitation letter and participant information sheet (Appendix D). However, to reduce their administrative burden, they were not asked to complete a written consent form but were advised that completion of the questionnaire would confirm their consent for the information to be used in secondary data analysis (Phase 3). At all previous stages of data collection (prior to my involvement in the study), participants had already provided written consent, and ethical approval had been granted, for all data to be used in future secondary data analyses. Therefore, appropriate participant consent was already in place for the use of pre-existing study data in the secondary data analysis in Phase 3.

Access to all pre-existing study data necessary for the completion of this PhD research was provided by members of the NTFS study team, including Professor Mark Pearce (study lead), Katharine Kirton (Senior Research Administrator) and Dr Kay Mann (Research Associate). Where possible, all research data was anonymised prior to receipt by myself, although some identifiable information was required, e.g. names and addresses, for sample recruitment in the qualitative interviews (Phase 1) and questionnaire distribution (Phase 2). Only the minimum necessary data was transferred to myself, all data was stored on a password-protected University computer and identifiable information was stored separately from all other study data.

3.6: The qualitative study

As outlined, the qualitative study aimed to explore in depth the factors across the life course which influence how and why individuals in the UK look after their oral health, and involved in-depth interviews with members of the NTFS study.

3.6.1: Sample population

The NTFS cohort was selected as the setting for this qualitative study for two key reasons. Firstly, clinical, socio-demographic and behavioural information related to oral health had previously been collected from participants at various stages across the life course (Table 11), thereby allowing participants to be purposively sampled for inclusion in the study. Secondly, the NTFS cohort had been identified as a unique setting for the quantitative component of this PhD and it was anticipated that aligning the qualitative and quantitative study settings would provide an opportunity for greater comparison and corroboration of findings between these two studies.

As discussed in more detail in relation to the quantitative study (sub-section 3.7.1), it was acknowledged that the NTFS cohort may not be representative of the UK population in general (being a North East England cohort), that its participants' health behaviours and beliefs may have been influenced by their longstanding participation in this study (French and Sutton 2010; Godin et al. 2008), and that the cohort may have been biased due to substantial loss to follow-up (Table 11). However, use of a non-probabilistic purposive sampling strategy (described in sub-section 3.6.3), which aimed to seek out participants based upon specific characteristics to ensure a broad and diverse sample (Patton 2015; Ritchie and Lewis 2014), should have limited the effects of the above.

Furthermore, it was also acknowledged that use of a historical birth cohort presented additional disadvantages. Firstly, participants were required to rely substantially on retrospective recall, especially regarding influences earlier in the life course. Secondly, determinants of OHBs applicable to this cohort may not be completely applicable to contemporary populations due to changes over time (known as period effects (Glenn 2005)) in influencing factors (Fielding 1999; Laranjo et al. 2014; Oláh et al. 2018). Alternative settings for this qualitative study were originally considered, such as interviewing several cohorts of individuals from different generations in the current UK population, who were hence at different stages across the life course. However, this would have been particularly resource intensive within the constraints of a PhD and the benefits of utilising the NTFS (presented above) would have been lost. Instead, issues of retrospective recall and period effects were acknowledged and managed (see sub-section 3.6.9).

3.6.2: Method of data collection

Several modes of data collection are available in the field of qualitative research to provide an in-depth understanding of a phenomenon, including individual interviews, group interviews, ethnography and document analysis (Green and Thorogood 2018). Ethnography and document analysis were eliminated as potential methods at the outset. Ethnography was not deemed a practical method for exploring a diverse range of influencing factors occurring in multiple settings across an extended timespan, whilst document analysis depends on the availability of appropriate documents to analyse. Leaving a choice between individual interviews and group interviews, it was decided that individual interviews were best suited to achieving the aim of this qualitative study, which was to obtain in-depth personal accounts about a potentially sensitive topic. Although group interviews can provide an ideal setting for some research, particularly where social interaction is a key focus (e.g. studies involving healthcare teams) (Green and Thorogood 2018), they can restrict the depth of individuals' own accounts and can be limited by various social conventions. Specifically, participants may avoid disclosing personal or sensitive information, attempt to present a 'normal' version of themselves, dramatise to impress others and change their accounts to avoid conflict (Barbour 2014b; Green and Thorogood 2018; Schneider and Palmer 2002). Discussions may also be dominated by more confident and expressive individuals, those higher in the social hierarchy and those holding more socially acceptable views (Green and Thorogood 2018). Furthermore, participants' views can be 'contaminated' in group discussions, whereby the data produced reflects views developed during the discussion process rather than participants' pre-existing views (Barbour 2014b; Green and Thorogood 2018).

Although individual interviews were selected as the most suitable option for data collection, their disadvantages were also acknowledged. In particular, the nature of interview data as people's 'accounts' of events was acknowledged. It has been argued that people's accounts reveal how patients 'make sense' of a phenomenon but reveal little about what actually happened (Stimson and Webb 1975). I also acknowledged that people's accounts may have been influenced by myself as the interviewer (discussed further in sub-section 3.6.8).

All interviews were audio-recorded. Additional written field notes were also made after each interview. Such notes included a description of the interviewee or the setting (to help me relate the transcript to the particular interview during future analysis), a summary of key ideas emerging from the interviews, notes about a participant's emotions or non-verbal communication that would not be captured by the audio recording, and a reflection on my interviewing technique and the interview process. Such notes helped develop the interview process and were also consulted during data analysis.

3.6.3: Sampling strategy

Non probabilistic, purposive sampling was used to select participants for interview. Such a sampling strategy is commonplace in qualitative research whereby the aim is not to produce a statistically representative sample but to ensure all key groups relevant to the subject matter are sampled and, within these groups, enough diversity is included so the impact of the characteristic concerned can be explored (Ritchie and Lewis 2014).

The primary criteria used to determine sample selection was the tooth loss trajectory of participants between the ages of 50 and 63, based on pre-existing dental examination data from the NTFS. As the aim of this qualitative research was to explore the influencing factors of people's OHBs, it was deemed critical to explore these determinants across groups experiencing differing oral health outcomes. This tooth loss trajectory, in particular, was selected as the most appropriate reflection of participants' clinical oral health experiences over their lifetime from the limited amount of oral health data available (sub-section 3.2.2). Specifically, tooth loss is a common end-point of two of the most prevalent dental diseases (Fuller et al. 2011; McCaul et al. 2001; Richards et al. 2005), whilst a trajectory between two time points provides an indication of longitudinal rather than static oral health. To allow for the use of this primary sampling criteria, the population for sampling was limited to 216 NTFS participants who previously attended the dental examinations at both ages 50 and 63.

The 'tooth loss trajectory' groups utilised for sample selection are listed in Table 12. The terms 'good', 'functional', 'poor' and 'edentate' reflect tooth retention at the age 50 follow-up, whilst the terms 'stable' and 'unstable' reflect the number of teeth lost between age 50 and age 63. For example, individuals with 24 or more teeth at age 50 and losing less than three teeth between age 50 and 63 were classified as 'good stable'. The minimum threshold of 21 teeth used to classify the age 50 tooth count as 'functional' was based on an established threshold used to define a 'functional dentition' (Fuller et al. 2011; Hobdell et al. 2003). Otherwise, the thresholds used were based on my clinical judgement. Being the primary selection criteria, the objective was to sample at least two individuals from each group. Ultimately, four individuals were selected from the 'good unstable' group, three each from the 'good stable', 'functional stable', 'functional unstable' and 'edentate' groups and two each from the 'poor stable' and 'poor unstable' trajectory groups (Table 13).

Tooth loss trajectory	**Age 50 tooth count**	**Teeth lost between age 50 and age 63**	**Number of individuals in sample population**
Good stable	24+	0-2	108
Good unstable	24+	3+	30
Functional stable	21-23	0-2	19
Functional unstable	21-23	3+	7
Poor stable	1-20	0-2	25
Poor unstable	1-20	3+	18
Edentate	0	0	9

Table 12: Tooth loss trajectory classifications used for the selection of participants for qualitative interview.

The secondary criteria for sample selection were the following socio-demographic characteristics: sex, region of current residence (whether North-East England or elsewhere in the UK), age 50 social class (groups I, II, III, IV and V based upon the 1990 Standard Occupational Classification (OPCS 1990)) and age 50 smoking status (whether current, never or ex-smoker). The justification for sampling based upon sex and social class was the previous body of evidence associating these characteristics with health behaviours (Pampel et al. 2010; Vlassoff 2007), including OHBs (Chadwick et al. 2011; Sabbah et al. 2009). Region of current residence was deemed important based on evidence that geography may influence OHBs (Chadwick et al. 2011) and to improve the generalisability of the study findings to areas outside of the North-East of England. Smoking status was included as a potential indicator of whether participants generally engaged in positive or negative health and oral health behaviours (Sanders et al. 2005; Singh et al. 2013), to ensure influencers of OHBs were studied across both groups. Social class and smoking status specifically *at age 50* were selected as the best reflections of these characteristics in adulthood out of two previous prospective assessments in adulthood (at age 50 and age 63 – Table 11, Page 72). Age 50 marital status (single, married, divorced or widowed) was not included initially as a secondary selection criterion but was subsequently added, after the importance of spousal influence emerged from initial interviews. Information on all of the above criteria was already available, having previously been collected by the wider study team in prior phases of the NTFS (Table 11). As secondary selection criteria, minimum quotas for sampling were not set but the intention was to sample participants from across a range of levels in each criteria. Ultimately, eleven interviewees were male, whilst nine were female. Fourteen currently lived in the North East of England, whilst six lived elsewhere in the UK. At age 50, six were in each of Social Class I, II and III, whilst two were in Social Class IV; two were current smokers, ten were ex-smokers, and eight were never smokers; and seventeen were married, two were divorced and one was single.

The full demographics of the final interviewed sample are outlined in Table 13.

Name[*]	Tooth count age 50	Tooth count age 63	Teeth lost age 50 to 63	Tooth loss trajectory	Sex	Region of current residence	Social class age 50	Smoking status age 50	Marital status age 50
Maureen	28	27	1	Good stable	Female	North East	IIIM	Current	Married
Alan	27	27	0	Good stable	Male	North East	II	Ex	Married
Keith	25	25	0	Good stable	Male	North East	I	Ex	Married
Malcolm	30	27	3	Good unstable	Male	East of England	I	Ex	Divorced
Donald	28	20	8	Good unstable	Male	North East	I	Never	Married
Lorraine	28	18	10	Good unstable	Female	North East	II	Never	Single
Michael	26	20	6	Good unstable	Male	North East	IIIM	Ex	Married
George	23	23	0	Functional stable	Male	Yorkshire & the Humber	II	Never	Married
Steve	23	22	1	Functional stable	Male	North West	II	Never	Married
Pam	23	21	2	Functional stable	Female	Yorkshire & the Humber	IIINM	Never	Married
Cynthia	25	22	3	Functional unstable	Female	East Midlands	IIIM	Never	Married
Jeremy	23	15	8	Functional unstable	Male	South East England	II	Ex	Married
Barbara	21	18	3	Functional unstable	Female	North East	II	Current	Divorced
Patricia	18	18	0	Poor stable	Female	North East	I	Never	Married
Edith	5	5	0	Poor stable	Female	North East	IIIM	Ex	Married
John	14	11	3	Poor unstable	Male	North East	I	Ex	Married
Rose	14	0	14	Poor unstable	Female	North West England	IV	Ex	Married
Dorothy	0	0	0	Edentate	Female	North East	IIIM	Ex	Married
Bruce	0	0	0	Edentate	Male	North East	IV	Ex	Married
Arthur	0	0	0	Edentate	Male	North East	I	Never	Married

Table 13: Demographics of the final interviewed sample.
**names are pseudonyms*

Sample selection was an iterative process, whereby small numbers of individuals were invited to interview in stages. The tooth loss trajectories and socio-demographic characteristics of responders then determined the selection of subsequent individuals. Emerging ideas from initial interviews also influenced the subsequent selection process, in an attempt to confirm or disconfirm emerging ideas and capture new ideas. This is exemplified by the subsequent inclusion of age 50 marital status as a secondary selection criterion, after initial interviews demonstrated an importance of spouses in influencing OHBs.

Ultimately, invitation letters were sent to 54 NTFS participants. Follow-up attempts were also made via telephone and e-mail, where information was available. Of the 54 individuals invited to interview, 26 (48%) agreed to participate. Of the remaining 28, 23 did not respond to the contact made and 5 responded that they were currently unable or unwilling to participate (two were too busy, one was unwell and two did not provide a reason). Six of the individuals consenting to interview were subsequently exempted, where response rates from certain individuals with similar characteristics were particularly high.

The number of interviews was not specified prospectively, but interviews were continued until it was deemed that 'data saturation' had been achieved, whilst remaining pragmatic about the number of interviews that could be completed within the limits of a PhD. Data saturation has been described in realistic terms as "the point of diminishing return where increasing the sample size no longer contributes new evidence" (Ritchie et al. 2014). This pragmatic point was judged to have been achieved after completing twenty interviews, which is about average compared to published qualitative studies in the field of oral health (Al-Moghrabi et al. 2019). It was certainly felt that little new content was emerging from the data in the latter interviews and that sufficient opportunity had been provided to sample individuals across a range of tooth loss trajectory groups. Twenty interviews also facilitated broad representation across the five secondary selection criteria.

The twenty interviews took place between 31st October 2014 and 18th February 2015. The mean interview length was 54 minutes, with the longest interview lasting 90 minutes and the shortest 39 minutes.

3.6.4: Interview location

Interviewees living close to Newcastle upon Tyne (the location of myself as the interviewer) were offered the choice of being interviewed in person, either in their own home, in an appropriate space within Newcastle University or at another location of their choosing (the furthest distance travelled for an in-person interview was approximately 30 miles). Interviewees living further afield were interviewed over the telephone. As a result, thirteen interviews were undertaken in person (seven in participants' homes, one at a participant's workplace and five within Newcastle University) and seven were completed over the telephone.

The choice of location offered for the in-person interviews was designed to reduce the burden placed on participants, encourage their participation and encourage them to feel comfortable and talk openly during the interviews. Previous evidence has shown that interview location can impact upon interview responses (Elwood and Martin 2000). Efforts were made to ensure that locations were always quiet and private and that respondents were comfortable.

Telephone interviews were conducted with participants living further afield, primarily based upon practical, environmental and resource constraints. As discussed in the literature, it was acknowledged that telephone interviews may impact upon interview responses, such as by providing a feeling of greater anonymity, preventing non-verbal communication, obscuring visible characteristics of the interviewer and interviewee (e.g. age, race, appearance) and introducing the potential for technological problems (Oltmann 2016). However, reassuringly, the majority of studies exploring the use of telephone compared to in-person interviews found results were comparable between these modes (Opdenakker 2006; Sturges and Hanrahan 2004). Similarly, no differences were also noted in the present research, based upon informal reflection throughout the interview process and more formal reflection during the data analysis stage. Encouragingly, there was also no association between the length of interview and the mode of interview.

3.6.5: The topic guide

The main aim of the interviews was to explore in depth the factors across the life course which influenced how and why individuals looked after their oral health. Therefore, in-depth (as opposed to structured or semi-structured) interviews were used to provide the interviewee sufficient opportunity to develop their own accounts of the issues important to them, rather than being guided by the agenda of the researcher (Green and Thorogood 2018). As prior research on this topic in the UK is limited (Section 2.14), a primarily inductive approach to this qualitative study was also taken, whereby the aim was not to test prior hypotheses or assumptions but to generate new knowledge and theories grounded in the data.

In line with these principles, a topic guide was developed, but this was intended as an aide memoir for myself as the interviewer, providing a list of potential topics to explore rather than a prescriptive list of questions. Many of the topics listed were often voluntarily covered by participants and, hence, little prompting was required. Where interviewees were less forthcoming, the questions on the topic guide were not read verbatim but the language and the structure of questions were adapted to individual interviewees, for example, using language previously used by the interviewees and weaving prompts naturally into existing discussions. Decisions about what to probe and how were made by myself as the interviewer in-situ, depending on factors such as participants' previous responses and themes emerging from previous interviews. The use of a topic guide in this flexible manner is standard practice in in-depth interviewing (Green and Thorogood 2018; Ritchie and Lewis 2014). Where possible, open and non-leading questions were used to encourage in-depth accounts of participants' own viewpoints.

The initial topic guide (Appendix E) was structured to first include an introductory section, intended to encourage individuals to start thinking about the topic of oral health. Interviewees were asked what they perceived having good teeth or good oral health involved, whether it was important and what factors might influence oral or dental health. Their thoughts were then focused on their own oral health, asking them how it had changed over their lifetime and whether they were happy with it. The vast majority of the topic guide then focused on exploring the perceived factors which had influenced individuals' OHBs over their lifetimes (the core aim). The initial prompts in this section were intended to be very broad, in line with an inductive approach, encouraging people to think about how they had looked after their teeth over their life course, and why, including whether certain time periods, events, people and feelings had been important. More specific prompts were included latterly in this section and these were based upon previous established knowledge. As discussed in detail in the literature review (Sections 2.6 and 2.9), it is well-established that oral hygiene, smoking, diet and dental attendance behaviours are the key behavioural determinants related to the most common oral diseases (caries, periodontal diseases, tooth loss, and non-carious tooth surface loss) (DoH 2005; WHO 2003). Therefore, it was necessary to prompt individuals to discuss these key OHBs if they did not do this voluntarily. The final section of the topic guide focused on concluding the interviews, primarily seeking interviewees' views on the relative importance of the influencing factors discussed and seeking any additional thoughts.

The topic guide was an evolving document and several additions were made after the initial interviews (up to the sixth interview). The final topic guide included ten additional prompts compared to the initial guide (as highlighted in Appendix F). These prompts were added based upon themes emerging from the initial interviews that warranted further exploration. For example, contradictory views emerged from initial interviews about the influence of financial issues on OHBs, particularly dental attendance, and about the availability of dental services, so this was an area warranting further exploration. Furthermore, a perceived significant influence of interviewees' children on their OHBs emerged from two of the initial interviews. As such an influence had not been identified in previous literature, I was keen to explore this theme further. Other prompts related to exploring participants' views about their personal responsibility for their own oral health, the sufficiency of knowledge in bringing about action and the formation of one's oral health expectations. In accordance with the use of the topic guide as an aide memoir for myself as the interviewer, rather than a prescriptive guide, these additions were themes which could be explored if appropriate rather than prompts which must be covered during every interview. This practice of modifying a topic guide after initial interviews is accepted as standard practice (Ritchie and Lewis 2014) and was anticipated. However, the potential for this approach to inappropriately 'lead' future discussions was recognised. Accordingly, I was attentive to how these prompts were introduced, trying to explore such topics neutrally when they flowed naturally from previous discussions and asking open questions.

It is important to note here that an alternative approach to interviewing could have involved a more deductive approach, whereby the interviews could have been structured around existing health behaviour theories. Multiple models and theories of health behaviour have been postulated over the past fifty years (McGrath 2019) and applied to oral health predominantly since the mid-1990s (McGrath 2019). The appropriateness of the more traditional of these, such as the Health Belief Model, the Theory of Planned Behaviour and the Theory of Reasoned Action, amongst others, has been disputed by contemporary researchers (Asimakopoulou and Newton 2015; Michie et al. 2005), due to evidence of their poor predictive power (Hardeman et al. 2002; McEachan et al. 2011; Suresh et al. 2012), their often narrow focus (Michie et al. 2005) and the challenges in distinguishing between multiple overlapping theories (Michie et al. 2005). However, the more contemporary theoretical frameworks of relevance to health behaviours – primarily the linked Theoretical Domains Framework (TDF) (Cane et al. 2012), COM-B model (Michie et al. 2011) and PRIME theory of motivation (West 2006) – are considered more applicable to oral health today (Asimakopoulou and Newton 2015). In brief, the TDF was devised in 2005 and simplified all previous traditional health behaviours theories into one single theory using a consensus approach involving a large number of expert researchers (Michie et al. 2005). It has since been further refined and now comprises a fourteen domain construct (with 83 smaller domains) (Table 14) (Cane et al. 2012). The COM-B model of behaviour was developed in 2011 and asserts that three components must be present for a behaviour to occur: motivation (which can be reflective or automatic), capability (which can be physical and psychological) and opportunity (which can be social and physical) (Michie et al. 2011). The domains of the TDF have since been mapped to these COM-B components (Cane et al. 2012). The PRIME theory of motivation (PRIME standing for plans, responses, impulses, motives and evaluations) was introduced in 2006 and aimed to produce a unifying theory of what determines motivation (West 2006). At its core, it argues that motivation is determined by our wants and needs at any particular moment, which can be influenced by complex interactions between learnt and innate processes. However, it was decided to utilise a more inductive approach to interviewing, as the appropriateness of these theories for explaining OHBs is predominantly theoretical (Asimakopoulou and Newton 2015; Michie et al. 2005; Michie et al. 2011). Instead, as discussed further in sub-section 3.6.6, such theories were considered to some extent during the data analysis process.

Domain
1. Knowledge
2. Skills
3. Social/professional role and identity
4. Beliefs about capabilities
5. Optimism
6. Beliefs about consequences
7. Reinforcement
8. Intentions
9. Goals
10. Memory, attention and decision processes
11. Environmental context and resources
12. Social influences
13. Emotion
14. Behavioural Regulation

Table 14: The fourteen domains of the revised Theoretical Domain Framework (Cane et al. 2012).

3.6.6: Data analysis – broad methodology

The data analysis process employed was based upon thematic analysis, a longstanding method commonly used to analyse qualitative data but explicitly described by Braun and Clark (2006). This process involves using a six-step approach to identify, analyse and report patterns within data, as summarised in Table 15. This method was selected as it offers a pragmatic and clear approach of analysing qualitative data (ideal for a novice qualitative researcher), whilst still offering the potential to provide a rich, detailed and complex account of data (Braun and Clarke 2006). It is also flexible in not being constrained to any particular ontological or epistemological foundation (Braun and Clarke 2006).

Phase	Description of the process
1. Familiarising yourself with your data	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas
2. Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code
3. Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme
4. Reviewing themes	Checking if the themes work in relation to the coded extracts and the entire data set, generating a thematic 'map' of the analysis.
5. Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6. Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts relating the analysis back to the research question and the literature, producing a scholarly report of the analysis

Table 15: The six phases of thematic analysis. Adapted from Braun and Clark (2006).

Other analysis techniques considered for use in this research study include, in particular, a grounded theory approach (Glaser and Strauss 1967) and a framework approach (Ritchie and Spencer 1994). The grounded theory approach was founded in 1967 (Glaser and Strauss 1967). It has evolved into multiple forms over the years (Charmaz 2006; Clarke 2005; Corbin and Strauss 2008; Glaser 1992) but is an approach to developing substantive theory grounded from within empirical data, which comprises several fundamental components (Green and Thorogood 2018; Sbaraini et al. 2011). These components include: taking an open and inductive approach to theory generation; constant comparison between codes, data and cases to explain variation; memo writing to stimulate and develop thinking; data analysis and data collection occurring in parallel, to facilitate theoretical sampling (whereby sampling is dictated by the need to develop and test emerging theories); and theoretical saturation, meaning all concepts in the developed theory are well understood and can be substantiated by the data (Green and Thorogood 2018; Sbaraini et al. 2011). Thematic analysis was selected over a grounded theory approach as a more flexible and less prescriptive method, but one which is still able to generate a rich and complex account of data.

The framework approach was developed in the late 1980s (Ritchie and Spencer 1994). It is often considered a specific type of thematic analysis whose defining feature is the production of a matrix output of summarised data, which provides a structure for systematically reducing the data so it can be analysed by case and by code (Green and Thorogood 2018; Ritchie and Lewis 2014). Framework analysis is generally geared towards generating policy and practice-orientated findings (Green and Thorogood 2018; Ritchie and Lewis 2014) and is sometimes associated to a greater extent with 'content analysis', which is focused more on describing participants' views rather than generating ideas, theories and explanations (Green and Thorogood 2018). Thematic analysis was selected over framework analysis as this research was not directly intended to generate policy orientated findings, and to avoid the risk of losing detail when working with summaries rather than raw data (Green and Thorogood 2018).

A primarily inductive approach was applied to the data analysis. The rationale was the limited extent of prior qualitative research on the determinants of OHBs in the UK (as discussed in Section 2.14), meaning the generation of new knowledge and theory from empirical data was a priority. As discussed in relation to the approach to interviewing (sub-section 3.6.5), an alternative method would have been to utilise a primarily deductive approach, exploring the empirical data according to contemporary behaviour theories, such as the TDF or COM-B models (Cane et al. 2012; Michie et al. 2011). However, as the appropriateness of these theories for explaining OHBs is predominantly theoretical (Asimakopoulou and Newton 2015; Michie et al. 2005; Michie et al. 2011), again, the preferred approach was to use the primarily inductive approach described. As is commonplace in qualitative research (Green and Thorogood 2018; Ritchie and Lewis 2014), however, deductive approaches to data analysis were also incorporated: the empirical findings were situated in the context of previous research and the above behaviour theories; whilst pre-existing knowledge and theory were also utilised to sensitise myself as the researcher to potential emergent themes. Similar, primarily inductive analysis approaches have also been taken by the majority of previous qualitative studies investigating the determinants of oral health (Borreani et al. 2010; Daly et al. 2010; Gibson et al. 2019; Gill et al. 2011), although a more deductive approach based upon the TDF framework has been applied in one study exploring parental experiences of tooth brushing with children (Marshman et al. 2016).

3.6.7: Data analysis – detailed methods

In line with the broad methodology described in the preceding section, the specific process taken during data analysis is described below.

The audio-recordings were firstly transcribed verbatim by Katharine Kirton, the senior research administrator within the NTFS team. Before commencing analysis on each interview, I subsequently listened to the corresponding audio recording, thoroughly checking the transcription for accuracy and familiarising myself with the data. The transcription was then uploaded to the NVivo software (QSR International), which was used to facilitate subsequent coding and analysis. It has been argued by some that transcription is a key phase of data analysis (Bird 2005) and, therefore, the practical decision made early on in this PhD process not to transcribe the interviews myself could be criticised. However, due to the additional steps I took to check and familiarise myself with the data, I didn't feel disadvantaged by not having transcribed the interviews myself.

The next step involved systematically coding each transcript, assigning codes to label any relevant feature of each section of text. Such codes were numerous and captured all interesting aspects in the data. As each subsequent interview was coded, new codes were generated and existing codes were reviewed and modified, perhaps refining the content or meaning of a code, condensing or dividing codes. This recursive process occurred alongside data collection, as is commonplace in qualitative data analysis (Green and Thorogood 2018) and, as discussed in sub-sections 3.6.3 and 3.6.5 respectively, allowed emerging ideas to influence the selection of further interviewees and the format of future interviews.

Once all interviews had been coded, the process of grouping codes based upon similarities, links and associations between them began and this started to generate a structure of initial themes and sub-themes. The next stage involved reviewing and refining these themes and sub-themes, which involved various processes, including: re-reading all of the coded extracts grouped under each theme or sub-theme to check the appropriateness of themes in relation to the extracts; re-reading all of the interview transcripts to ensure all relevant data had been coded and the themes reflected the whole dataset; and re-visiting the field notes made after each interview to ensure any ideas not captured within 'accounts' had been incorporated. Copious written notes, mind-maps and tables were also drafted during this process to help organise ideas.

During the above stages, the intention was to really interrogate the data, exploring patterns both within and between cases, in an attempt to really understand and explain the influencers of OHBs across the life course.

Figure 5 documents the final thematic map of the main themes and sub-themes which was produced at the end of this process (Figure 6 also expands upon the ‘multiple sources of influence’ theme due to a limitation of space in Figure 5).

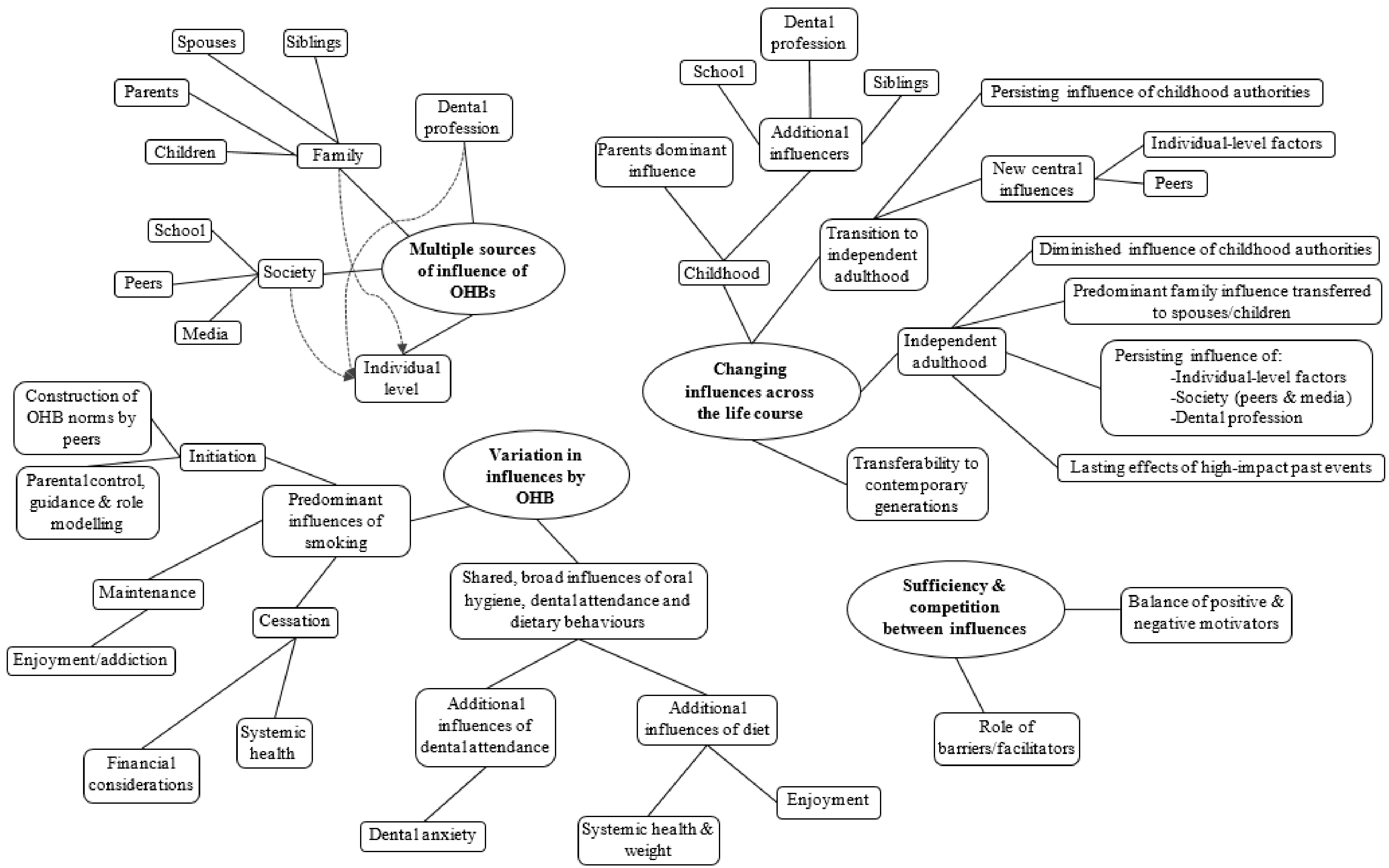

Figure 5: Thematic map of the main themes and sub-themes identified during data analysis of the qualitative interviews. NB: The 'multiple sources of influence' theme is further expanded in Figure 6 due to space limitations within this diagram.

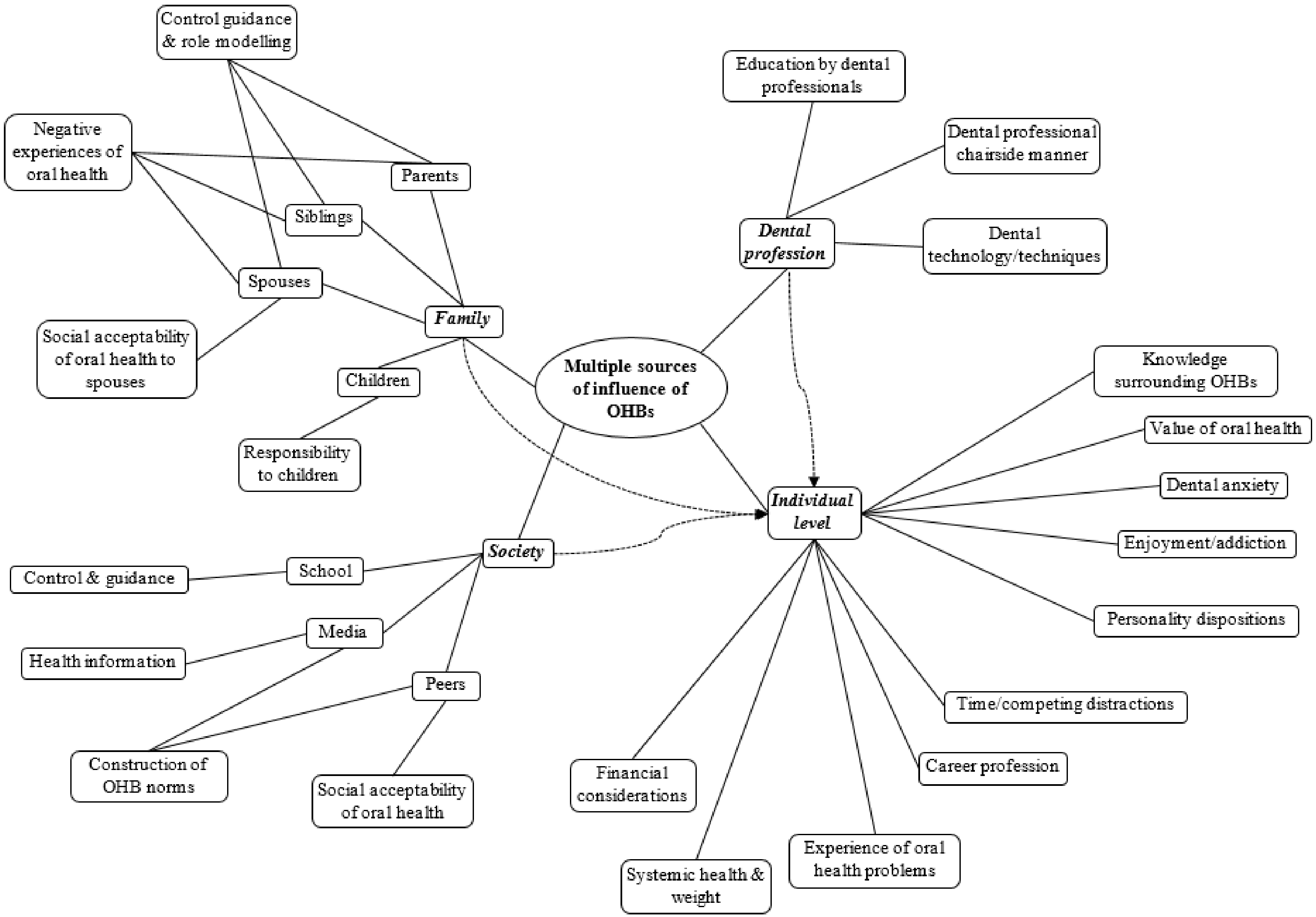

Figure 6: Expansion of the 'multiple sources of influence' theme due to space limitations in Figure 5.

The final stage of data analysis involved planning how to convey the emergent findings from the interviews in this thesis. As in common practice in the reporting of qualitative research (Barbour 2014b; Green and Thorogood 2018), the Qualitative Results chapter (Chapter 4) begins to situate the findings of this study within the context of previous knowledge and theory and also considers their transferability to contemporary UK generations. These processes are also continued in the Discussion chapter (Chapter 6), whereby the findings of this qualitative research are discussed in more detail in relation to previous knowledge and theory, and their implications for current policy and practice considered, alongside the findings of the quantitative study.

The majority of the data analysis process was undertaken independently by myself. However, my supervisor, Professor Catherine Exley, reviewed the coded transcripts of the first two interviews with me and, together, we discussed and revised the codes applied. She also reviewed the emerging coding framework with me on several occasions, challenging me about the content and meaning of codes and contributing to their refinement. Likewise, myself and Professor Exley held several discussions about the emerging content and organisation of themes and sub-themes, how they situated within previous literature and about the presentation of the findings in this thesis. Although the independent coding of all transcripts by two researchers, followed by the collaborative construction of a coding framework, can improve the validity of qualitative research (Burnard et al. 2008; Mays and Pope 1995), this was not practical within the constraints of this PhD.

3.6.8: Reflexivity

Reflexivity is the process of examining and explicitly recognising the effect that the researcher, or the social or political environment, may have upon the research process. Assuming an interpretivist stance, such factors are acknowledged to influence the research process in its entirety, from the development of a research question, through data collection, to data analysis and the generation of conclusions (Berger 2015; Green and Thorogood 2018). The process of reflexivity is important in all research but is a particularly important component of maintaining rigour in qualitative research (CASP 2018; Mays and Pope 2000). In this qualitative study, I believe the key issues relate to the influence of myself as the researcher on the data collection and data analysis processes and so I explore these two aspects below.

In qualitative interviewing, an interviewer's personal characteristics, such as age, gender, race, social position and professional role, can influence the interviewer-interviewee relationship and the nature of their responses (Berger 2015; Green and Thorogood 2018; Richards and Emslie 2000; Williams and Heikes 1993). With regard to these characteristics, perhaps the most important consideration in this research was the impact of my professional background as a dentist. Indeed, previous evidence has specifically shown that disclosure of medical professional status can influence interview responses (Richards and Emslie 2000). In light of this concern, my role was disclosed to the interviewees because it felt dishonest not to offer this information. However, I emphasised to interviewees that I was approaching these interviews from the perspective of a researcher, not a dentist, and participants were encouraged to be open about their behaviours and assured they would not be judged. Consequently, my general perception was that interviewees were open and honest – for example, many continued to reveal 'negative' oral health practices or to criticise dentists – but it may be that these responses had been tempered based upon participants' knowledge of my role. Indeed, participants did often ask for clinical advice or refer to my role as a dentist (for example, "you will know all about…."), demonstrating they continued to be alert to my professional role.

My interviewing technique may also have influenced participants' responses, particularly in light of my pre-existing beliefs and assumptions but also my relative inexperience as a research interviewer. It was a challenge, especially initially, to put aside my pre-existing assumptions regarding what influenced how and why people cared for their oral health, constructed from my personal experiences with patients, previous research or my own personal oral health experiences. Due to my inexperience as a qualitative interviewer, it was also a steep learning curve exploring how much prompting was necessary without overly guiding or restricting participants' responses, exploring what type of language to use, remembering to use open questions and learning to be comfortable with silence. Conscious of the above, however, I conducted two pilot interviews before the study interviews – with a parent in a similar age bracket to the NTFS study members and with a NTFS participant on the study's steering group. Reviewing the audio recordings and transcriptions of these pilot interviews subsequently allowed me to critique my interview approach, with the support of my supervisors. This process led to refinement of my interview technique, as I identified occasions where I asked leading questions, cut short silences and missed opportunities for further prompting. This process of reflection was also continued throughout the main study interviews and my influence on individuals' responses also constantly considered during the data analysis stage.

Furthermore, I was also conscious of how my pre-existing beliefs might influence my interpretation of the data during the analysis process. Due to my clinical dental background and prior studies in the natural sciences, rather than social sciences, I acknowledged my initial tendency to interpret accounts from a more clinical perspective than 'social' perspective. Increasing my familiarity with social science literature, explicitly recognising my bias and conducting joint data analysis sessions with my supervisor, Professor Exley (a medical sociologist), helped to provide balance to my perspective. For example, when analysing an extract from an initial interview, whereby a participant was discussing issues surrounding access to a dentist, I interpreted the key barrier as being a lack of an NHS dentist nearby (an issue I am very aware of due to my clinical background), whereas Professor Exley highlighted to a greater extent the concomitant psycho-social issues, such as the participant's willingness to travel, the efforts they made to identify a dentist and their sense of personal responsibility related to their oral health. Furthermore, due to my inexperience in analysing qualitative data, I acknowledge that I found it challenging initially to move from a more descriptive analysis, focused on describing the content of participants' views, to a more analytical approach, involving the identification of patterns and relationships and the development of explanations and theories (Braun and Clarke 2006; Green and Thorogood 2018). However, with perseverance and senior guidance, I feel I have made progress towards the latter, although acknowledge that such skills may only be fully embedded upon more extensive experience in this field.

3.6.9: Managing issues of retrospective recall and period effects

As previously mentioned (sub-section 3.6.1), use of the older NTFS birth cohort for this qualitative study presented disadvantages relating to: 1) the reliance on interviewees' retrospective recall of past events, and 2) the impact of period effects on the transferability of findings to more contemporary generations.

Regarding the former disadvantage, problems with remembering information were expressed in many interviews, especially in relation to memories from earlier lives. The account from Cynthia below, in which she is discussing why she started attending the dentist regularly around the age of 16, provides an example of this:

> *"It would probably be just to look after my teeth, to make sure I didn't lose any more if I could help it. Because you're a teenager, then you become a grown up and you want to do things for yourself and, I don't know, I can't remember. I probably just thought it was the right thing to do…I'm just trying, my memory is struggling a bit. I think probably…you didn't have a dentist regularly but you had one you went to when you had a problem and I think…they then encourage you to go six monthly. They get you to come back…I think that's how I ended up as well going regularly, them just encouraging it."*

However, although not uncommon, such explicitly recognised memory issues were generally restricted to specific memories within accounts, rather than being widespread concerns across whole interviews or a whole life stage. Furthermore, the topics of discussion affected by such memory loss were generally very variable between accounts. Hence, memory issues did not hinder a general understanding of the determinants of OHBs across the interview sample as a whole, even if the contributions of a particular account to a topic occasionally had to be discounted. Crucially, where specific recollections were clearly compromised by recall issues, the contribution of these recollections to the research findings were modified accordingly during the data analysis stage. For example, where statements were clearly complete speculation, these were not utilised. Alternatively, where information was reputedly based on some recall but doubt was evident, its contribution was moderated. Nonetheless, it is accepted that some recall issues may not have been identifiable, i.e. where participants' memories were unconsciously distorted by more recent events or where participants resorted to conjecture in their desire to provide a complete response.

Regarding the impact of period effects on the transferability of the research findings to more contemporary populations, the solution was to explicitly consider such period effects in any interpretation and application of the data (see sub-section 4.3.4). Indeed, several period changes were recalled in participants' accounts, such as the changing influence of the media, and could also be postulated according to previous knowledge and evidence (Fielding 1999; Glenn 2005; Oláh et al. 2018). That said, it is acknowledged that such a process relied to a certain extent on conjecture and postulation and was a research limitation.

3.7: The quantitative study

The quantitative study aimed to model the contributions of determinant factors across the life course to oral health outcomes. As outlined (Section 3.1), it involved additional data collection from the NTFS cohort, via a questionnaire, followed by a life course path analysis of the determinants of age 63 tooth loss in the NTFS cohort. This section firstly justifies the use of the NTFS cohort for this study (sub-section 3.7.1), the reason for using path analysis as the statistical modelling technique (sub-section 3.7.2) and the selection of age 63 tooth retention as the oral health outcome measure (sub-section 3.7.3). Subsequently, sub-sections 3.7.4 to 3.7.9 address the selection of predictor variables for the life course path analysis. Such variables were obtained from pre-existing NTFS data but also via the distribution of an additional questionnaire to NTFS participants as part of this research project. Therefore, these sections include significant discussion regarding the design and robustness of this additional questionnaire. Finally, sub-sections 3.7.10 to 3.7.17 provide the detail of the statistical methods used to conduct the life course path analysis.

3.7.1: Study setting

The NTFS cohort was utilised for this quantitative study as is it the only prospective birth cohort study in the UK to have measured dental outcomes in later life (as discussed in the literature review (sub-section 2.11.2)). Hence, it provided a unique opportunity to achieve the objective of this quantitative study. Indeed, two previously published studies have already used NTFS data to model the life course determinants of age 50 oral health outcomes, although these relied upon now superseded statistical techniques (hierarchical regression modelling), which resulted in significant limitations (Mason et al. 2006; Pearce et al. 2004). The intention of this present study was to extend the above research, utilising measures of oral health from later in the life course (age 63) and utilising a more appropriate and contemporary statistical technique (path analysis).

From the outset, the limitations of the NTFS cohort were acknowledged. Perhaps most importantly, the study lacked existing life course data on some important determinants of oral health, particularly diet prior to the age of 50, life course oral hygiene behaviours and life course dental attendance behaviours.

Additionally, there were concerns regarding the representativeness of the NTFS cohort of the general UK population. Firstly, being a North-East birth cohort, the characteristics of this cohort may have differed in some respects to the rest of the UK, due to regional variations in factors such as economic, cultural, social and healthcare environments (Marmot et al. 2020; ONS 2016). For example, over the cohort's lifetime, the economic profile of the North-East has been below average, compared to the rest of the UK (ONS 2016), whilst the North of England has suffered below average oral health outcomes and OHBs (Chenery 2011; Kelly et al. 2000). Many NTFS participants have moved away from North-East England since birth, however; for example, 18% of those participating in the age 50 clinical assessment were resident outside of the north of England (Pearce et al. 2009b). However, this only mitigates but does not eradicate the above limitation.

Secondly, there is evidence that loss to follow-up in the NTFS cohort may have introduced some bias into the remaining cohort. At age 50, 50% of the original cohort returned the main follow-up questionnaire (Pearce et al. 2009b) and this reduced to 38% at the age 63 follow-up, with 30% attending for the age 63 dental examination (Table 11, Page 62). Of those attending the latter, 55% were female, compared to 49% of the original cohort (Pearce et al. 2009b). Furthermore, 23% were from unskilled or partly skilled social class groups at birth (the two lowest social class groups of the Registrar General's Social Classification (OPCS 1990)), compared to 32% of the original sample (unpublished data).

Thirdly, it is arguable that the NTFS may have resulted in a 'professional' cohort who, having participated in research throughout the whole life course, may have an increased awareness of health – a phenomenon known as the Hawthorne effect (French and Sutton 2010; Godin et al. 2008).

Despite the above limitations, the use of the NTFS cohort as a setting for this life course analysis was still deemed worthwhile, given the potential to collect absent life course information retrospectively, the importance of the research question and the absence of superior alternative cohorts. Alternative settings for this research were considered. However, as stated, no other prospective birth cohort study in the UK had collected dental data beyond the age of 33 (Connelly and Platt 2014; Delgado-Angulo and Bernabe 2015b; Dudding et al. 2018; Skafida and Chambers 2018). Alternatively, pre-existing UK prospective birth cohorts without existing measures of dental health could have been utilised – such as the 1946 British National Survey of Health and Development (Wadsworth et al. 2006) or the 1970 British Cohort Study (Elliott and Shepherd 2006) – and dental outcomes measured via additional primary data collection. However, such data collection, especially relating to clinical measures, would have been too resource intensive within the limits of a PhD. Additionally, like the NTFS cohort, these cohorts are also limited by a lack of data regarding important OHBs, such as oral hygiene and dental attendance behaviours (Elliott and Shepherd 2006; Wadsworth et al. 2006).

3.7.2: The path analysis technique

As detailed in the literature review (sub-section 2.12.1), quantitative research utilising a life course approach to study the development of oral health and disease should employ statistical techniques which allow the modelling of complex paths and dependencies between variables across the life course (Crall and Forrest 2018; Newton and Bower 2005; Nicolau et al. 2007b). Such techniques include hierarchical regression modelling, SEM and path analysis techniques (Bub and Ferretti 2014; Newton and Bower 2005; Streiner 2005; Victora et al. 1997). These methods are superior to traditional regression modelling techniques because they take into account both the direct and indirect effects of predictor variables on outcomes (Figure 3b & c, Page 39) (Bub and Ferretti 2014; Newton and Bower 2005; Victora et al. 1997). In contrast, traditional regression modelling techniques treat the effects of proximal and distal determinants as being only direct and equally distant to the outcome (Figure 3a, Page 39), which causes the effects of more distal determinants to be underestimated (Newton and Bower 2005; Weitkunat and Wildner 2002).

More specifically, path analysis was selected over hierarchical regression modelling for this study because it allows complex direct and indirect pathways between *individual* predictor variables and an outcome to be elucidated (Figure 3c, Page 39), rather than only paths between *groups* of variables (Figure 3b, Page 39) (Newton and Bower 2005; Victora et al. 1997). In the context of this research, this allowed the overall, direct and indirect effects of individual variables, rather than purely life course stages, on later life oral health outcomes to be elucidated.

Furthermore, path analysis was selected over SEM for this study because the incorporation of latent variables was not required. As previously discussed (sub-section 2.12.1), SEM is an extension of path analysis which allows the inclusion of latent variables – variables which cannot be measured directly but can be estimated by a number of other observable variables (Lei and Wu 2007). The justification for not requiring latent variables was that the observable variables available within the existing NTFS dataset (and planned for collection in the additional questionnaire) were considered sufficient to measure the predictor and outcome factors of interest, without the need to create latent variables.

As evidenced in the literature review (sub-sections 2.12.2 and 2.12.3), path analysis has been used in many fields of research (Beran and Violato 2010; Garson 2014; Lei and Wu 2007; Streiner 2005) mainly over the past three decades and has been applied to oral health research in more recent years (Goettems et al. 2018; Lu et al. 2011). In simple terms, it is an extension of multiple regression analysis and involves running a series of multivariable regression analyses simultaneously, for each relationship specified in a path diagram of causal relationships (Figure 3c, Page 39) (Garson 2014). Distinguishing both the direct and indirect effects of predictor variables on an outcome, it can therefore provide an accurate representation of the contribution of different factors to an outcome, when analysing sequentially caused relationships (Garson 2014; Shipley 2016; Streiner 2005).

Path analysis can be conducted via two techniques: 1) previously specifiying two or more path diagrams, based on previous theory and hypotheses, and testing and comparing these models, or 2) constructing a path diagram via an iterative process of model building and model trimming, based on the results of multiple sequential analyses (Shipley 2016; Streiner 2005). This research utilised the latter technique as its aim was not to test a previously hypothesised model, but to generate a model that best fit the NTFS data. The broad process for this latter technique involves constructing an initial limited path model, often based on significant relationships identified by traditional multivariable regression analyses. New variables and paths are then continuously added to this initial model, based on statistical indications plus theoretical knowledge and justification (Garson 2014; Streiner 2005). Concurrently, as the model evolves, non-significant paths are removed (Garson 2014). The end point of this iterative process is a final path model which best fits the observed data, but is also based on sound, theoretically justifiable relationships (Garson 2014). The fit of this model should subsequently be assessed via goodness-of-fit measures (Garson 2014). Such a method of path model building is widely used (Mann et al. 2013; Pearce et al. 2012; Tennant et al. 2008).

3.7.3: The outcome variable

The outcome variable utilised in this quantitative study was natural tooth count at age 63. This measure was already available within existing NTFS study data, having been obtained via a clinical dental examination at the Royal Victoria Infirmary (Newcastle upon Tyne) between January 2010 and October 2011, as part of the age 63 study follow-up. The conduct of this clinical examination has already been described in detail in sub-section 3.2.2.

The rationale for using natural tooth count as an indicator of oral health is its status as a common oral health outcome (Fuller et al. 2011), which is relevant to individuals, having positive effects upon chewing function (Bortoluzzi et al. 2012; Wright et al. 2018), aesthetics, psycho-social factors (Rousseau et al. 2014) and OHRQoL (Gerritsen et al. 2010). Being an irreversible outcome, tooth count is also a cumulative measure of oral health experience across the life course and, therefore, appropriate for a life course study of the determinants of oral health. Furthermore, being an outcome of multiple oral diseases, tooth count provides a broad, rather than narrow, reflection of life course oral health experience; evidence from across the UK over the last few decades has found that around a third (but up to 58%) of dental extractions in general dental practice were due to caries and around a third were due to periodontal disease (Hull et al. 1997; McCaul et al. 2001; Richards et al. 2005) – the two most common oral diseases globally and in the UK (Dye 2017; White et al. 2011). The remainder were due to other factors, particularly trauma and orthodontic problems (Hull et al. 1997; McCaul et al. 2001; Richards et al. 2005).

More specifically, tooth counts at both age 50 and 63 were previously obtained within the NTFS, but the age 63 tooth count was utilised as it reflects oral health experience across a longer period of the life course.

The limitations of the use of tooth count, however, were acknowledged. Firstly, the reflection of this outcome of broad oral disease experience can be a disadvantage as well as an advantage. Specifically, the determinants of oral diseases vary between disease outcomes (as reviewed in Section 2.9 of the literature review) and, therefore, the determinants of tooth retention may not reflect the determinants of the individual disease components leading to tooth loss. Furthermore, tooth loss only reflects a proportion of disease experience from these component causes, as only the most severe proportion of affected teeth are ultimately lost (Hirschfeld and Wasserman 1978; McLeod et al. 1997; Ramseier et al. 2017; Wriedt et al. 2010). Tooth retention can also be influenced not only by disease experience but also by other factors, such as patient choice, dental attendance, treatment costs and dentists' treatment decisions (Brennan and Spencer 2005; Kalsi and Hemmings 2013; Kay and Blinkhorn 1996). It also does not reflect all oral diseases and conditions, such as oral cancer or temporomandibular diseases, which still induce a significant burden (Berger et al. 2015; Oral Health Foundation 2020b). Furthermore, and by no means of least importance, tooth count is a clinical measure of oral health, rather than a patient-orientated outcome. Although tooth retention is generally associated with positive physical and psycho-social effects (Bortoluzzi et al. 2012; Gerritsen et al. 2010), the prioritisation of patient-orientated outcome measures (PROMs) has been advocated in recent years, to capture the *impact* of clinical conditions (Black 2013; NHS England 2015; Reissmann 2019).

Despite the above limitations, tooth count is still a very useful oral health outcome measure and its use has been widespread in previous research exploring the life course determinants of oral health (as reviewed extensively in sub-sections 2.13.1 and 2.13.4).

Finally, the rationale for not also utilising other oral health outcomes previously measured in the NTFS was that these were very limited. As outlined in sub-section 3.2.2, the only other dental outcome measures obtained at age 63 included: a clinical assessment of the presence, or not, of dentures (a crude and not particularly useful outcome); a self-reported assessment of the presence, or not, of any loose teeth (a measure which demonstrates low sensitivity for identifying periodontal disease (Abbood et al. 2016) and does not reflect experience of other oral diseases); a single self-reported assessment of the frequency of oral pain experience across the life course (oral pain experience is a potentially useful PROM in itself (Aggarwal et al. 2005; Mittal et al. 2019) but, in the context of this research, not in the form of a single assessment of pain frequency over the entire life course); and a self-completed Oral Health Impact Profile (OHIP) questionnaire (Slade 1997). As a widely used and validated PROM (John et al. 2006; Larsson et al. 2004; Slade 1997), the latter could have been used as an additional outcome measure in this research. This was not undertaken, due to the time constraints of a PhD, but could be considered in future research.

In addition to the above measures obtained at age 63, clinical assessments of the number of grossly decayed/broken down teeth, visibly loose teeth and premolar and molar opposing tooth contacts were also obtained in the NTFS at age 50. However, these were not utilised as they would have limited this study to the first 50 rather than 63 years of the life course, amongst other limitations.

3.7.4: Identification of potential predictors

Table 16 outlines the information already available within the NTFS dataset, which was considered potentially relevant to an analysis of the life course determinants of tooth retention. Final decisions on the pre-existing variables to be included, however, were dependent upon the information collected in the additional questionnaire data collection stage and, hence, are discussed further and confirmed in sub-section 3.7.9.

Nevertheless, the justification for consideration of the above variables is as follows: there is some support for a role of birth weight in caries outcomes, based upon the contribution of low birth weight to the disruption of enamel formation and maturation, although findings have been contradictory (Nicolau et al. 2003a; Saraiva et al. 2007; Tanaka and Miyake 2014); extensive evidence supports the role of sex (Ferraro and Vieira 2010; Fuller et al. 2011; Ioannidou 2017), systemic health (Albandar et al. 2018; Anders and Davis 2010; Mathews et al. 2008) and socio-economic factors – such as education (Bernabe et al. 2011; Steele et al. 2014) and social class (Fuller et al. 2011; Ramsay et al. 2018; Thomson 2012) – in determining oral health outcomes, including tooth loss, via their influences on behavioural, but also biological, pathways (Anders and Davis 2010; Gomaa et al. 2016; Hamasha et al. 2006; Ioannidou 2017); it is well established that smoking and sugar consumption are key determinants of periodontal disease and caries, respectively (Moynihan and Kelly 2014; Warnakulasuriya et al. 2010), and, therefore, potential determinants of tooth loss (Tiwari et al. 2016; Warnakulasuriya et al. 2010); evidence supports the influence of dental attendance on caries, tooth loss outcomes and periodontal outcomes, although the latter is less well established (Alikutty and Bernabe 2016; Crocombe et al. 2012; Thomson et al. 2010); and the literature suggests that marital status influences oral health (Treasure et al. 2001; Zhang et al. 2016) and certainly general health (Kiecolt-Glaser and Newton 2001; Tatangelo et al. 2017) via physiological and behavioural pathways. In addition, the qualitative study in this PhD research provided evidence for the role of spouses in influencing OHBs (see Chapter 4).

Topic	Information available	Age and method of collection
Birth Factors		
Standardised Birth Weight	Birth weight standardised for sex and gestational age, according to UK 1990 Growth Reference Curves (Freeman et al. 1995).	Midwives' reports
Demographics		
Sex		Midwives' reports
Social Factors		
Social Class	According to Registrar General's Social Classification (renamed Social Class based on Occupation in 1990) (OPCS 1990).	At birth and throughout childhood, up to age 15 (using information from household surveys). Age 25, 35 and 50 (using information from age 50 Health & Lifestyle questionnaire). Age 63 (using information from age 63 Health & Lifestyle questionnaire).
Education	Highest educational attainment	Age 50 Health & Lifestyle questionnaire
Marriage	Chronology of marital history	Age 50 Health & Lifestyle questionnaire
General health and disability		
Health and disability	Extensive medical information	Age 50 Health & Lifestyle questionnaire and clinical assessment.
	Extensive medical information and World Health Organisation Disability Assessment Scale (WHODAS 2.0) score (Üstün et al. 2010)	Age 63 Health & Lifestyle questionnaire and clinical assessment.
Behavioural factors		
Smoking	Detailed smoking histories	Age 15, 25, 35 and 50 (from age 50 Health & Lifestyle questionnaire). Age 63 (from age 63 Health & Lifestyle questionnaire).
Sugar consumption	Average daily total sugar intake, calculated from the European Prospective Investigation into Cancer and Nutrition Norfolk Food Frequency Questionnaire (EPIC-Norfolk FFQ) (Bingham et al. 2001), using the FETA FFQ EPIC Tool for Analysis (Mulligan et al. 2014).	Age 50 (via age 50 Health & Lifestyle questionnaire). Age 63 (via age 63 Health & Lifestyle questionnaire).
Dental attendance	Current frequency of dental attendance	Self-completed questionnaire at age 50 dental examination.
	Whether attended dentist in last year/Whether registered with a dentist	Asked by examiner at age 63 dental examination/Age 63 Health & Lifestyle questionnaire

Table 16: Existing data available in the NTFS of potential relevance to a life course analysis of the determinants of tooth loss.

In addition, however, much information not previously collected in the NTFS was also deemed potentially key to the development of tooth loss. As discussed in the literature review, oral hygiene is a well-established determinant of oral health, particularly caries and periodontal disease and, therefore, tooth loss (Axelsson et al. 2004; Broadbent et al. 2011; Turani et al. 2013). Evidence also supports the role of dental anxiety in oral health outcomes, particularly caries and tooth loss (Kisely et al. 2015). Furthermore, research has demonstrated a role of parental influence in childhood and even adulthood oral health outcomes, including tooth loss (Broadbent et al. 2016; Castilho et al. 2013), whilst parental influence was also perceived to be a key determinant factor in the qualitative component of this research study (see Chapter 4). However, no data on the above determinants was available.

In addition, although data regarding dental attendance and sugar consumption at ages 50 and 63 were already available in the NTFS (and its relevance acknowledged earlier in this sub-section), such information pertaining to other points across the life course was not available (Table 16). Similarly, although marital history information was collected at age 50 (Table 16) (and its relevance acknowledged above), such information was not updated at the age 63 follow-up. Lastly, information was also absent regarding the perceived involvement of partners and spouses in influencing study members' oral health, although partners and spouses emerged as key sources of influence in the qualitative study within this PhD (see Chapter 4).

In light of the potential key relevance, but lack of availability, of the above information, the decision was made to collect self-reported current and retrospective information on these factors via a questionnaire sent to NTFS participants. Self-reporting was the method of choice (or only option) for assessing most of these factors, other than for dental attendance (where dental records could have been used) and current oral hygiene (where clinical assessments of plaque could have been undertaken). However, within the constraints of this PhD, and in light of evidence demonstrating good validity of self-reported dental attendance (Gilbert et al. 2002) and oral hygiene measures (Gil et al. 2015), self-reporting was deemed most appropriate. Furthermore, a self-completed questionnaire, rather than interviewer-administered questionnaire, was selected given resource availability within this PhD, the high compliance rates expected of this longstanding cohort, the reasonably short and simple nature of the questionnaire and the minimisation of social desirability and interviewer bias associated with this approach (McColl et al. 2001). Hereafter, this questionnaire is referred to as the age 69 dental questionnaire and is included in Appendix G.

3.7.5: Questionnaire design and testing strategy

The key quality aims in relation to quantitative survey research are to collect information that is valid, reliable, unbiased and discriminating (McColl et al. 2001). Validity refers to the ability of a question to measure the concept that is intended to be measured and can be tested via several processes: seeking the opinions of lay individuals (such as colleagues, friends or family) as to whether 'on the face of it' questions seem to address what is intended (face validity), review by a panel of experts in the field (such as researchers, clinicians and members of the target population) to ensure questions assess all aspects of a concept (content validity), and results analysis (McColl and Thomas 2000). The latter includes assessing whether statistical relationships are as expected, such as comparing correlations between measures targeting similar concepts (construct validity), assessing correlations with gold standard methods or outcomes (criterion validity), and assessing whether results reflect levels and distributions expected in the target population (freedom from absolute bias) and subpopulations (freedom from relative bias) (McColl and Thomas 2000). Reliability refers to whether a measure is consistent and, in the context of self-completed questionnaires, can be assessed via test-retest and internal consistency statistics (McColl and Thomas 2000). The former assess whether results provided by the same individual are reproducible at two different time points. The latter assess whether multiple questions measuring the same or related concepts yield consistent results. Furthermore, unbiased results are those which are not systematically different from the truth as a result of any part of the research process (McColl and Thomas 2000), whilst discrimination refers to the ability of questions to distinguish sufficiently between individuals who display different levels of the concept being measured (McColl et al. 2001). Ensuring quality in relation to the above measures was an important consideration in relation to the age 69 dental questionnaire and was considered at each stage of the iterative process of questionnaire drafting, testing and refinement, and also the initial data analysis stage.

In overview, the initial drafting stage was informed by a review of the following: previous literature on topics of interest; previous surveys of relevance; and existing evidence and theory relating to questionnaire design (Eysenbach 2004; Fink 2003; Fowler 1995; Gromshaw 2014; McColl et al. 2001; McColl and Thomas 2000). In addition, advice from supervisors and other relevant experts – such as Professor Paula Moynihan (Professor of Nutrition and Oral Health at Newcastle University) – was sought. The questionnaire then went through a process of testing and refinement. The first stage ('stage one') involved review by five lay individuals of a similar age to the study members – my two parents, two family friends and Katharine Kirton (the Senior Research Administrator who provided some administrative support for this study). Next, 'stage two' involved review by the two NTFS participants in the NTFS steering group. Finally, 'stage three' involved conducting a focus-group review with five members of 'Voice North', a well-established, large, local public engagement group set up by Newcastle University to provide public involvement in ageing research. A high response was received from Voice North members following an online advertisement targeted at individuals born between 1944 and 1950 (32 offers to take part). Therefore, to best reflect the characteristics and diversity of the NTFS cohort, six members were selected (one could not attend on the day), who were all born in the North-East of England and included both males and females and a range of education histories and previous occupation groups. The refined questionnaire following the latter focus group was subsequently reviewed again with two new and two previously involved lay individuals of a similar age to NTFS members ('stage four') – my two parents and two other family members.

At each of these stages of testing, a 'debriefing interview' process was used, whereby participants were allowed to complete the questionnaire independently and then were retrospectively questioned about this process. This debriefing process was thorough and involved discussing each section of the questionnaire in depth, probing a multitude of topics, such as: whether questions were clear and understandable; whether participants could remember the required information; the cognitive processes they used to retrieve information; the appropriateness and range of response categories available; and the layout and visual aspects of the questionnaire. This debriefing process evolved through stage one to stage four of the review process, to meet the needs of each review stage. Broadly speaking, the justification for a four-stage review process was to seek feedback from a diverse range of participants, but also to allow the questionnaire to be repeatedly re-evaluated as modifications were made.

Finally, at the data analysis stage, a number of tests of validity were conducted, where possible, including tests of construct validity and criterion validity. It is acknowledged that there was a limitation to what was achieved using the above post-hoc validity tests, particularly in relation to the tests of criterion validity, which were only possible for two measures (frequency of dental attendance and daily sugar consumption at age 50). Moreover, tests of reliability were not conducted. Ideally, each of the previously unvalidated measures included in this questionnaire should have undergone comprehensive reliability and validity testing (McColl et al. 2001). However, due to time and resource constraints within this PhD, and also due to my inexperience relating to questionnaire design in the earlier stages of this PhD, this was not always achieved.

The above processes of questionnaire design and testing are subsequently discussed in more detail in sub-sections 3.7.6 and 3.7.8.

3.7.6: Details of questionnaire design and testing

Questions relating to the frequency of tooth brushing were included in the age 69 dental questionnaire as a measure of oral hygiene, as plaque is the causative agent of caries and periodontal disease (the primary causes of tooth loss) (Selwitz et al. 2007; Turani et al. 2013) and tooth brushing the primary mode of plaque removal. It was acknowledged that tooth brushing frequency may not necessarily reflect effectiveness of plaque control but, in the absence of clinical assessments, this measure was the best alternative. Some evidence also supports the validity of this proxy measure of plaque control in epidemiological studies (Gil et al. 2015), and it has been widely used in national (Chadwick et al. 2011; Ministry of Health 2010) and longitudinal oral health studies (Broadbent et al. 2016; Peres et al. 2011a; Polk et al. 2014). Measurement of other oral hygiene measures was also considered, such as use of mouthwash or the fluoride content of oral hygiene products used, but these were excluded because mouthwash has only been commercially available over the latter few decades of participants' lives, whilst research (Martin et al. 2019) and anecdotal clinical experience suggests that awareness of fluoride content in toothpaste is low.

The response categories selected for this tooth brushing question were those used in the most recent UK Adult Dental Health Survey (ADHS) (O'Sullivan et al. 2011). Throughout all stages of testing, the wording and response options to this question were well received and no additional refinement was required. This question was asked retrospectively in relation to the ages of 15, 25, 35, 50 and 60, as these time points captured key stages across the life course without being excessive in number. Time points earlier than age 15 were not included – a study limitation – due to concerns of myself and supervisors, and supported by reviewers, about the ability to recall events prior to this age. It is acknowledged that no studies have previously tested the robustness of retrospective recall of tooth brushing frequency. During the questionnaire testing process, the majority of reviewers were confident in their abilities to recall tooth brushing behaviours at the included ages, although four out of the twelve reviewers (the two family friends and two NTFS steering group members) reported that they were not completely confident in their recall relating to the earlier included time points.

Frequency of attending the dentist for a check-up was utilised as a measure of dental attendance, because it is this aspect of dental attendance that is considered the most important determinant of oral health (Crocombe et al. 2012; Thomson et al. 2010). The validity of self-reported measures of dental attendance have also been demonstrated (Gilbert et al. 2002) and such measures have been widely used in previous national (ARCPOH 2019; Ministry of Health 2010; Morris et al. 2011) and longitudinal (Crocombe et al. 2012) studies. The question utilised in this study was based upon that used in the UK 2009 ADHS (O'Sullivan et al. 2011), but the response options were altered to remove the associated ambiguity. In the ADHS, such options included ‘regular check-up’, ‘occasional check-up’ and ‘only when having trouble’ (O'Sullivan et al. 2011), whereas options in the age 69 dental questionnaire included ‘at least once every year’, ‘at least once every two years’, ‘less frequently than every two years’ and ‘only when having trouble’. These time periods were selected to allow conformance with ‘National Institute for Health and Care Excellence’ guidelines to be distinguished, which advise that under eighteens and adults should attend at least yearly and two-yearly, respectively (NICE 2004). The question wording and response options were positively reviewed throughout the testing process and no refinement was necessary. The frequency of dental attendance was measured in relation to multiple ages across the life course, as for tooth brushing frequency. Again, no studies were identified which had previously tested the robustness of retrospective recall of dental attendance patterns. Throughout the testing process, reviewers were generally confident in their abilities to recall this information, apart from two of the twelve reviewers (the two family friends), who were reasonably, but not completely confident, in their recall relating to the earlier time points. Other life course studies have also relied upon such retrospective recall across similar time periods to this study (Holst and Schuller 2012; Listl et al. 2014).

Anxiety about visiting the dentist was measured using the Modified Dental Anxiety Scale (MDAS), a five-item questionnaire summed together to produce a Likert scale response, which was developed in the UK and first published in 1995 (Humphris et al. 1995). This measure of dental anxiety is intended for both clinical and research purposes (Humphris et al. 2009), is widely used (Dailey et al. 2001; Vainionpää et al. 2019; Wong et al. 2020; Zinke et al. 2018) and has been extensively validated for use in the UK, showing consistently high validity, reliability and discrimination properties (Humphris et al. 2009; Humphris et al. 2000; Humphris et al. 1995; Newton and Edwards 2005). Although concerns have been raised that the MDAS does not measure the multidimensional component of dental anxiety in full (Armfield 2010), it is considered superior to several other measures (Armfield 2010). The MDAS assessment was included in the age 69 dental questionnaire as a measure of *current* dental anxiety (Humphris et al. 2009), although the intention was to use this assessment as a proxy measure of dental anxiety over the latter years leading up to the age of 63 (the age at which the outcome of tooth loss was measured). However, it is acknowledged this is not without its limitations. In addition, in an attempt to measure dental anxiety earlier in the life course, a single question attempting to summarise the MDAS questionnaire was asked in relation to the ages of 15, 25, 35, 50 and 60: "How would you have felt if you needed to go the dentist for treatment?". It is acknowledged that this question itself as a single measure of dental anxiety is unvalidated and, in addition, that the validity of retrospective assessment of dental anxiety has not been previously explored. However, throughout the testing process applied to this age 69 dental questionnaire, views regarding the validity and perceived reliability of these retrospective questions were positive.

The dietary sugar consumption section included in this questionnaire was, by far, the most challenging to design, requiring repeated modifications. Only limited previous research has explored retrospective dietary recall relating to distant time periods and has generally involved the use of comprehensive food frequency questionnaires (Chavarro et al. 2009; Eysteinsdottir et al. 2011; Fraser et al. 1998; Friedenreich et al. 1992). Findings regarding the robustness of such retrospective measures are mixed, and the evidence suggests this generally decreases with more distant time periods (Friedenreich et al. 1992). Comparable to the age groups and recall periods being proposed in the present questionnaire, a study of Icelandic adults aged 56 to 72 years found that recall pertaining to 18 or 19 years earlier was reasonably acceptable for most but not all food groups, although the food groups tested did not include carbohydrates or sugary foods (Eysteinsdottir et al. 2011). Another study found that recall in US adults aged 49 to 76 years pertaining to adolescence was reasonable for some food groups, but not for overall diet or for carbohydrate groups (Chavarro et al. 2009).

Given the uncertain robustness of such comprehensive food-frequency questionnaires when applied to distant recall periods, the decision was made to devise a new and simpler assessment of past sugar intake, which would likely be less challenging to respondents' recall abilities. It was identified that the most desirable information related to the frequency rather than the amount of sugar consumption, as the former rather than the latter is most relevant to dental caries initiation and progression (Van Loveren 2019). In addition, with expert input from Professor Paula Moynihan (a Professor of Nutrition and Oral Health at Newcastle University), it was supposed that asking respondents to align themselves with examples of daily dietary patterns (a 'scenario-based' question) would be more robust than asking them to recall their exact daily frequency of sugar consumption (a 'direct' question). These factors led to the development of an initial scenario-based question (Appendix H), requiring respondents to identify the daily sugar consumption pattern most similar to their own (at the ages of 15, 25, 35, 50 and 62) from three given examples.

This initial question was subsequently modified after stage one and two testing. The modifications to the scenario-based question firstly involved restructuring the verbose dietary examples into simple lists of times when sugary intakes occurred (Appendix I). This was in response to feedback at stage one testing that there was too much information to assimilate and that discrimination between the examples was influenced by the types of foods included, as well as the frequency of sugary intakes. Secondly, food and drink examples were re-introduced to these simplified lists (Appendix J), in response to stage two feedback that this helped clarify the sort of products considered 'sugary'.

Alongside the scenario-based question, a direct question was also trialled at stage two and stage three testing, following responses at stage one testing that a direct question might be preferable. This question was newly devised in the absence of any pre-existing previously validated question, but was based upon simplified assessments of current sugar consumption frequency used in other surveys (Kumar et al. 2017), including the most recent UK Adult and Child Dental Health Surveys (Anderson et al. 2015). The key difference between this newly devised question and previous examples was that, whilst others sought the frequency of consumption of individual products, such as cakes, sweets, biscuits and soft drinks, this question sought a single assessment of the daily frequency of sugar consumption in general, the intention being to provide a more useful measure of the overall frequency of sugar intake. At stage two and three testing, this direct question was unanimously preferred over the scenario-based question. This was primarily because respondents often could not relate to the scenarios provided if the particular times of day and particular sugary products cited did not match their own experiences. Therefore, this direct question, rather than the scenario-based question, was ultimately included in the final questionnaire (Appendix H). The only modification made to this direct question throughout the testing process was the addition of an example of question completion, using the fictional case of 'Mr Smith', which was added following feedback at stage three testing.

Nevertheless, at each stage of review, there consistently remained some uncertainty regarding abilities to recall the required information, certainly more than for other questions. Most reviewers were reasonably confident in their abilities, but one NTFS participant and one Voice North participant expressed moderate uncertainty about their recall relating to the earlier time points, whilst one Voice North participant expressed significant uncertainty.

The influence of parents and spouses/partners on oral health was assessed by two newly devised questions, which asked respondents to rate the influence of the former in childhood, and the latter in adulthood, on how they had looked after their teeth. A review of the literature found multiple pre-existing surveys designed to measure parenting styles (Olivari et al. 2013; Parker et al. 1979; Schaefer 1965; Touliatos et al. 2001) and various aspects of marriage and couple relationships (Child Trends 2003; Reynolds et al. 2014), some of which had been used in previous research exploring the determinants of oral health (Dabawala et al. 2017; Kumar et al. 2017). However, none of these directly measured the concept of interest in this research – the influence of such family members specifically on OHBs – hence, the decision to generate a new measure. This newly devised measure was positively reviewed at each testing stage, including testing of face and content validity, perceptions of information recall and reliability, the language used, and the appropriateness and discrimination of response categories. Hence, no modifications were made throughout testing. However, it is acknowledged that the above does not constitute a comprehensive assessment of the psychometric properties of this measure (McColl et al. 2001) and that, on reflection, this could have been improved by including additional processes, such as test-retest procedures and tests of internal consistency. Moreover, the potential for recall bias is a particular concern, such that memories may be vague or biased by more recent circumstances, although research suggests that simple information regarding parental factors in childhood is accurately recalled across all stages of adulthood (Berney and Blane 1997; Krieger et al. 1998).

Finally, marital history information was updated, by asking respondents to provide dates for any changes in marital status between 1996 and 2002. This was the period between the age 50 follow-up (at which marital information was already obtained (Table 16)) and the age at which the tooth retention outcome was measured (age 63). This question was positively reviewed throughout testing, and only minor changes to the question wording were made in response to feedback. Previous research suggests that retrospective recall of dates of marital status change is very accurate (Mitchell 2010).

More generally, in accordance with established guidance (McColl et al. 2001), the aim throughout the questionnaire was to be as concise as possible, to use non-leading and non-technical language and to keep phrasing and grammar simple and straightforward. The order of questioning was considered, aiming for a logical sequence to topic ordering, whilst avoiding the positioning of more complicated questions (e.g. the diet question), or more sensitive questions (e.g. the dental anxiety questions), towards the beginning of the questionnaire. Layout and visuals were also considered, such as selecting a sufficient text size, using headings and colour coding to lead respondents through the questionnaire, and achieving a clear, consistent and non-cluttered appearance. Such aspects were positively reviewed throughout testing and only minimal changes were necessary.

3.7.7: Questionnaire distribution and response rates

The diagram in Figure 7 illustrates the selection of the sample for distribution of this age 69 dental questionnaire. The intended sample was the NTFS study participants who attended for the dental examination at age 63 (n=343) – at which the outcome variable of tooth retention was measured – but who had also completed both the age 50 and age 63 Health and Lifestyle questionnaires – via which much of the relevant potential predictor information had been collected. This resulted in a distribution sample of 296 participants. Of these intended recipients, five had been notified to the study team as deceased, whilst three had been recorded as no longer living at the address on file. Hence, questionnaires were distributed to the remaining 288 individuals. All of these individuals lived in the UK, apart from six individuals, one each of whom lived in Mallorca and South Africa and two each of whom lived in Spain and Canada.

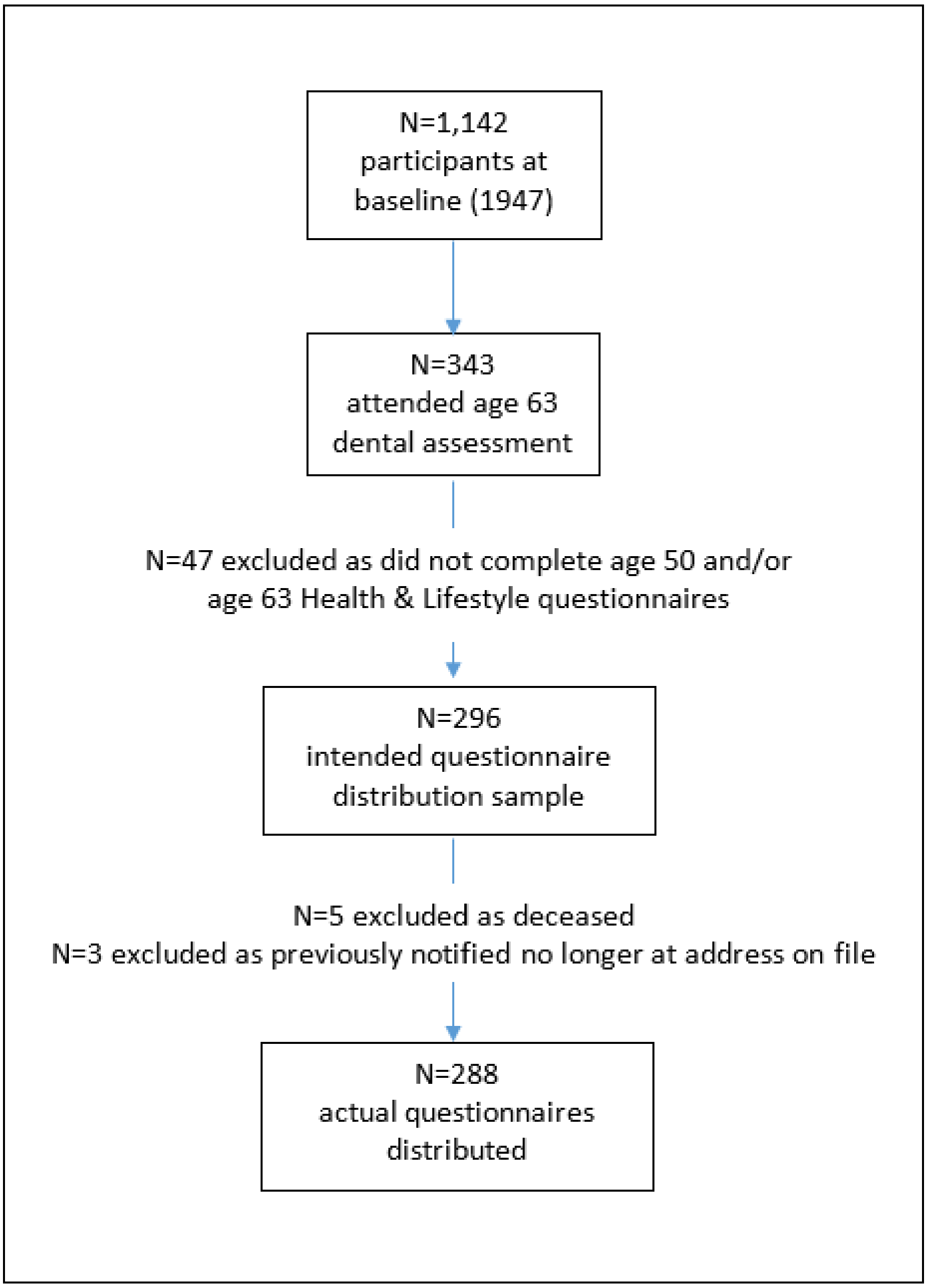

Figure 7: Flowchart showing the process of sample selection for distribution of the age 69 dental questionnaire.

The initial method of questionnaire distribution was via postal delivery (utilising self-addressed and stamped return envelopes), in line with previous practice in the NTFS – e-mail addresses are not routinely available for all study participants. However, for one UK individual, who only had an active e-mail address but no postal address available, and for two overseas participants, who had e-mail addresses available, electronic questionnaires were initially distributed via e-mail. The paper questionnaire, initially created using Adobe Acrobat DC® software, was easily converted to an electronic format by adding self-completion tick and text boxes. Participants needed a version of Adobe Reader® to complete the questionnaire and returned their responses via e-mail. Consideration was given to creating an online version of the questionnaire, using programmes such as Survey Monkey® or Newcastle University's 'Form Builder' software, but this would have involved significantly changing the layout and formatting compared to the paper questionnaire, so the former electronic Adobe option was preferred. The technological process of downloading the appropriate software (if necessary) and electronically completing the questionnaire was thoroughly tested with three of the lay individuals and two of the NTFS participants previously involved in the questionnaire testing process.

The response after this initial distribution wave was 81.3% (234 out of 288). Six weeks after initial distribution, non-respondents were sent a further questionnaire via post and via email (if a working address was available, which it was for 23 out of the 54 non-responders). This second wave of follow-up achieved a further 6.6% response (19 out of 288). After a further three weeks, non-respondents were contacted by telephone, if a working contact number was available (which it was for 15 out of the remaining 35 non-responders). Of these fifteen individuals, contact was made with thirteen individuals. Eight of these ultimately returned a completed questionnaire either via post or e-mail.

Overall, 261 (90.6%) questionnaires were returned (4 online and 257 by post), one notification was received of a participant death and 26 questionnaires (9.0%) were unreturned. Questionnaires were all distributed and returned between August and November 2016, when participants were age 69. This excellent response rate was expected due to the known high compliance rate within the targeted sample. However, this response was also maximised (from an initial rate of 81% to a final rate of 91%) by a comprehensive follow-up process. Such high survey response rates of long-term responders within the NTFS study have been previously demonstrated in other research (Mann 2017).

Data input of the survey responses was completed by Katharine Kirton (Senior Research Administrator at Newcastle University) using Microsoft Excel®. I subsequently transferred this dataset to the STATA® programme (Version 13, StataCorp), which was used to perform the post-hoc assessments described below.

3.7.8: Post-hoc assessment of questionnaire psychometrics

The low prevalence of missing responses across the returned age 69 dental questionnaires, overall and relating to individual questions, was an encouraging sign that respondents felt able to recall the required information. Within the 261 returned questionnaires, the overall prevalence of missing responses was 2.95%, ranging from 0 to 5.36% across individual questions (a maximum of 14 out of 261 responses). Missing responses were highest (although still low) for the daily tooth brushing frequency and dental attendance frequency questions (consistently between 3.8% and 5.4%), slightly lower for the sugar consumption frequency questions (consistently between 2.7% and 3.8%), lower again for the dental anxiety questions (consistently between 0.8% and 2.3%) and very low for the parental and spousal influence questions (0.4% and 0% respectively). For all of the topics covered, there was no pattern to the prevalence of missing responses according to the age focus of the question, i.e. there was no increase in missing data for questions pertaining to earlier life compared to more recent adult life.

Although encouraging, this low prevalence of missing responses is not confirmatory evidence of respondents' abilities to reliably and accurately recall past events, however, as the desire to provide a complete response must be considered. Indeed, five participants included comments on their questionnaires relating to issues with recall (Table 17), supporting such concerns. These pertained to a variety of topics and predominantly, but not exclusively, to earlier life.

Question topic	**Comment**
Age 15 tooth brushing	Before, or at age 15, not sure how often I brushed my teeth. My memory of my early years is vague.
Age 15 dental attendance	Not sure.
Age 15, 25 and 35 sugar consumption	A guess, can barely remember.
Age 15 sugar consumption	Can't remember.
General comment	Having looked at your questions, I'm afraid I could not answer them at the ages you are asking! I would just be putting anything down so I would not be a true questionnaire.

Table 17: Respondent comments on returned age 69 dental questionnaires, relating to issues with memory recall.

Results analysis provided an opportunity to further assess the criterion validity of the age 50 measures of dental attendance and sugar consumption, as related measures had previously been obtained prospectively at the original age 50 follow-up (Table 16). The Spearman's rank correlation coefficient (the appropriate non-parametric test to assess the association between an ordinal and continuous variable) between the frequency of daily sugar consumption at age 50 (as recorded retrospectively in the age 69 dental questionnaire) and the average daily total sugar intake at age 50 (calculated contemporaneously from the European Prospective Investigation into Cancer and Nutrition-Norfolk Food Frequency Questionnaire (EPIC-Norfolk FFQ) at the original age 50 follow-up) was statistically significant but weak (ρ=0.1623, p=0.0106, n=247). The coefficient between the equivalent measures at age 63 was also weak but non-significant (ρ=0.1148, p=0.0695, n=251). Although these relationships would not be expected to demonstrate perfect correlations, as the involved variables measure different aspects of daily sugar consumption (frequency and amount), such weak or non-existent relationships are concerning given evidence of strong correlations between the amount and frequency of sugar intake in the literature (Bernabé et al. 2016; Moynihan et al. 2018).

Correspondence between the frequency of age 50 dental attendance recorded contemporaneously at the age 50 follow-up, and retrospectively in the age 69 dental questionnaire, showed reasonable concordance (Table 18). However, this could only be assessed to a certain extent, as the different questions and response options in the former and the latter do not map directly to each other in a mutually exclusive manner. Of particular note: of the 121 individuals reporting regular check-ups in the contemporaneous age 50 assessment, the vast majority reported at least once yearly, or at least biennial, dental check-ups in the retrospective assessment; of the 25 individuals contemporaneously reporting occasional check-ups, 21 retrospectively recalled attending for dental check-ups at some level of frequency; however, of the 4 individuals contemporaneously reporting never visiting the dentist, all retrospectively reported attending for dental check-ups at some level of frequency.

		Contemporaneous age 50 questionnaire. “Do you see your dentist nowadays for…?”			
		Regular check-up	**Occasional check-up**	**Only when having trouble**	**Never see a dentist**
Retrospective dental questionnaire. “How frequently did you attend the dentist for a check-up at age 50?”	**At least once per year**	112	17	10	3
	At least once every 2 years	4	2	1	0
	Less frequently than every 2 years	2	2	3	1
	Never/only when trouble	3	4	6	0

Table 18: Concordance in age 50 dental attendance responses between the retrospective age 69 dental questionnaire and the contemporaneous age 50 Health and Lifestyle questionnaire (n=170).

Finally, an assessment of construct validity was possible for the majority of the questionnaire measures, according to whether results between groups were as expected (McColl and Thomas 2000). Using the characteristic of gender as a suitable comparator, data from the decennial UK ADHS series since 1968 suggest that daily tooth brushing frequency, regularity of attendance for dental check-ups and dental anxiety have been consistently higher for females than males over the majority of the life course of the NTFS participants (Chadwick et al. 2011; Gray et al. 1970; Kelly et al. 2000; Morris et al. 2011; Nuttall et al. 2011a; Todd and Lader 1991; Todd and Walker 1980; Todd et al. 1982; Tsakos et al. 2015). National UK dietary surveys conducted over the last three decades have also consistently found sugar consumption to be lower in females (Bates et al. 2011; Roberts et al. 2018). Furthermore, literature in the general health field suggests that the influence of females on partners' health behaviours is generally more positive than the influence of males, as a result of better health behaviours in women and greater tendencies to coerce the behaviours of others (Norcross et al. 1996; Umberson 1992; Umberson et al. 2018). Encouragingly, the questionnaire data replicates all of the above expected trends (Appendix K).

3.7.9: Final potential predictors

The final potential predictor variables included in the life course path analysis of the determinants of tooth loss are illustrated in Figure 8 (which also represents their point of occurrence across the life course). This final list of variables was selected based upon a joint evaluation of the relevant data available in the pre-existing NTFS dataset (see sub-section 3.7.4) and the robustness of the new data collected in the age 69 dental questionnaire (discussed in sub-sections 3.7.6 and 3.7.8) plus considerations of sample size requirements in path analysis. This section reports upon these final decisions and also documents the specific details of each final potential predictor variable.

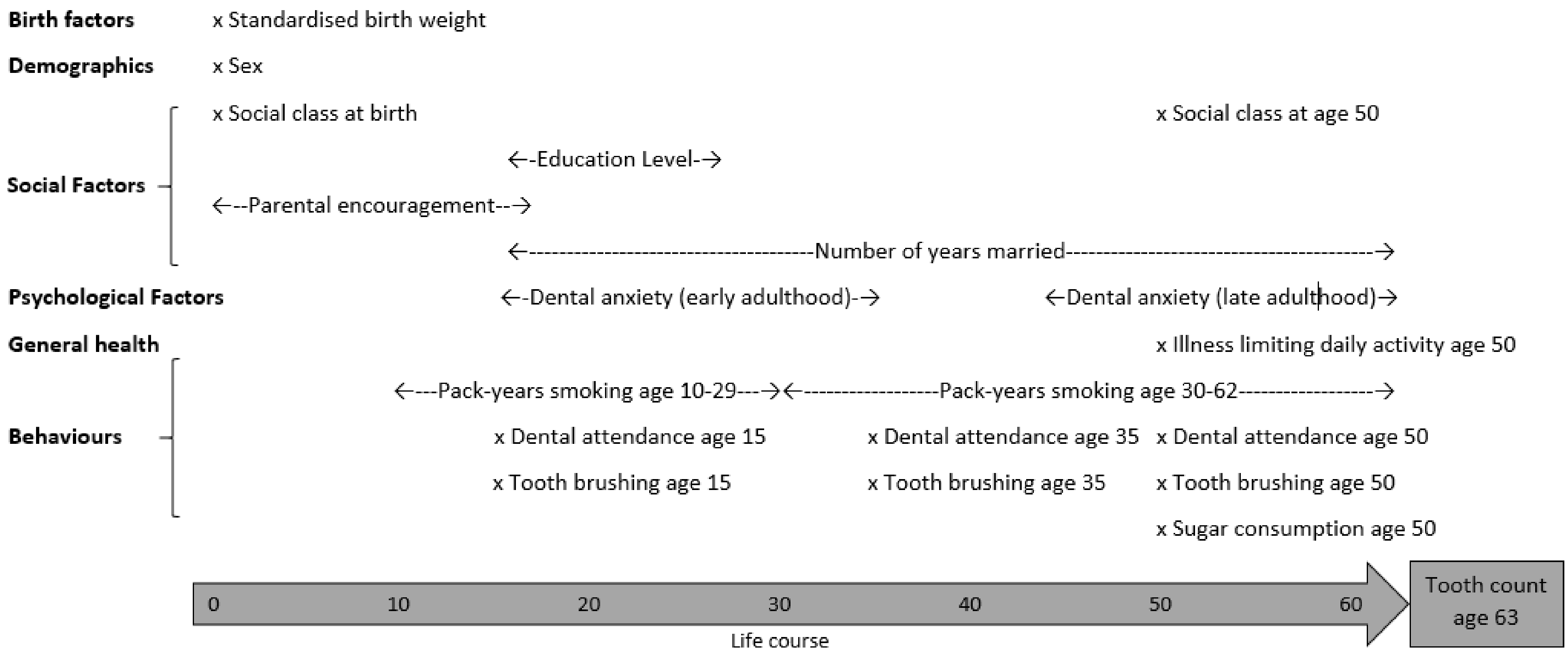

Figure 8: Diagram of the final predictor variables included in the quantitative path analysis.
Variables are positioned at the approximate point (or period) of occurrence across the life course.

An important consideration in the production of the final list of potential predictor variables was the sample size requirements of the path analysis technique. An a priori calculation of the maximum number of predictor variables that could be included in the path model building process was not possible. This is because sample size requirements in path analysis are based upon the number of parameters to be estimated, which is the sum of the number of variables in a model (whose error variances must be estimated) and the number of paths specified in the model (Garson 2015). When constructing a path diagram via an iterative process of model building and model trimming (described in sub-section 3.7.13), this number of parameters to be estimated is unknown at the outset. Therefore, the aim was to include all relevant predictor information in as concise a number of variables as possible, and to check sample size requirements were met upon completion of model building. As a general guide, research suggests that, when using maximum likelihood estimation (as in this research – discussed further in sub-section 3.7.13), the sample size should be at least five times the number of parameters to be estimated, if data distributions are normal, but at least ten times larger for more arbitrary distributions (Bentler and Chou 1987; Kline 2016). Exploratory attempts at path model building suggested that meeting such requirements was realistic.

Sex and standardised birth weight were included as final potential predictors. In addition to their potential relevance to an analysis of tooth loss (see sub-section 3.7.4), there were no concerns about the robustness of these variables, having been constructed from data obtained prospectively from midwives' reports (Table 16). These variables were used in their original binary and continuous forms, respectively.

Variables reflecting both social class and education level were included, as these characteristics reflect different socio-economic elements and may influence oral health outcomes in different ways (Steele et al. 2014). Specifically, two social class variables (at birth and at age 50) were included to provide information about social class across the life course, without including an excessive number of variables. The social class measures were likely robust as these were based upon a widely used and validated measure of social class (the Registrar General's Social Classification, renamed Social Class based on Occupation in 1990 (OPCS 1990)), derived from prospective self-reported information (Table 16). The education level variable, based upon self-reported, highest level of educational attainment at age 50 (Table 16), was also assumed to be reasonably robust (although no evidence could be identified to refute or support this). Both social class and education level variables were condensed to binary variables (as for all other categorical predictors), in an attempt to reduce the number of parameters to be estimated and, therefore, better satisfy sample size requirements. The risk of losing detail in this process was acknowledged but was balanced against the sample size requirements. Education level responses were collapsed into 'below A-levels' and 'A-Levels or above', primarily based upon generating similar group sizes. Similarly, the social class responses were collapsed into 'unskilled/partly skilled' and 'skilled/managerial and technical/professional' groups.

The total number of years married (or in a civil partnership), utilised as a continuous variable, was selected as the best measure of marital status, as it provided a longitudinal measure reflecting the whole life course. As previously discussed, although the information used to derive this variable was self-reported retrospectively at ages 50 and 69, the robustness of such reporting in relation to marital changes is supported by previous research (Mitchell 2010). The measure of spousal/partner influence on adult OHBs (obtained from the age 69 dental questionnaire) was not also included, given the need to restrict the number of predictor variables where possible and the less certain robustness of this subjective measure (sub-section 3.7.6).

Despite similar uncertainties about the robustness of the measure of parental encouragement to look after one's teeth in childhood (obtained from the age 69 dental questionnaire) (see sub-section 3.7.6), this measure was included as a final potential predictor variable. The rationale for this was the potential key importance of this information (see sub-section 3.7.4), support for the validity of this measure throughout the questionnaire testing process (where this was tested) and from previous research (sub-section 3.7.6), and the absence of an alternative more superior measure. This was condensed to a binary variable with the categories 'strong/moderate' and 'little/no' parental encouragement, governed by logic and the aim to producing categories of a similar size.

The total MDAS score, assessed in the age 69 dental questionnaire and ranging from 5 to 25, was included as a final potential predictor variable, as this measure had previously been extensively validated (see sub-section 3.7.6). In addition to this variable (used as a measure of dental anxiety in later adulthood), a second dental anxiety variable was also included, comprising the sum of the scored responses to the single dental anxiety question completed retrospectively for ages 15, 25 and 35 in the age 69 dental questionnaire (ranging from 3 to

15). Despite being a previously unvalidated variable, the robustness of this latter variable was deemed reasonable based upon the results of the questionnaire testing process (sub-section 3.7.6). This variable was constructed using data from the above three time points to provide a reflection of dental anxiety in earlier adulthood, quite distinct from the later adulthood dental anxiety variable, and without excessively increasing the number of variables included. Both dental anxiety variables were used as continuous variables.

From the extensive information relating to general health and disability already pre-existing in the NTFS dataset (Table 16), the predictor variable included in the path analysis – 'illness limiting daily activity at age 50' – was based on whether the participant answered 'yes' to both of the following questions in the age 50 Health and Lifestyle questionnaire: "Do you have any long-term illness, health problem or handicap?"; and "Does this limit your daily activities in any way?". The influence of general health on oral health is multi-dimensional, via both biological and behavioural pathways (Anders and Davis 2010; Dorfer et al. 2017; Lopez Silva et al. ; Wilson et al. 2019) and selecting measures of general health that would allow the breadth of this impact to be captured in one or a very small number of variables was challenging. The selected measure, although crude and unvalidated, provided this overall prospective measure of health and disability at age 50. This measure was, however, unfortunately unavailable from other time points. The World Health Organisation Disability Assessment Scale (WHODAS 2.0) (Üstün et al. 2010), measured in the age 63 Health and Lifestyle questionnaire, was considered as an additional potential variable, providing a validated and summary measure of health and disability (Üstün et al. 2010). However, the disadvantage of this measure was its assessment at the same age as the outcome variable, therefore violating assumptions of temporal causation.

Pack-years of cigarettes smoked was selected as a measure of smoking, a pack-year of cigarettes being equivalent to smoking twenty cigarettes per day for a year. This was selected as a widely used measure, reflecting both the duration and intensity of smoking histories (Leffondré et al. 2002; Mori et al. 2000; Thomson et al. 2007). Its limitation is that it does not take into account other forms of tobacco use, such as pipe, cigar or chewing tobacco use. However, given the comparatively very low use of these latter tobacco forms in the NTFS sample, compared to cigarettes, and the difficulties of equating these forms of tobacco use to cigarette usage, this limitation was accepted.

Concerns were acknowledged about the retrospective and self-reported nature of the smoking histories, which were collected in the age 50 and age 63 Health and Lifestyle questionnaires. However, a number of studies have explored the validity of self-reported smoking practices and, on the whole, suggest that self-reporting of numbers of cigarettes smoked is relatively accurate, although under-reporting is more often a problem than over-reporting (Blank et al. 2016; Connor Gorber et al. 2009). Furthermore, research exploring the psychometrics of retrospective smoking behaviour recall, including the long-term recall of the number of cigarettes smoked, has generally reported reasonable reliability and validity (Bernaards et al. 2001; Brigham et al. 2009; Brigham et al. 2010; Brigham et al. 2008).

Specifically, pack-years of smoking was divided into two time periods (age 10 to 29 and age 30 to 62), to allow comparisons between smoking in earlier compared to later life, without introducing an excessive number of variables. The threshold between the first and second time period was relatively arbitrary, although was selected according to reasoning that it delineated adolescence and earlier adulthood from perhaps more established adulthood. The lower limit of the first time period was the earliest age of smoking commencement reported by any of the participants. The method of calculating pack-years for these time periods was based upon extrapolating the average number of cigarettes smoked daily, provided in relation to ages 15, 25, 35 and 50, and taking into account start and quit dates of smoking provided. Hence, average daily smoking at age 15 was extrapolated between the age of smoking commencement and age 20, smoking at age 25 extrapolated between ages 20 and 30, smoking at age 35 extrapolated between ages 30 and 42.5 and smoking at age 50 extrapolated between ages 42.5 and 62 (or the point of quitting smoking if earlier).

The only variable included to represent sugar consumption – 'sugar consumption age 50' – represented the average daily total sugar intake (in grams) calculated from the EPIC-Norfolk FFQ (Bingham et al. 2001), which was included in the study's age 50 Health and Lifestyle Questionnaire. This FFQ explores the frequency of consumption of 130 different foods over the preceding year (Bingham et al. 2001). Average daily total sugar intake was calculated using the openly available FETA FFQ EPIC Tool for Analysis (Mulligan et al. 2014). This questionnaire and analysis tool have been widely used across the UK (Bingham et al. 2001; Groarke et al. 2019; Trichia et al. 2019) and subjected to extensive validation studies (Bingham et al. 2007; Bingham et al. 1997; Bingham et al. 2001; McKeown et al. 2001).

These studies support the reliability of the FFQ for sugar measurement, with test-retest correlations for sugar consumption ranging between 0.6 and 0.8 (Bingham et al. 2001; McKeown et al. 2001). Furthermore, although the validity of this questionnaire for measuring sugar intake could be better (Bingham et al. 1997; Bingham et al. 2001; McKeown et al. 2001) – for example, the correlation between sugar estimates according to this FFQ and weighed food records has been shown to be around 0.5 (Bingham et al. 1997) – its reasonable validity was considered acceptable for inclusion as a predictor variable in this research. To mitigate the impact of this suboptimal validity, this variable was made binary; the daily intake values across the full original dataset (n=541) were divided into two equal quantiles to determine an appropriate threshold (109.86g/day) for these two categories. It was accepted that this variable reflected the amount rather than frequency of sugar consumption, even though the latter is most relevant to dental caries initiation and progression (Van Loveren 2019), as evidence suggests these two measures are strongly correlated (Bernabé et al. 2016; Moynihan et al. 2018). Although the average amount of total daily sugar consumption was also measured at age 63 using the EPIC-Norfolk FFQ (Table 16), this data was not included as a potential predictor because its measurement at the same time point as the outcome would have violated the assumption of temporal causation.

The additional measures of daily sugar consumption frequency across the life course, obtained via the age 69 dental questionnaire, were ultimately not included as potential predictor variables. This decision was based primarily upon feedback throughout the questionnaire testing process, wherein confidence in recall abilities relating to the dietary questions was substantially lower than for other questions (sub-section 3.7.6). However, it was also influenced by the weak correlation between the age 50 measure of daily sugar consumption frequency, assessed retrospectively in the age 69 dental questionnaire, and the age 50 measure of total daily sugar consumption, assessed contemporaneously in the age 50 Health and Lifestyle questionnaire (sub-section 3.7.8). The absence of this life course information on sugar consumption was acknowledged as a significant limitation of this quantitative study. However, given the availability of the validated measure of sugar consumption at age 50 – measured contemporaneously via the EPIC-Norfolk FFQ – including the latter and excluding the former was selected as the most robust strategy.

The three dental attendance variables included as final potential predictors were derived from the information gathered in the age 69 dental questionnaire. This was because the questionnaire testing process and post-hoc validity assessments were reasonably supportive of the validity of these measures (sub-sections 3.7.6 and 3.7.8, respectively). Only three variables were included (relating to ages 15, 35 and 50), in an attempt to reflect dental attendance across the life course without utilising too many variables. Furthermore, these variables were made binary, with categories based upon current guidance around recall intervals from the 'National Institute for Health and Care Excellence' (NICE 2004): for age 15, categories were 'at least once per year' and 'less than once per year' based on the recommendation for under-eighteens to attend at least yearly check-ups (NICE 2004); for ages 35 and 50, categories were 'at least once every two years' and 'less than once every two years' based on the recommendation for adults to attend at least biennial check-ups (NICE 2004). Although these recall guidelines were only implemented in 2004 and, hence, did not exist for the NTFS cohort when they were 15, 35 or 50, these categories were utilised to improve the contemporary applicability of the study findings. Notably, the alternative measure of age 50 dental attendance, obtained contemporaneously at the age 50 clinical dental assessment (Table 16), was not utilised. This was due to the subjectivity of the response options available and, therefore, the dubious validity of this measure (as discussed in sub-section 3.7.6).

Lastly, the tooth brushing frequency information, obtained via the age 69 dental questionnaire, was utilised in the path analysis. As discussed (sub-sections 3.7.6 and 3.7.8, respectively), the questionnaire testing process and post-hoc construct validity assessment were reasonably supportive of the validity of these measures. Specifically, variables at only three time points (age 15, 35 and 50) were included, according to the same rationale as for the dental attendance variables. Responses were collapsed to binary categories – 'twice daily or more' and 'once daily or less' – as the recommended brushing frequency is twice daily (DoH 2017a).

Overall, the above collection of final potential predictor variables was considered a comprehensive list of variables, representing almost all areas of potential influence across the life course on age 63 tooth retention (within the constraints of being pragmatic about the number of variables included). However, undoubtedly, the lack of inclusion of sugar consumption information prior to the age of 50 was a significant limitation, as was the lack of definitive evidence regarding the robustness of several of the retrospectively collected variables – particularly relating to past dental attendance, tooth brushing habits, dental anxiety and parental encouragement. Such limitations are considered further in the Discussion chapter, in relation to the interpretation and application of the study's findings (sub-section 6.2.3).

3.7.10: Data preparation

Part of the data preparation required for variable construction had already been completed by the wider NTFS study team, where variables had been utilised in previous research. However, for several variables, additional data manipulation was required and conducted by myself. Specifically, production of the outcome variable (tooth retention at age 63) and two of the predictor variables – sex and standardised birth weight – required very little data manipulation. Most other predictor variables required only minimal data preparation, such as condensing responses to binary variables or producing summary scores. However, for three variables – the number of years married and the two smoking variables – more significant data preparation was required from raw data responses across multiple questionnaires (see sub-section 3.7.9). STATA® (Version 13, StataCorp) was utilised for all such data preparation.

3.7.11: Summary statistics

Summary statistics for all final potential predictor variables and the outcome variable were calculated. For categorical variables, numbers and proportions were produced. For normally distributed continuous variables, this involved means and standard deviations. For non-normally distributed continuous variables, medians and interquartile ranges were calculated.

3.7.12: Univariable and multivariable regression models

Univariable linear regression analyses were conducted between each predictor variable and the outcome, to observe univariate relationships. Multivariable regression analyses were subsequently conducted to assess the effect of each predictor variable on the outcome, independent of the effect of other predictor variables, and to determine an initial path model for model building. Two multivariable models were conducted: 1) a full analysis including all predictor variables, and 2) a reduced analysis including only the predictor variables demonstrating a significant association with the outcome in the first analysis (at the 5% level). As introduced in sub-section 3.7.2, the latter formed the starting point for the construction of the final path model.

The statistical programme STATA® (Version 13, StataCorp) was used for the production of all summary statistics and regression analyses.

3.7.13: Building a path model

As justified in sub-section 3.7.2, an iterative process of model building and model trimming was used to construct a final model of the life course determinants of tooth retention at age 63. This process of model building was based on both statistical indications and theoretical knowledge and justification (Garson 2014; Shipley 2016; Streiner 2005). SPSS AMOS® (Version 24, IBM) was utilised as a widely used and accessible SEM programme (El-Sheikh et al. 2017).

The detailed process of path model building utilised is shown in Figure 9. As is standard practice (Mann et al. 2013; Pearce et al. 2012; Tennant et al. 2008), the reduced multivariable regression model provided the basis for the initial path model. The model building process then proceeded using standard methods of model building and model trimming (Garson 2015; Kline 2016; Mann et al. 2013). Starting with the initial model, new paths were added based on modification indices (MI), which indicate the expected reduction in the model chi-square statistic should a new path be added to the model or should two variables be allowed to covary (Garson 2015). Only MIs of four or above were obtained, as the addition of paths or covariances associated with MIs below this threshold do not reduce model chi-square statistics by statistically significant amounts (Garson 2015). New paths were added in turn, starting with those associated with the greatest MIs first. The type of path (covariance or regression), and the direction of regression paths, were determined based on what was theoretically sound and justifiable. Alongside the above process, beta regression coefficients and associated p-values were continuously estimated for all model paths, and paths removed if the significance of their regression coefficients became greater than 0.05. The maximum likelihood estimation method was used, as this method is the default estimation method in path analysis (Kline 2016) and is recommended in AMOS when using only continuous and binary variables (Arbuckle 2016). In this method, estimates are those which maximise the likelihood that data was drawn from a population with these estimates (Kline 2016).

Once no new theoretically sound MIs were generated and all paths remained significant, a new predictor variable was added to the model. The above processes of adding theoretically sound paths, based on MIs, and removing non-significant paths, at the 5% level, then continued. If no modifications were suggested with the addition of a new variable, this variable was removed from the model. This process of introducing new variables, model building based on MIs and model trimming non-significant paths continued until all potential predictor variables had been considered in the model.

At the end of this model building process, any variables or paths without a route to the outcome (direct or indirect) were removed. Final robust significance values for regression coefficients were then estimated using bootstrapping procedures, based on 50,000 samples. Bootstrapping is recommended in path analysis to provide robust estimates of these parameters where data is not multivariate normal (Garson 2014; Shipley 2016). Following bootstrapping procedures, any direct paths which were no longer significant at the 5% level were subsequently removed from the model. The remaining final path model represented a robust model, which produced a specified covariance structure that best fit the data, but was also based on sound justifiable theory. This is the accepted goal of model trimming and model building in path analysis (Kline 2016).

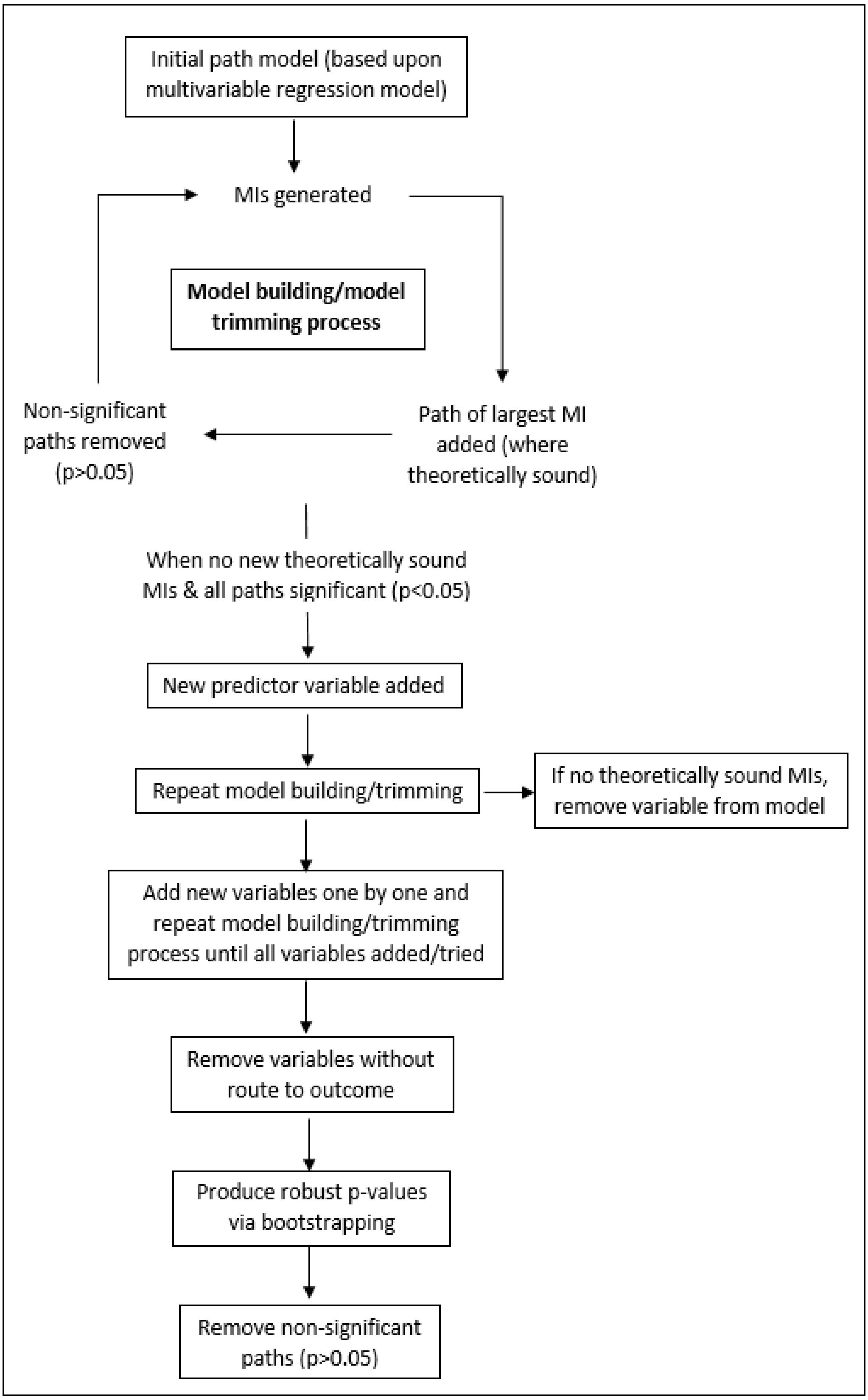

Figure 9: A step-by-step overview of the model building process used to produce a final path model of the life course determinants of tooth retention age 63.
MI (modification indices)

The actual path model building process involved 54 model iterations. These iterations and the rationale at each model building step are documented in Appendix L. Paths were only added to the model (based on MIs) if the theoretical rationale was clear; for example, the causal path from sex to pack-years of smoking between ages 10 and 29 (added at iteration 31) is supported by extensive evidence that males have demonstrated worse smoking behaviours in adolescence and young adulthood in the UK since prior to the inception of the NTFS cohort (Forey et al. 2016; ONS 2020a). Similarly, paths were not included (when suggested by MIs) when no clear rationale existed; for example, there is no plausible pathway via which a baby's sex would influence the social class of their household at birth or, conversely, the social class of a household would influence a baby's sex (suggested at iteration 38). Where uncertainty existed regarding the plausibility of a suggested relationship, the MI was monitored, rather than the path added initially. Such uncertainty was uncommon and, where present, associated MIs did not persist as the path model evolved. For example, a theoretical rationale was identified for the causal path between dental attendance at age 15 and pack-years of smoking between ages 10 and 29 (suggested at iteration 17), as evidence suggests smoking advice received at dental check-ups influences future smoking (Carr and Ebbert 2012). However, the applicability of this rationale to this particular circumstance was doubted given the temporal position of the dental attendance variable five years into the temporal period of the smoking variable and, moreover, given uncertainty about the existence of smoking advice by dentists in 1962 (Carr and Ebbert 2012). Negating the importance of these concerns, the associated MI did not persist as the model involved (Appendix L).

The order in which new variables are added to a path model does not change its final outcome, although it changes the iteration process required to reach this outcome. In order to reduce the number of iterations in this research, variables likely to be central to the model were prioritised, based on low p-values in the full multivariable regression model or exploratory analyses. Furthermore, variables were occasionally added in groups to the model where they were highly correlated (e.g. all three tooth brushing variables – iteration 22) to reduce the number of iterations required; the addition of such variables individually in exploratory analyses resulted in many paths being added and then subsequently removed upon addition of each subsequent variable. Based upon the same rationale, the addition of suggested paths was occasionally postponed in the final model building process until the addition of further variables. For example, paths between the three dental attendance and two dental anxiety variables were not added until all such five variables were included (see iteration 2, Appendix L).

3.7.14: Checking data assumptions

Two key assumptions made of the underlying data in path analysis are that data are multivariate normal and that low multicollinearity exists (Garson 2014; Shipley 2016).

Multivariate normality is an extension of univariate normality, in which the joint distribution of variables is normally distributed (Shipley 2016). It can be assessed by the Doornik-Hansen test (Doornik and Hansen 2008). This test was applied (using STATA®) to the predictor variables utilised in this path analysis, in two arrangements: 1) including all potential predictor variables of age 63 tooth count utilised in the path model building process, and 2) including only the predictor variables retained in the final path model (see Section 5.5). Both tests found significant evidence to reject the assumption of multivariate normality (Table 19). When data are not multivariate normal, this does not preclude the use of path analysis (Shipley 2016). However, non-normality can affect the significance values associated with regression coefficients and goodness-of-fit statistics. Therefore, it is recommended that robust significance values are estimated using bootstrapping procedures and robust goodness-of-fit statistics utilised (Shipley 2016). Hence, such methods were utilised as described further in the following two sub-sections.

Variables included	**Chi-squared statistic**	**p-value**
All potential predictor variables	5419.8	<0.001
Predictor variables in final path model only	2660.6	<0.001

Table 19: Assessment of multivariate normality of the predictor variables included in the path analysis, according to the Doornik-Hansen test (n=198).

Multicollinearity refers to the correlation between one or more predictor variables (Daoud 2017). As is standard practice (Daoud 2017), multicollinearity was assessed by examining bivariate Pearson’s correlation coefficients between all pairs of variables, and also by examining variance inflation factors for each variable (using STATA®). The former range from -1 to +1, with values of 0 indicating no correlation, and non-zero values indicating stronger correlation the closer they get to + 1 or -1. The latter measure how much the variance of a coefficient is ‘inflated’ because of linear dependence with other predictors (Daoud 2017). A value of 1 indicates that a variable is completely uncorrelated with other predictors (Daoud 2017), whilst various arbitrary thresholds have been proposed above which multicollinearity is considered an issue – commonly ten but as low as four (Belsley et al. 1980).

Bivariate Pearson’s correlation coefficients between all predictor variables included in the path model building process were relatively low. Where pairs of variables were more highly correlated (correlation coefficients greater than 0.5 or -0.5) (Table 20), these all involved repeated measures of the same behaviours at different time points, which were connected by direct effects during the model building process and in the final path model. Therefore, this does not violate the assumption of low multicollinearity. Variance inflation factors for all predictor variables also showed generally low to moderate multicollinearity, not sufficient to violate this assumption (Table 21).

Variable	Pearson’s correlation coefficient
Pack-years 10-29/Pack-years 30-62	0.749
Tooth brushing 15/Tooth brushing 35	0.548
Tooth brushing 35/Tooth brushing 50	0.765
Dental attendance 35/Dental attendance 50	0.520
Dental anxiety (early adulthood)/Dental anxiety (late adulthood)	0.530

Table 20: Pearson’s correlation coefficients between highly correlated predictor variables (coefficients > 0.5 or -0.5) included in the path analysis.

Variable	Variance inflation factor
Sex	1.49
Standardised birth weight	1.10
Social class birth	1.26
Social class 50	1.10
Education level	1.39
Pack-years 10-29	2.43
Pack-years 30-62	2.47
Illness limiting daily activity (age 50)	1.08
Dental anxiety (early adulthood)	1.67
Dental anxiety (late adulthood)	1.67
Dental attendance 15	1.71
Dental attendance 35	1.64
Dental attendance 50	1.56
Tooth brushing 15	1.76
Tooth brushing 35	3.06
Tooth brushing 50	2.58
Parental encouragement	1.36
Sugar consumption 50	1.11
Years married	1.08
Mean	**1.66**

Table 21: Variance inflation factors associated with predictor variables included in the path analysis.

3.7.15: Standardised estimates, total, direct and indirect effects

Based on the final path model, direct, indirect and total effects of predictor variables on the outcome were calculated. Direct effects represent the effects of predictor variables on the outcome, not mediated by other variables in the model, and are the beta regression coefficients associated with paths passing directly from predictor variables to the outcome (Garson 2014). Indirect effects represent the effects of predictor variables on the outcome, which are mediated through other variables, and are calculated by multiplying together regression coefficients along each indirect path and summing these indirect paths (Garson 2014). Total effects represent the overall effects of predictor variables on the outcome, via both direct and indirect pathways (Garson 2014).

To aid relative comparisons of effects across predictor variables, standardised as well as unstandardised effects were calculated. Unstandardised effects represent the unit change in the outcome variable given a one unit change in a predictor variable, whereas standardised effects represent the standard deviation change in the outcome variable given a one standard deviation change in the predictor variable (Lei and Wu 2007). In practice, unstandardised effects are difficult to compare between variables with differing units, hence the common use of standardisation to help eliminate these difficulties (Curtis et al. 2018a; Lei and Wu 2007; Mann et al. 2011). However, legitimate concerns exist about using standardised estimates to compare the relative sizes of causal effects, as their size can be misleadingly influenced by a variable's sample variance (Frone 2012; Greenland et al. 1991). For the above reasons, both standardised and unstandardised estimates were calculated in this research, to enable the advantages of each statistic to be utilised, whilst minimising their disadvantages.

Bootstrapped p-values and 95% confidence intervals (based upon 50,000 samples) were presented for all standardised and unstandardised direct, indirect and total effects, as recommended when data is not multivariate normal (see sub-section 3.7.14) (Garson 2014; Shipley 2016).

3.7.16: Checking model fit

The fit of the final path model was primarily assessed using the following goodness-of-fit measures: model chi-squared statistics, their associated p-values, and normed chi square values.

The chi-squared statistic is recommended as the primary goodness-of-fit statistic for path analysis and measures the difference between the covariance matrix using observed data and the covariance matrix predicted by the model (Kline 2016; Shipley 2016). Significance testing of this statistic assesses the probability of observing this difference if the model truly reflects the population parameters, taking into account random sampling variation. Therefore, a p-value above 0.05 suggests that there is no evidence, at the 5% level, to reject a model and the concept that the data are consistent with it (Kline 2016; Shipley 2016).

The chi-squared statistic and its associated p-value are sensitive to sample size, with small samples more likely to result in spuriously low and statistically non-significant chi-squared statistics, and large samples more likely to result in spuriously high and statistically significant chi-squared statistics (Garson 2015; Shipley 2016). Although evidence generally suggests that samples around the size used in this study will not spuriously affect chi-squared p-values (Kline 2016), normed chi-squared values are also reported in this research. These are the ratio of the model chi-squared statistic to the degrees of freedom in the model, and are less sensitive to sample size (Hooper et al. 2008). There is no universally agreed consensus regarding normed chi-squared thresholds below which model fit is deemed acceptable, but thresholds as high as five and as low as two have been recommended (Hooper et al. 2008).

Model chi-squared statistics and their associated p-values and, consequently, normed chi square values are also sensitive to multivariate non-normality (Kline 2016; Shipley 2016; Walker and Smith 2017). Hence, both unadjusted and robust versions were produced where possible. Robust model chi-squared p-values were produced using modified bootstrapping procedures, according to the Bollen-Stine bootstrap method (Bollen and Stine 1992). Robust model chi-squared statistics were produced by applying robust Bollen-Stine chi-squared p-values to an inverse chi-square distribution function (Walker and Smith 2017).

Further goodness-of-fit indices, known as approximate fit indices were also produced, including the Root Mean Square Error of Approximation (RMSEA) and Comparative Fit Index (CFI). These are well established fit indices that assess model fit from different perspectives (Garson 2014; Kline 2016; Shipley 2016). However, they are used as supplemental fit statistics of secondary use to the chi-squared statistic, as they do not distinguish between sampling error and real covariance evidence against the model, being simple continuous measures of model-data correspondence (Kline 2016).

The CFI measures how much the proposed model reduces the degree of misspecification relative to a baseline model (Shipley 2016). The closer the CFI gets to 1, the better the model fit (Shipley 2016). Although thresholds are arbitrary, statistics above 0.95 have often been considered indicators of good fit, and values over 0.9 indicators of adequate fit (Garson 2015).

The RMSEA evaluates discrepancies between model covariance matrices and observed covariance matrices (Garson 2014). The closer the value to 0, the lower the discrepancy and the better the model fit. Although thresholds are arbitrary, values below 0.05 or 0.06 have generally been considered indicative of good model fit, whilst values below 0.08 have been suggested to represent adequate model fit (Garson 2015).

As both the CFI and RMSEA are also sensitive to multivariate non-normality, values based on both unadjusted chi-squared statistics, but also robust chi-squared statistics, were produced – the latter involved substituting robust chi-squared statistics into the formulas for the approximate fit indices using methods presented by Walker and Smith (2017).

Finally, R-squared values for final path models are presented, which indicate the proportion of the variance in age 63 tooth count explained by the variables in the models.

3.7.17: Sample sizes and missing data

Figure 10 provides an overview of the sample sizes involved in the life course path analysis. 261 NTFS participants were considered for inclusion as they had completed the age 69 dental questionnaire, previously attended the age 63 dental examination and returned both the age 50 and age 63 Health and Lifestyle questionnaires – therefore, they had completed all stages of data collection necessary for measurement of the outcome and all selected predictor variables. Two of these individuals were excluded, due to missing age 63 tooth count data (despite attendance at the examination), and a further fourteen excluded because they were edentate at the age 63 dental examination. This left a final eligible sample for the life course path analysis of n=245.

As 47 of these 245 individuals had missing data for at least one of the potential predictor variables, however, the process of path model building (and the preceding multivariable regression analyses) were conducted using a reduced sample of n=198, as the AMOS software does not allow calculation of modification indices in the presence of missing data (Arbuckle 2016). The final path model derived from this reduced sample was subsequently tested on the full sample of 245 participants using full-information maximum likelihood (FIML) estimation, which allows for missing data (Garson 2015). As AMOS does not permit bootstrapping or the calculation of robust model chi-squared p-values in the case of missing data (Arbuckle 2016), the final path model was also tested on the sample of 223 participants, who had complete data at least for all of the predictor variables included in the model (Figure 10).

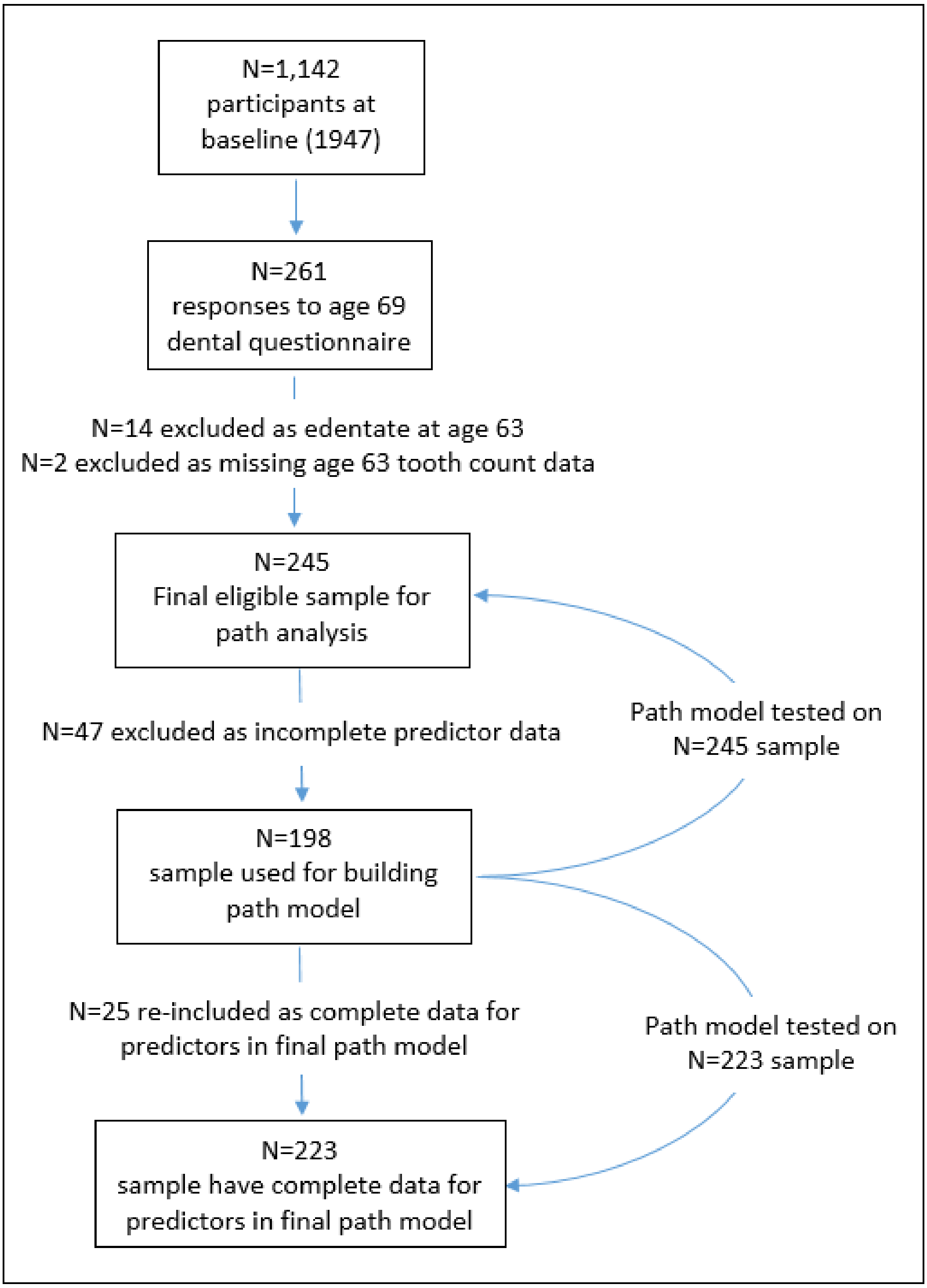

Figure 10: Flowchart of the process of sample selection for the path analyses.

The exclusion of individuals who were edentate at age 63 was undertaken so as not to violate the temporal assumption that the predictor variables preceded the outcome. For example, if a participant became edentate at age 25, the predictor variables occurring after this time could not have further influenced the tooth retention outcome. Including such edentate individuals would have overestimated the effects of predictors occurring after the event of edentulism. The exclusion of such edentate individuals, however, had its disadvantages. Most importantly, this limits the findings of the path analysis to groups remaining dentate at age 63 and, if generalised to groups experiencing edentulism prior to age 63, the effects of predictors preceding and succeeding the outcome of edentulism will likely be underestimated and overestimated, respectively. Despite much consideration, however, including expert statistical advice from Professor Stephen Rushton (Professor of Biological Modelling at Newcastle University), this latter limitation was deemed unavoidable. The only other option would have been to null the effect of variables occurring after the age of edentulism by designating these variables as missing for those individuals. However, as discussed, the AMOS software does not allow the calculation of modification indices, robust model chi-squared p-values or the process of bootstrapping in the presence of missing data (Arbuckle 2016), hence, such a solution was not practicable. Fortunately, the prevalence of edentulism by the seventh decade is reducing over time, and is likely to be very low for future generations (Steele et al. 2012), reducing the importance of this limitation in applying these study findings going forward.

The building of the path model on the reduced sample with complete data (n=198), rather than the full eligible sample (n=245), was a further limitation of this research, due to the potential for sample bias due to missing data. Exploring these concerns (Appendix M), there were no significant differences (at the 5% level) for any of the variables between the complete sample of 198 individuals and the 47 individuals with missing data. However, crude comparison of means, medians and proportions revealed obvious differences for many variables, in particular, significant differences at the 10% level for standardised birth weight, education level, social class at birth, social class at age 50, age 63 tooth count and parental encouragement. Those in the sample of 198 generally fared better for all of these latter variables, suggesting the sample was biased towards these more fortunate groups. For this reason, testing of the final path model on the larger samples (n=245 and 223) was paramount, to explore and mitigate the effects of missing data.

Of note, the FIML estimation method utilised with the full eligible sample (n=245) involved using all available data to estimate the model, as opposed to replacing or imputing missing data, and has been shown to produce unbiased results when data are missing at random (MAR) (Garson 2015). Such an assumption was made in this study; although there appeared to be a pattern to which cases had missing data (violating the assumption of 'missing completely at random' (MCAR)), it was assumed that there was no relationship between the values of missing and non-missing data – an assumption which seemed reasonable although not possible to prove. Reassuringly, the prevalence of missing data in this sample of n=245 was low, at 1.9% overall and a maximum of 4.9% per variable (Table 22).

Variable	Missing (n)	Missing (%)
Sex	0	0
Standardised birth weight	0	0
Social class birth	4	1.6
Social class 50	4	1.6
Education level	7	2.9
Pack-years 10-29	0	0
Pack-years 30-62	3	1.2
Illness limiting daily activity (age 50)	3	1.2
Dental anxiety (early adulthood)	3	1.2
Dental anxiety (late adulthood)	3	1.2
Dental attendance 15	8	3.3
Dental attendance 35	9	3.7
Dental attendance 50	6	2.4
Tooth brushing 15	10	4.1
Tooth brushing 35	11	4.5
Tooth brushing 50	12	4.9
Parental encouragement	1	0.4
Sugar consumption 50	3	1.2
Years married	12	4.9
Tooth count age 63	0	0

Table 22: The frequency of missing data, by variable, for the final eligible sample for the path analysis (n=245).

In retrospect, methods of imputing missing data could have been utilised prior to path model building, specifically multiple imputation methods, which are now generally considered the gold-standard of imputation (Cummings 2013; Dong and Peng 2013). Such methods take into account the uncertainty in the values of missing data by imputing multiple plausible values of missing data from existing variables, conducting multiple analyses using each possible missing data value and then combining these analyses to produce a final result (Cummings 2013; Dong and Peng 2013). Such methods were not utilised in this PhD due to time constraints – incorporating such unfamiliar methods into an already very complex statistical process would have been unmanageable in this already multi-component mixed-methods project. However, I acknowledge this may be desirable in future research utilising this dataset.

4: Qualitative Results

The overarching aim of the qualitative component of this research was to explore in depth the factors across the life course influencing how and why UK individuals looked after their oral health. This was achieved via in-depth interviews with twenty members of the NTFS study at the age of 67.

This chapter presents the findings of these interviews, identified by a process of thematic analysis. As depicted in Figure 5 (Page 93), four major themes were identified, the focus of which were: 1) the multiple sources of influence of OHBs, 2) variation in influences between different OHBs, 3) how influences changed across the life course, and 4) sufficiency and competition between influencing factors. This chapter is structured around these four major themes.

For context, the names and numbers following quotes (e.g. Donald, 28/20) refer to the pseudonym names of the interviewees and their number of retained teeth at the age 50 and 63 NTFS dental examinations respectively.

4.1: The multiple sources of influence of OHBs

In harmony with socio-ecological theories of human development (Bronfenbrenner 1979) and contemporary beliefs about the determinants of oral health (DoH 2005; Watt et al. 2015), the qualitative interviews revealed that the factors determining how and why people looked after their oral health were numerous and stemmed from multiple sources. Figure 11 illustrates the key factors identified and how they appeared to group around the following sources of influence: the dental profession, society, family members and the individual. As depicted, the interviews suggested that influencing factors were generally not independent of each other but were interconnected by multiple relationships. In particular, many factors directly related to the individual were themselves reportedly influenced by factors related to society, the dental profession and family members (as represented by solid arrows). Additional relationships (suggested by dotted lines) also almost certainly existed between the latter three sources of influence, as speculated by the interviewees and supported by previous evidence (Bronfenbrenner 1979; Watt et al. 2015). However, being based upon interviewees' speculation (i.e. the influence of the dental profession on interviewees' family members), these were not the focus of this qualitative study.

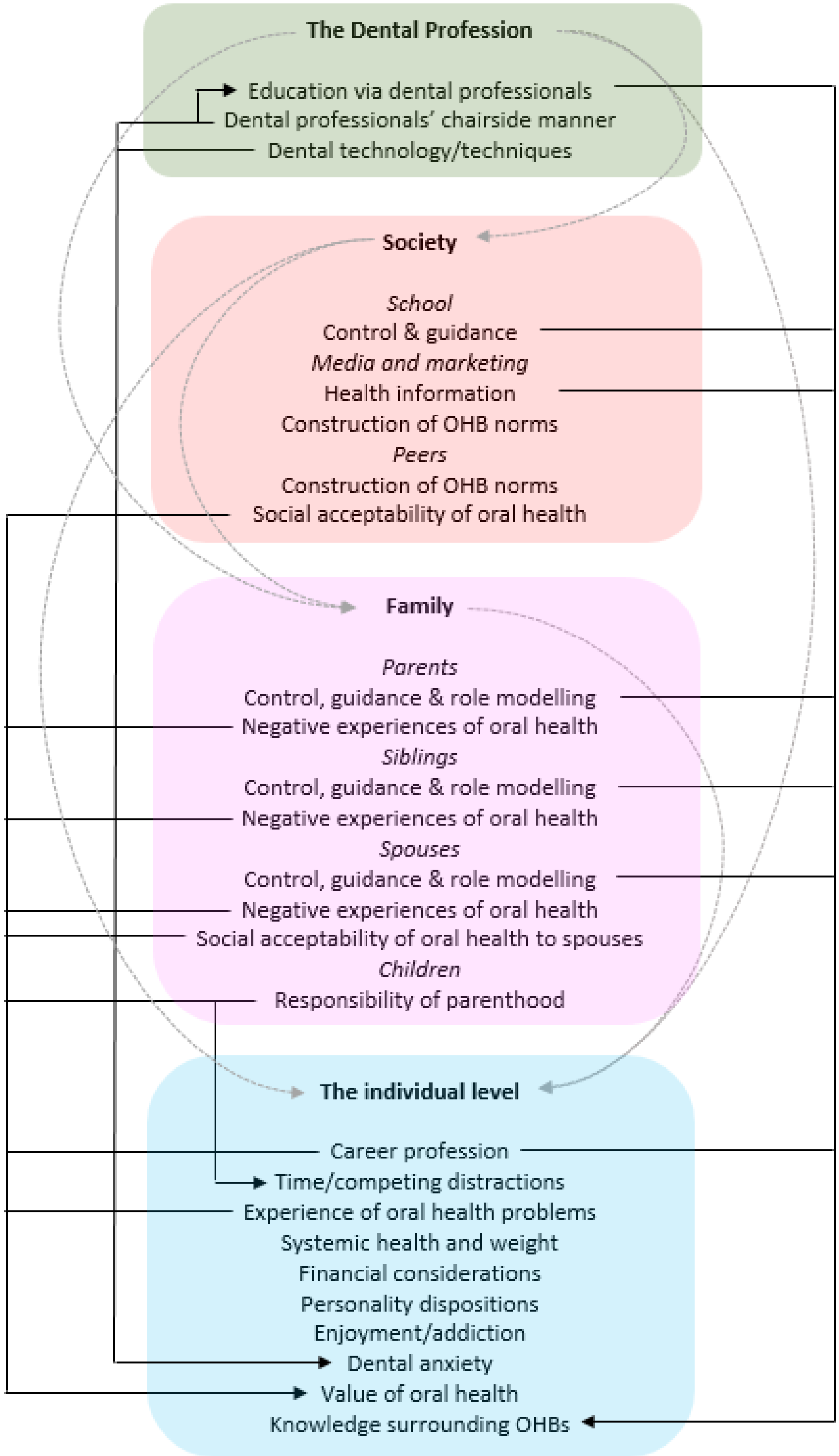

Figure 11: The key factors determining how and why individuals looked after their oral health, according to the qualitative interviews.
NB: Solid lines represent reported relationships between specific influencing factors, where these could be reasonably assessed by the interviewees themselves.
Dotted lines represent postulated broader relationships between the various sources of influence. These are based upon both the speculation of interviewees, but also upon previous knowledge and theory and reasonable assumption.

4.1.1: Influence of the dental profession

The recalled contribution of the dental profession was predominantly via two main pathways. Firstly, supporting previous evidence (Gibson et al. 2019; Jensen et al. 2011), many participants recalled their OHBs being shaped by oral health education provided by dental professionals:

> *"They used to tell you what to do with your teeth and how to clean them, and any dentist would say, you know, you must do this with your teeth and brush in between your teeth, so it's just been picked up over the space of time going to different dentists"* (Barbara, 21/18).

Secondly, dental anxiety was frequently reported as a barrier to dental attendance and, in accordance with previous research (Borreani et al. 2010; Gregory et al. 2012), such levels of dental anxiety were often attributed to previous experiences of dental visiting:

> *"I remember going to the dentist once…at about 10 or 11, something like that…and I remember going under, but I felt it. I remembered it and when I came out of it, my eyes were streaming. I mean really full tears and all that, and the pain was terrible…[Since then], I'd rather put up with toothache than go to the dentist"* (Bruce, 0/0).

Reflecting previous findings from both within dentistry (Borreani et al. 2010) and other fields of health care (Harmon et al. 2006; Roter 1983), the chairside manner of dental professionals was also identified as a particularly important factor in determining both the impact of their oral health education advice and their effect on patients' dental anxiety:

> *"He was very, very good at giving advice out, you know…With him, you just took it as good advice to act upon… I think establishing a relationship and a rapport and empathy with a dentist over a period of time is really, really good, and I think that's had a long-term impact upon me"* (Steve, 23/22).

> *"Once I got a dentist who was more approachable, understanding and empathetic…that changed [my fear of the dentist] quite a lot" (Patricia, 18/18).*

Furthermore, other research has shown that the sophistication of technology and techniques used within dentistry can be an important factor in the determination of dental anxiety (Borreani et al. 2010). This accords with the experiences of some in this study:

"*When I was younger…the needles that they used to use…were absolutely enormous…and they really hurt…I can remember the needle, it was that long, it was terrible…They come towards you with this big thing…and, oh my God"* (John, 14/11).

4.1.2: The influence of society

Sources within wider society, specifically schools, peers, media and marketing sources also emerged as influencers of individuals' behaviours. As documented in Figure 11, schools reportedly exerted their influence by controlling or guiding participants' OHBs. For example, as with Gibson's work (2019), some individuals attributed their behaviours to advice they had received at school, whilst some recalled attending dental check-ups at school:

> *"I can remember the dentist used to attend the school on, I would guess, a yearly basis…I can remember him coming and checking your teeth…They had a receptionist come nurse who did all the telling you how to do it and showing you how to clean your teeth"* (John, 14/11).

Peers (referring to one's social group within society) were also perceived to have influenced many individuals' behaviours, and this was primarily via two pathways. Firstly, participants recalled being influenced by the 'normal' OHB practices of their peers:

> *"When you were with your friends, if they brushed their teeth, you'd think that's the right thing to do, you know. [And I started smoking] because everybody else did"* (Barbara, 21/18).

Secondly, concerns about the social acceptability of one's oral health to peers emerged as a positive driver of OHBs:

> *"If I was ever going out, and I still do this now, you always clean your teeth. That is for your teeth and for your breath. When I had the children and I was taking the children anywhere, I would always nip to the bathroom and give my teeth a quick clean, and then you're ready to go, at least you know your breath's alright"* (Rose, 14/0).

Such findings accord with the importance of social norms recognised by both traditional (Ajzen 1991; Bandura 1986) and more contemporary (Cane et al. 2012) health behaviour theories. Furthermore, evidence from empirical research pertaining to both oral health-related behaviours (Hall-Scullin et al. 2015; Ostberg et al. 2002; Simons-Morton and Farhat

2010; Stead et al. 2011) and other behaviours (Ragelienė and Grønhøj 2020; Salvy et al. 2012) also confirms the central contribution of peers to health behaviour.

Lastly, aligning with the well-accepted role of the media in health (Institute of Medicine 2003; Seale 2003), media and marketing sources – including television, magazines, newspapers, billboards and the internet – were also accredited for determining how people looked after their oral health. This was in part because they contributed to views about 'normal' behaviour practices, but also because they were a source of health information:

> *"There's a greater awareness that has come along as to the impact on your health – general health but dental health as well – of your diet and smoking…I guess it's come from the media really, you know, because I would have a general interest in what was being broadcast in TV programmes, in newspapers, magazine articles and so on around these issues…That's how I educated myself about things"* (Malcolm, 30/27).

4.1.3: The influence of family members

The role of family members in shaping individuals' beliefs and behaviours was a central theme running through many interviews. As depicted in Figure 11, reports mainly focused around parents, spouses, children and siblings.

The influence of parents appeared to be central. In accordance with previous research (Case and Paxson 2002; Kettle et al. 2019; Stokes et al. 2006; Umberson et al. 2010), individuals talked about parents role modelling certain behaviours or actively controlling or guiding behaviours:

> *"I've always been taken to the dentist regularly…and I was always taught to clean my teeth…I mean that was instilled by my mother…I had really very, very good parents"* (Rose, 14/0).

Perhaps not surprisingly given traditional parenting roles (Parke and Tinsley 1987; Sigel et al. 1984), mothers generally appeared to have been much more influential than fathers in this role:

> *"My father…never bothered with us really. He was working down the shipyard. He must have been working six or seven days a week down there at the time…and he never had time to do anything with us…It was always my mum that sort of took me [to the dentist]"* (Keith, 25/25).

In addition to the above, participants also frequently mentioned the effects of witnessing their parents experience oral health problems:

> *"That's when I started trying to look after my teeth…dental treatment and make sure I clean them at least twice a day …I'll tell you why. My dad got all his teeth out and I noticed how he changed, you know. It changed his health. I says, 'well, I don't want to be like my dad'…I think I were 30. My dad loved his food, then all of a sudden it was like soup and that type of thing, you know, couldn't chew"* (Michael, 26/20).

The above pathways of influence were also described in relation to siblings and spouses. Like the predominant role of mothers, it was also particularly notable that wives seemingly imposed more control over their spouses' OHBs than husbands did. The account from Alan (27/27) below is one example of this common narrative around the role of wives:

> *"Getting married has been when the dental appointments started, because the wife would say 'got to go', you know…My wife all her life has been like a secretary right and, if you know anything about secretaries, they organise people, don't they? They make sure they're there. They make sure they do this, they do that…She's very organised to a painful degree…got the dentist lined up. She likes doing that and organising".*

Such spousal influence of health behaviours has been previously evidenced (Lewis and Butterfield 2007; Markey et al. 2008; Thomeer et al. 2019), and explorations of gender differences support the present study (Lewis et al. 2004; Umberson 1992; Umberson et al. 2018). In particular, disparities have been attributed to differing attitudes to health prevention, nurturing roles and responsibilities for living habits in the home between men and women (Umberson 1992; Umberson et al. 2018).

Beyond the above routes of influence, a further positive role of spouses also emerged. Similar to concerns discussed in relation to peers (Section 4.1.2), some interviewees were conscious of the social acceptability of their oral health to their spouse:

> *"I was having problems with my gums and they were getting all pussy...That's when I started to go pretty regular [to the dentist]…It was getting embarrassing because there was a smell…The wife would say sometimes 'oh I can smell your breath', you know"* (Jeremy, 23/15).

Finally, the responsibility associated with parenthood seemingly influenced participants' beliefs and behaviours in several ways. Firstly, individuals expressed a desire to perform good OHBs to set an example to their children:

> "*You want to lead by example so that your children can imitate what you've learned over your lifetime, so they don't make the same mistakes and replicate the things that you did. So that was the real reason I think why I re-engaged [with the dentist]… If dad's doing it, you should be doing it sort of thing"* (Steve, 23/22).

Secondly, interviewees described how it seemed more important to protect their own health once they entered parenthood, as they now had additional responsibilities to others:

> *"You get more responsibilities don't you, when you have children. You're not just the free agent yourself, so you've got to look after your health a bit more closely"* (Arthur, 0/0).

Thirdly, in some cases, parenthood was reported to have detrimentally affected interviewees' OHBs by placing excessive demands on their time:

> *"I was so busy bringing the children up, you never think about going to the dentist"* (Maureen, 28/27).

This supports other previous work which demonstrates the positive and negative implications of parenthood on various health behaviours (Delaney and McCarthy 2011; Schooling and Kuh 2002; Thomeer et al. 2019; Umberson et al. 2010).

4.1.4: Influences at the individual level

Lastly, multiple individual-level factors reportedly influenced how people looked after their oral health.

A particularly central determinant appeared to be one's level of knowledge surrounding oral health, such as the effects of different behaviours on oral health outcomes. Many accounts evidenced the positive impact of knowledge on their OHBs:

> *"If I'm having a drink, I'll have slimline tonic and stuff like that, slimline coke, diet coke. I never have anything full fat…or eat lots of sugar. I'm very careful with things like that because obviously the plaque will stick to your teeth and then disintegrate your teeth eventually"* (Pam, 23/21).

In contrast, the absence of accurate knowledge was frequently blamed for suboptimal OHBs:

> *"Well, I didn't realise a lot of things in them days. You're just a daft kid. Didn't realise you're supposed to clean your teeth morning and night"* (Michael, 26/20).

Similarly, interviewees reported valuing their oral health in many ways, particularly relating to functional matters, such as chewing or smiling, the avoidance of pain and discomfort and aesthetic concerns, and such value appeared to be crucial to people's behaviours:

> *"It's irrelevant how much we spend on our body. It's always the most important way to spend your money so that's the way I work through life…Dentistry has always been the focus…It [fear of the dentist] doesn't stop me [attending the dentist] cos I know how important it is and I know how it's got to be done"* (John, 14/11).

Notably, this importance of knowledge and the value of health in determining behaviours resonates with many traditional (Ajzen 1991; Bandura 1986; Fisher and Fisher 1992; Rosenstock 1974) and more contemporary (Cane et al. 2012; Michie et al. 2011) health behaviour theories.

Such levels of knowledge and the value placed on oral health were, in turn, reportedly determined by many other factors. In addition to the influence of the dental profession, family and societal sources (as already discussed in sub-sections 4.1.1 to 4.1.3), individual-level factors were also influential. In particular, individuals' previous experiences of oral health problems contributed to the value they placed on their oral health. Markedly, problems which had a tangible impact on the individual appeared to have the greatest influence, such as pain and discomfort, functional impacts and social impacts:

> *"It all came to a head when I was twenty-one…I was in discomfort because of the pain, which was becoming increasing difficult to live with…[and] the way it deprived you of confidence in a social sense, I think it was quite significant…Certainly I became aware it could not go on like this…I was aware of the consequences of neglect and it wasn't a pleasant place to be, and therefore the way to avoid it is to look after what you've got. I came to that conclusion very, very strongly"* (Malcolm, 30/27).

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Furthermore, factors such as one's career profession were cited as individual-level influencers of oral health knowledge or the value placed on oral health, where their profession exposed them to the topic of oral health:

> *"I picked up incidental knowledge through teaching…because there would be regular dental inspections and dental visits and what not, so teeth and general sort of oral health became a regular running feature throughout my life, through education really…seeing these people come into school and talk"* (Steve, 23/22).

A further key theme which emerged from the interviews was that systemic health concerns were central determinants of oral health-related behaviours, where such behaviours were also common risk factors for systemic health conditions (e.g. smoking and dietary behaviours). Such concerns were sometimes related quite broadly to the detrimental effects of such behaviours on general health, whereas, for others, like Maureen (28/27) and Edith (5/5) below, they were associated with very specific health experiences:

> *"I smoked…from when I was fifteen...It's only the last four years I've never smoked. I had a massive heart attack. I stopped drinking at the same time" (Maureen, 28/27).*

> *"In childhood, it was all sweets, chocolate. It was all the wrong things I used to eat, but that was because I could I suppose. I'm diabetic now so I've got to be really careful. That'll be thirteen years ago [my diagnosis]. I mean I still do have the odd one, but I've had to cut down tremendously because of my diabetes. I used to have a bar or two bars of chocolate a day. I just loved chocolate I did…Now, of course, I just watch what I'm eating all the time"* (Edith, 5/5).

Such systemic health concerns were also sometimes triggered by specific negative experiences of close family members, such as parents or spouses:

> *"I stopped in 1986, my dad died with lung cancer and he was at home and that was horrendous so I stopped. I was about 40…Watching him die was just horrendous, that was just the motivation I needed"* (Patricia, 18/18).

Such generic and more specific origins of health concerns have similarly been reflected in previous behaviour change research (Delaney and McCarthy 2011; McCaul et al. 2006). Significantly, the practice of improving behaviours following a specific negative health event also resonates with a commonly observable phenomenon coined the Sentinel Event Effect (Boudreaux et al. 2012).

A range of cognitive or personality dispositions also emerged from this research as influencers of people's behaviours. According with the previously recognised importance of self-efficacy (beliefs about one's ability to succeed or accomplish a task) in determining health behaviours (Bandura 1977; 1986; Schwarzer et al. 2011; Syrjala et al. 2001; Woelber et al. 2015), participants often alluded to concepts of self-efficacy when explaining their behaviours:

> *"I went to the doctors…and he gave me a [stop smoking] leaflet and I…put it in my bag, no intentions of giving up, and I went to work… I don't know why I did it but I just…pinned this notice up on the notice board, and one of the cleaners came in and she…started laughing and said, 'You give up smoking. You could never do that. You'll go in your coffin and they'll be shoving one in your mouth'. And I thought, 'You little bitch. I'll show you what I can and can't do', and that was the trigger...I wouldn't go back…Once I give my word for something, that's it, I stick to it and that's the motivation…It was actually nothing to do with how I'd be in better health and I'd taste better…It was to prove a point – yes, I will do it and, yes, I can do it. And I've proved a point that I'm strong willed, and to pick up a cigarette now, to me, that would be sort of saying I'm not as strong willed as I thought I was, and I wouldn't do that"* (Rose, 14/0).

Beliefs about whether oral health outcomes were within individuals' control also appeared to be influential, resonating with the importance of 'locus of control' beliefs within health behaviour theory (Lefcourt 1992; Rotter 1966) and previous oral health literature (Kneckt et al. 1999; Peker and Bermek 2011). Interviewees sometimes attributed their oral health problems to innate biological susceptibility, such as inheriting weak teeth, which diminished their sense of control and their motivation to try and improve their oral health. Additionally, individuals discussed levels of personal responsibility for their own oral health, compared to the responsibilities of others, such as dental professionals or parents. It was sometimes evident that placing an increased level of responsibility on others detrimentally impacted one's personal efforts to maintain their own oral health. It was generally accepted across the interviews however that, once individuals were old enough, fundamental responsibility lay with themselves:

"It all boils down to yourself. I mean, it's like everything regarding your body, really, it's all up to you. You've got to go to the dentist for him to have any effect on you. It does all come down to the individual." (Edith, 5/5)

Furthermore, the interviews revealed that denial and self-deception about the impact of oral health practices, or one's susceptibility to oral health problems, had a negative impact upon behaviour (see Rose and Michael's comments below). Both concepts are recognised as contributors to behaviour, denial being when 'a person has a desire for a certain outcome and fails to face the high probability of the undesired outcome', and self-deception being 'when a person actively tells oneself a narrative that is in tension with the actual evidence but in line with the desired outcome' (Blumenthal-Barby and Ubel 2018):

"Deep down, I probably did know [about the harm smoking was doing to my teeth], but it's one of these things that you know but won't admit to yourself. Can you understand? You sort of, you won't bring it forward in your mind. Yes, I did know but, no, I wouldn't accept it… We [also] did know that sugar was harmful, but you still continued to eat it. Forget about it, ignore it and it'll go away, but the only thing that went away was your bloody teeth" (Rose, 14/0).

"I often used to say I could drink what I like and eat what I like and smoke, and it wouldn't affect my health, nor my weight, one bit…I used to honestly believe that in my case God was going to make an exception" (Malcolm, 30/27).

Finally, several additional, individual-level determinants were discussed in the interviews as determinants of OHBs. These included the experience of enjoyment, the absence of time or the presence of competing distractions, and financial considerations. Specifically, participants regularly identified enjoyment as a reason for performing detrimental smoking and dietary behaviours:

"When I was going to the dentist once…they scraped my teeth and all the rest of it, then they said a lot of that was through cigarettes and tea…It didn't make any difference though, it didn't prevent me, because I enjoyed the cigarettes and I enjoyed a cup of tea" (Bruce, 0/0).

Factors such as full social schedules or intensive working schedules were often blamed for suboptimal behaviours:

"When I was working and that I missed a long time going to the dentist, maybe about five or six years. I think it was just time…I was working all the time you know" (Keith 25/25).

Lastly, financial considerations were recalled to have influenced a variety of behaviours, in particular acting as a key motivation for smoking cessation:

"I was spending ten pounds a week on cigarettes, and I thought I could be putting that away, you know…and I thought 'right, I'm going to do it' [quit smoking], and I just did, and that was it" (Edith, 5/5).

4.2: Variation in influences between different OHBs

The second key theme from the interviews was that the factors influencing how and why people looked after their teeth appeared to vary depending upon the OHB in question – the key behaviours of interest being oral hygiene, dental attendance, dietary (particularly sugar consumption) and smoking behaviours (as discussed in sub-section 3.6.5).

Most of the influencing factors listed in Figure 11 were discussed in relation to both dental attendance and oral hygiene behaviours. This is with the exception of enjoyment and systemic health concerns, which were not discussed in relation to either of these OHBs, and dental anxiety, which was discussed in relation to dental attendance but not oral hygiene practices. Therefore, dental attendance and oral hygiene behaviours appeared to share a broad and generally similar profile of influencing factors, although dental anxiety presented an additional barrier to dental attendance.

All of the above determinants of dental attendance and oral hygiene behaviours were also generally discussed in relation to dietary behaviours (with the exception of dental anxiety). However, dietary behaviours also appeared to have additional influences. Specifically, the experience of enjoyment was commonly recalled as a driver of negative dietary behaviours:

"I stuffed my face with chocolates... I ate a lot of sugar…It's always been chocolate, you know. I'm afraid I'm one that would have a bit of toothache and would still eat a bloody chocolate and, if I had the toothache at one side, I would eat the chocolate at the other. I mean how stupid can you be…The sweet tooth, chocolate has always been my downfall" (Rose, 14/0).

Moreover, dietary behaviours were frequently reported to have been shaped by systemic health concerns, a driver of food choice acknowledged in previous literature (Delaney and McCarthy 2011; Devine 2005; Devine et al. 1998; Rawahi et al. 2018). As discussed in sub-section 4.1.4, systemic health influences were either related quite generally to health concerns or to very specific health experiences. In addition, they were also frequently related to weight in the case of dietary influences, noticeably always in the case of females.

Interestingly, in the sample as a whole, systemic health concerns appeared to have influenced dietary behaviours at least to the same – if not even a greater – extent than any concerns relating to oral health. Cynthia's (25/22) account exemplified this when she explained why she reduced her sugar consumption when she started working:

> *"I've always been overweight from being a child, but I think, you know, when you start working and you're with your peers and you see how they are, you try to improve what you have. I can't say I'll never not like sweets because I love chocolate and stuff, but you just have to tend to look after yourself and restrict how much of these things that you have…I think, in the back of your mind, you're thinking about your teeth getting rotten because of all the sugar and the enamel and everything. But, I think, basically, it was probably for my weight".*

Even within the same accounts, an oral/systemic health distinction was sometimes apparent between the influencing factors of dietary behaviours and other OHBs. Patricia's (18/18) account illustrates this as she frequently justified her positive oral hygiene and dental attendance patterns with oral health-related reasons, such as seeing her husband *"lose his teeth at a very young age"* or *"coming across people who had very unhealthy mouths"* in her nursing profession. However, she reported high levels of sugar consumption up to her early fifties and justified improving her sugar consumption at this age:

> *"because I got too heavy and realised that I'd have to keep my mouth shut as my father used to say".*

The implications of the above findings are that the emotional experience of enjoyment may present an additional challenge to bringing about dietary behaviour change, above and beyond the barriers associated with oral hygiene and dental attendance behaviours. Secondly, interventions aimed at improving sugar consumption behaviours may benefit to a greater, or at least equal, extent by focusing on systemic health rather than purely oral health concerns (discussed further in sub-section 6.3.3).

Finally, in relation to smoking behaviours, the predominant influencing factors discussed were quite specific. In agreement with previous literature (Hoffman et al. 2007; Simons-Morton and Farhat 2010), the initiation of smoking was predominantly attributed to the influence of behavioural norms within peer groups:

> *"I would be fifteen and I was going out with a friend. There was about three or four of us used to go out dancing, and they all smoked and I didn't…So, a couple of times I said 'no'…and then one of them pointed out that, you know, I was the only one that didn't smoke, so I wasn't a paid up member of the club sort of thing. I mean, she didn't say that, but that was, you know. So then I sort of half-heartedly got into this, and so then the inevitable happened. You start smoking and people give you one. Then you can't be seen as mean, so what do you do? You go out and buy some and give them back and that's the way you go"* (Rose, 14/0).

Parents were also sometimes implicated in decisions around smoking initiation although, according with previous evidence (Hoffman et al. 2007; Simons-Morton and Farhat 2010), their influence generally appeared to be substantially less than that of peers.

In relation to the maintenance of smoking habits, enjoyment, and moreover addiction, were by far the primary reasons discussed:

> *"I enjoyed smoking and I just smoked…Smoking is a habit that's hard to break. It's easy to take it up but it's hard to break it"* (Maureen, 28/27).

This accords with contemporary knowledge about the addictive nature of smoking (Benowitz 2010) and highlights the additional challenges involved in achieving smoking cessation.

Lastly, with regards to smoking cessation, motivation was principally attributed to two factors – predominantly systemic health concerns but also financial concerns – both of which have been identified as key drivers in previous research (McCaul et al. 2006). Significantly, only one individual mentioned oral health concerns in his decision to stop smoking:

> *"I just woke up one morning and I thought I'm not going to do that anymore. I was just thinking more about gums, you know, like mouth cancers and thing like that…I was*

thinking to myself, 'I'm just going to pack these in, they can't be any good for your health or anything', you know" (Keith, 25/25).

This has particular relevance for smoking cessation efforts within a dental context, suggesting that a focus on systemic health and financial concerns may be more beneficial than a focus on oral health (discussed further in sub-section 6.3.3).

Notably, self-efficacy beliefs also emerged as a particularly central determinant of smoking cessation attempts and success (as previously illustrated by Rose's quote on Page 153). This supports the argument for addressing self-efficacy as a component of smoking cessation therapy (Elshatarat et al. 2016). It is likely that this importance of self-efficacy relates to the highly addictive nature of smoking (Benowitz 2010).

4.3: Changing influences across the life course

The third major theme determined from the interviews was that the factors influencing how and why individuals looked after their oral health changed across the life course. Specifically, three life course stages emerged as being reasonably distinct from each other – childhood, the transition to independent adulthood and independent adulthood itself. These periods were not strictly defined periods, not being defined by age nor being abruptly delineated in other ways, but, broadly speaking, they emerged as being distinct from each other according to the circumstances of individuals. The 'transition to independent adulthood' was generally characterised as the period from when individuals started to gain significant independence from parents, until they had fully established this independence. The former often started in adolescence, and the latter was often associated with factors such as being established in living arrangements away from home, being financially independent or entering into a marital partnership. Accordingly, 'childhood' was considered the period prior to this transition stage and 'independent adulthood' the remaining period of adulthood beyond this transition stage, up until age 67 (the age of the participants at interview). These three phases accord relatively closely, although not exactly, with previously proposed life course stages of relevance to health behaviour, such as Schooling and Kuh's (2002) recognition of the importance of 'childhood', 'adolescence and early adulthood', and 'adulthood'.

Of note, older adulthood is also often recognised as a distinct life course stage (Barkan 2011; Kowal and Dowd 2001), often starting around age 60 or 65, although definitions vary (Kowal and Dowd 2001). However, such a distinct stage was not identified in this research in relation to the influences of OHBs, most likely because interviewees had only reached the age of 67.

The following three sub-sections outline how the determinants of people's beliefs and behaviours appeared to change across these three life course stages. Figure 12 supports these sections, summarising these changing influences. Sub-section 4.3.4 further considers how such life course influences may have changed in more contemporary generations.

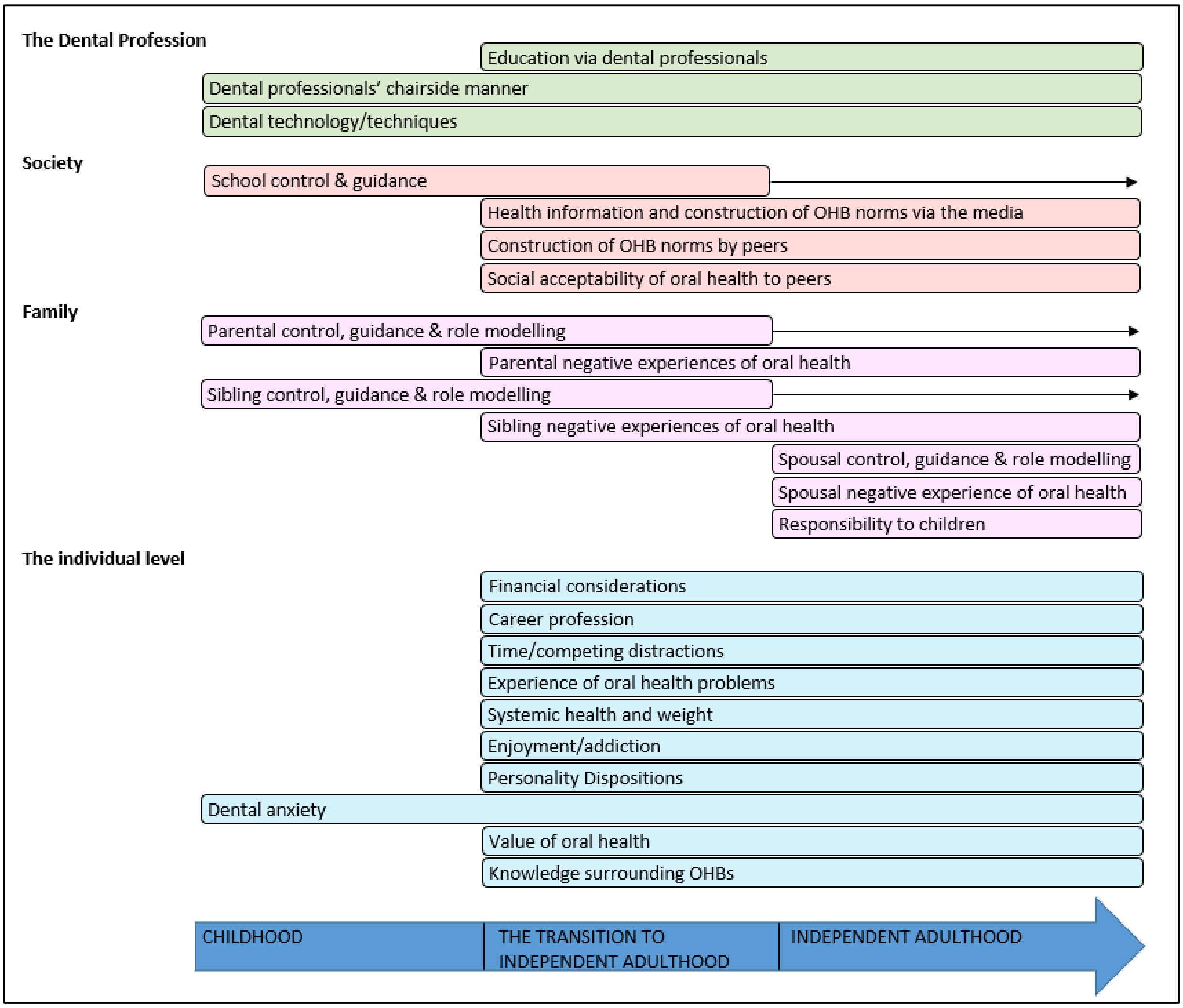

Figure 12: The key factors determining how and why NTFS participants looked after their oral health, according to a life course perspective.
NB: Blocks represent periods of contemporary influence. Single black arrows represent lasting effects of past influences.

4.3.1: Childhood determinants

In childhood, the role of individual-level factors in determining behaviours appeared to be very limited. Instead, predominant influences seemed to centre, not surprisingly, around parents, with other authorities – such as the dental profession, schools and siblings – also playing a role.

The predominant influence of parents during this stage related to their roles in controlling, guiding and role modelling OHBs. As evidenced by Rose's (14/0) quote on Page 148, many individuals described positive parental influences. However, this was certainly not universal:

> "*Well, the simple fact is, to put it bluntly, it was a failure of parenting to get me into a habit of brushing my teeth. I'm not aware of any habit having been formed of brushing my teeth in the morning or the evening. I have no recollection whatsoever of ever having received any information from them"* (Malcolm, 30/27).

Regarding the influence of the dental profession, this appeared to have been almost exclusively via its role in the development of dental anxiety and its subsequent impact upon dental attendance. Unfortunately, traumatic experiences at the dentist were reportedly very common at this time. These were particularly attributed to the 'frightening' technology and techniques used by dentists in those days (see John's (14/11) quote on Page 147) and the particularly abrupt and uncompassionate chairside manner of dentists:

> *"I was terrified of the dentist…It was horrendous…The dentist just drilled, he went on and on until I was just about out of the chair... He wouldn't stop. You would be waving your hand and he'd still keep going"* (Lorraine, 28/18).

The reported contribution of schools and older siblings also related to their roles in controlling, guiding and role modelling OHBs in this period, but was generally relatively minor across the sample as a whole. Only a minority of individuals recalled seeing a dentist at school, whilst the provision of oral health education by these dentists or other sources within school was generally perceived to have been quite limited:

> *"Classes were lined up outside the room and you were sort of wheeled in, and it was a very quick look and then out again. So, I don't think there was any feedback to me or to my parents at that time. It was quite a superficial examination…Probably the dentist had about two hours to inspect about 200 kids or something"* (Arthur, 0/0).

Importantly, interviewees' accounts and contemporary literature suggest that some of the above childhood influences may be different in more contemporary cohorts, in particular relating to gender parenting roles and childhood experiences of dental visiting, but this will be explored further in sub-section 4.3.4.

4.3.2: The transition to independent adulthood

As individuals transitioned into independent adulthood, they began to gain greater autonomy from childhood authorities, although had not yet fully established their independence. Consequently, the influence of parents, siblings and school in controlling and guiding behaviours appeared to persist in this period, but generally to a lesser extent than in childhood.

Moreover, this was a period in which individual-level factors reportedly started to become key, as identified in previous health literature (Schooling and Kuh 2002):

> *"I think, when you're younger, it's the responsibility of your parents to ensure that you look after your teeth…but, as you get older, it's obviously up to you. You're the one that's got to look after yourself, so it's up to you"* (George, 23/23).

For example, this was the stage when factors such as the value placed on oral health and one's level of oral health knowledge started to contribute to behaviours:

> *"Well, my mother had false teeth by the time she was eighteen…and my brother had false teeth in his twenties…I had a bit more knowledge, plus I always looked after my teeth…I moved away from home when I was nineteen, so I had my own regime, you know, so I took care of it, because it was sensible, because I certainly didn't want to have false teeth…Plus, I read up a bit about things if there was a problem, finding out what's wrong…I was determined I wouldn't have false teeth, and I think, it's awful to say, I had a bit more intelligence than them [my parents], so I could see where things were leading"* (Pam, 23/21).

Notably, the increased individual responsibility attached to this stage of life resulted in some individuals improving their OHBs, like Pam (23/21) above. However, for others (interestingly always males), it resulted in the temporary deterioration of their OHBs. This was often attributed to the informality of this stage of life in the absence of parental control:

> *"In my teen years my teeth were pretty good, but when I went to college, I left Newcastle and I did slip there. Out of the sight of your parents, you tend to let things slide, and so my [dental] treatment was responsive to sort of problems really…It was my*

own fault, as I say, I hadn't continued the good practice that my mother had regularised for me, and away from parental control I did let things drift…And given the sort of vagaries of youth, I think it [my diet] probably deteriorated quite badly to be honest. You tend not to think about things like planning and what not…When you're sort of young and carefree, those things tend to be of secondary importance really" (Steve, 23/22).

As established in previous health literature (Schooling and Kuh 2002; Umberson et al. 2010), the role of peers also appeared to become particularly key in this period of increased independence. Mirroring observations in previous oral health studies of adolescents (Ostberg et al. 2002; Stokes et al. 2006), many participants recalled improving their OHBs because the social acceptability of their oral health was a prominent concern when they started 'going out' and 'socialising with the opposite sex':

"I don't remember cleaning me teeth at all when I was young…[I started] when I was going out looking for boys, do you know what I mean? Fifteenish, something like that. Like all the young ones that age, they start getting showers, don't they, when they start going out on the town" (Dorothy, 0/0).

Additionally, the OHBs of peers were perceived to have influenced participants' own behaviours during this stage of life, as individuals started conforming to social norms. As previously discussed in Section 4.2, peers were particularly influential in the initiation of smoking behaviours at the time.

4.3.3: Independent adulthood

As individuals progressed into independent adulthood, they had fully established their autonomy from childhood authorities. As a result, the influence of individual-level factors appeared to remain key. Of note, many individuals also recounted that they became more sensible, thoughtful and responsible as they got older, which had a positive impact on their behaviours:

"Until you become a little bit older and a little bit more sensible and a little bit more starting looking at your future, you don't give it [going to the dentist] a thought…" (Alan, 27/27).

Societal influences also remained prominent in this period, such as peer influences. However, it was notable that concerns about the social acceptability of oral health to peers did not seem to be quite as important as in the transition to independent adulthood. Furthermore, it was throughout independent adulthood that the influence of media and marketing sources became increasingly prominent. Importantly, its increasing influence was generally attributed to changes in the presence, accessibility and oral health content of media sources over time (period effects), rather than age or life course effects, the implications of which are discussed further in sub-section 4.3.4:

> *"There's more advertising now about looking after your teeth because you have the social media...and TV"* (Cynthia, 25/22).

> *"When it became advertised on television and what not about dental hygiene, and there was all these different toothpastes and different types of toothbrushes that did this and that and the other, then I think you become more aware…There was no television when we were kids. I think the first television we got in our house was in 1957, 1960s, sort of thing, so there was no advertising because it was all BBC, so how would you know about dental hygiene and toothpastes? It was only what you'd see on the billboard or what you'd read in the paper…Because of advertisement on the television I'm more aware of dental hygiene and what have you now than I was in the past. I think that's just because of that"* (Bruce 0/0).

Similarly, the influence of the dental profession was also perceived to have remained key for many individuals across the whole of adulthood. Specifically, their continued impact on dental anxiety was recognised. Notably, however, there was a common consensus that this influence had become more positive over this cohort's lifetime, due to improvements in technology and dental professionals' chairside manners:

> *"Now I find that dentists have got time for you. Before, they were very abrupt and rough, whereas now they'll give you time. And, if you tell them you're afraid, they'll say, 'don't worry, you're doing well', you know. They just put you at ease now more than they ever did"* (Barbara, 21/18).

Furthermore, the dental profession's influence via oral health education also seemed to have become increasingly prominent over this cohort's lifetime. This was predominantly attributed to the provision of such education becoming more commonplace over time, which accords with the increasingly recognised importance of prevention within dentistry (DoH 2005; 2017a; Steele et al. 2009):

"Now, I think the whole dental hygiene issue is being addressed, people are more aware…I think dentists educate, I think dentists are more preventive. It used to be 'we'll fill the holes in', but now they seem to want to prevent things happening" (Lorraine, 28/18).

The implications of such period changes on more contemporary UK generations are discussed further in sub-section 4.3.4.

Regarding family influences, parental and sibling roles in actively guiding and controlling interviewees' behaviours generally seemed to cease in independent adulthood. Instead, central family influences reportedly transferred to spouses and children (where these were present). Indeed, as discussed in sub-section 4.1.3, such influences (especially of spouses) were quite dominant for several individuals.

This did not mean, however, that the influence of parents, siblings and other childhood authorities (such as schools) completely ceased in independent adulthood. As introduced in sub-section 4.1.3, witnessing parents and siblings experience oral health problems was a commonly reported motivation for looking after one's oral health, and such motivations were reported across the whole of adulthood. Furthermore, guidance received around looking after one's teeth in childhood was frequently reported to have had a lasting effect (beyond an active influence), sometimes even across the whole life course:

"From the age of eleven, the school I went to, you had to go out in the yard in the morning and you were inspected. Your shoes had to be clean, they checked that you cleaned, washed, [cleaned your] teeth. That instigated the way you live from a personal hygiene point of view for the rest of your life" (Donald, 28/20).

In a similar manner, it is important to highlight that many other influencing factors were also recognised to have had a lasting effect across the life course, beyond their active influence. Such lasting effects were generally associated with high-impact events, such as particularly traumatic experiences of dental visiting, or experiences of major systemic or oral health problems. An example of the former is Bruce's (0/0) quote on Page 146, where he justifies avoiding the dentist if at all possible for the remainder of his life following a traumatic experience in his childhood. An example of the latter is Malcolm's (30/27) quote below. Continuing his account of severe oral health problems at the age of 21 (see Page 151), he reported:

"I'd been in a place which wasn't very nice because of my neglect. I didn't want to go back, I wanted to avoid that in the future…I had a wake-up call when I was 21 and it changed my whole attitude to dental care, which has held me in good stead for the rest of my life".

Previous evidence has also supported the long-lasting effects of such impactful events. For example, studies have revealed the long-term effects of negative dental experiences on future dental anxiety and attendance (Borreani et al. 2010; Oliveira et al. 2017), whilst studies have also demonstrated the long-lasting impact of the Sentinel Event Effect (where a specific health event triggers behaviour change) (Boudreaux et al. 2012; Rigotti et al. 1994).

4.3.4: Transferability of findings to contemporary generations

As alluded to throughout this section so far (Section 4.3), a number of the factors determining how and why NTFS participants looked after their oral health may be period specific (i.e. specific to the particular period of time in which this cohort lived). Consequently, some findings of this research may not be transferable to more contemporary UK cohorts.

As discussed in sub-section 4.3.3, there was a common consensus that the influence of the media and oral health education from dental professionals had increased over this cohort's lifetime, as exposure to these influences had increased. Consequently, it is arguable that these influences may commence earlier in the life course in more contemporary cohorts. Indeed, studies of more recent generations of adolescents support this hypothesis (Fitzgerald et al. 2004; Hall-Scullin et al. 2015; Östberg 2005). Furthermore, the influence of the dental profession on dental anxiety was generally perceived to have become less negative over time. Therefore, the profession's contribution to dental anxiety may be more favourable in contemporary cohorts. Nonetheless, evidence does show that dental anxiety and its impact upon childhood attendance is still a major current concern in the UK (Tsakos et al. 2015).

In addition, period changes may be relevant to the contemporary transferability of some other findings. Specifically, the predominant role of mothers in controlling and guiding the OHBs of this sample in childhood (sub-section 4.1.3) may be diminished in more recent generations, given greater balancing of gender roles (Monna and Gauthier 2008; Oláh et al. 2018). However, it is likely such disparities will still persist to a certain extent (Curtice et al.

2019; ONS 2020b). It is also worth considering whether the role of schools in controlling and guiding OHBs will be similar now to in the 1950s. Although schools in some areas currently benefit from local oral health initiatives (Childsmile 2014; Designed to Smile 2020a; Greater Manchester Health and Social Care Partnership 2019; NHS.UK 2020a), evidence suggests the focus on oral health in UK schools in general remains poor (FDI 2019).

4.4: Sufficiency and competition between influencing factors

Interviewees' accounts revealed that multiple influences of their oral health beliefs and behaviours were often present concurrently. The final major theme emerging from this study related to the interplay between such influences.

The first observation related closely to the PRIME theory of motivation – a contemporary theory which argues that people make decisions based on the balance of all of their motivations (West 2006). According with this theory, many of the identified determinants of behaviours in this research appeared to impart their influence by shaping motivation, and it was apparent that the overall direction of motivation was determined by the balance of its component contributors. Influences such as systemic health issues, concerns about the social acceptability of oral health and experiences of one's own oral health problems were frequently reported positive motivators of behaviours. Conversely, factors such as the pleasure of enjoyment, dental anxiety and time availability were common negative influencers of motivation. In addition, it was particularly notable that, in some cases, negative motivators only seemed to prevail in the absence of compelling positive drivers. However, in other cases, negative motivators could be so strong – often related to enjoyment and dental anxiety – that few positive motivators, however strong, could outweigh this motivation. In illustration of the former, George talked about balancing the enjoyment of sugary foods with oral health harms, but had experienced relatively few oral health problems over his life. In contrast, in illustration of the latter, Michael suggested that very little, if anything, could be more important than his experience of enjoyment:

> *"Over a day, I have maybe six cups of tea, and I always have a spoonful of sugar…And on a morning, I tend to have cornflakes and a banana, but then I'll sprinkle some sugar on…Over the years, I've been told that sweet stuff like sweets and sugar can, well, rot your teeth basically, but you tend to ignore it I think. I think the thing is you tend to*

offset the pleasure of the taste of the sugar against what harm it's doing you…It's a balancing act really" (George, 23/23).

"They say, 'go on a diet, do this do that'. I'm not into that…A lot of time the foods are not appetising so I just eat what I enjoy and that's it…Even [if it was] life threatening, I would carry on. I don't know what it would take for me to change. I don't think I could change…People say you live another five year. Well, it's enjoying yourself while you're here not how long you live" (Michael, 26/20).

The second observation related closely to the contemporary COM-B theory of behaviour, which asserts that behaviour is not only the result of motivation, but that capability and opportunity must also be present (Michie et al. 2011). Supporting this theory, several of the influencing factors of OHBs identified in this research appeared not to impart their influence by affecting motivation but instead by acting as barriers and facilitators of behaviours, i.e. determining capability and opportunity. For example, parents and spouses seemingly acted as facilitators when controlling and guiding interviewees' OHBs, such as arranging dental appointments. Furthermore, the possession of knowledge was, more often than not, discussed as a facilitator of behaviours once motivation was present from elsewhere. The latter accords with contemporary understandings of health behaviour, which recognise that knowledge and information alone do not generally drive behaviour (Darnton 2008; Kelly and Barker 2016; NICE 2014).

Crucially, in support of the COM-B model, interviewees' accounts often suggested that, if a sufficient barrier was present (to capability or opportunity), the behaviour was not performed, irrespective of the level of the motivation:

"I considered that I don't think I'll go to a dentist again because of the experience I had [when I was twenty]…It was horrible…If I had a pain in my tooth, I'd keep that pain in my tooth rather than go, until I couldn't stand it any longer. You just take the pain killers and hope for the best" (Dorothy, 0/0).

Conversely, the acquisition of capability and opportunity did not generally result in behaviour change until an accompanying motivation was not present. Cynthia's (25/22) account illustrates this when she talks about the receipt of oral health education from the dental profession:

"You went to the dentist, and you tried to take in what they were telling you, but I can't say I've ever [paid any attention]…until later life, until I've had a couple of problems, and then you have to listen to what they're telling you".

4.5: Summary of qualitative findings

In summary, the qualitative interviews suggested that multiple factors determined how and why the interviewees looked after their oral health across their life course, and that these particularly related to the dental profession, society, family and the individuals themselves (Figure 11). The dental profession was predominantly perceived to have exerted its influence by contributing to dental anxiety and by providing oral health education. Societal determinants included schools, peers and media and marketing sources, whilst family influences focused around parents and spouses but also included siblings and children. Such societal and family sources reportedly exerted their influence via a range of pathways, such as controlling or guiding OHBs, providing oral health information or shaping behavioural norms. Individual-level factors included a multitude of influences, such as oral health knowledge, beliefs about the value of oral health, systemic health concerns, personality dispositions, the availability of time and financial considerations. The above influencing factors were invariably not independent of each other but connected by multiple pathways (Figure 11).

The influences of different OHBs reportedly varied depending upon the specific behaviour in question. Broadly speaking, this research suggested that oral hygiene and dental attendance behaviours shared a similar profile of influencing factors, with the addition of dental anxiety as a key determinant of dental attendance. Dietary behaviours (i.e. sugar consumption) also appeared to share a similar profile of determinants, but the pleasure of enjoyment and, moreover, systemic health concerns were additional central influences. In relation to smoking behaviours, the predominant influencing factors discussed were quite specific. The initiation of smoking was almost exclusively attributed to peer influences and, to a lesser extent, parental influences. The experience of enjoyment, or moreover addiction, was then predominantly blamed for the continuation of smoking. Subsequently, smoking cessation was principally attributed to two factors – predominantly systemic health but also financial concerns, with oral health being a rarely considered factor.

Furthermore, this research suggested that the factors influencing how individuals cared for their oral health changed across the life course (Figure 12). In childhood, individuals had little independence, and predominant influences seemed to centre around parents, particularly mothers. The dental profession also reportedly significantly influenced dental anxiety, whilst schools and siblings appeared to play a more minor role. As individuals transitioned to independent adulthood, they gained greater independence, although this was not yet fully established. Consequently, the influence of parents and other childhood authorities (such as schools and siblings) seemed to persist in this period, but generally to a lesser extent than in childhood. Moreover, individual-level factors and peers become particularly important during this stage. As individuals progressed into independent adulthood, a central role of individual-level factors, society (peers and the media) and the dental profession reportedly persisted. However, the predominant influence of family members generally shifted away from parents (and siblings) and re-centred especially around spouses, but also around children.

This research also provided an insight into the interplay between determinant factors, when multiple competing influences were present. Firstly, this research supported the applicability of the PRIME theory of motivation (West 2006) to OHBs – i.e. motivation for behaviours seemed to be determined by the overall balance of competing motivators at that time. Moreover, negative motivators of OHBs, such as enjoyment and dental anxiety, were sometimes so strong that few positive motivators could outweigh them. Secondly, this research supported the applicability of the COM-B model (Michie et al. 2011) to OHBs. Crucially, it demonstrated that the absence of capability or opportunity impeded behaviours even if motivation was high, and that the presence of capability or opportunity was often insufficient to affect behaviour in the absence of motivation.

It is important to note, however, that there are likely some differences in the determinants of behaviours between this cohort and more contemporary populations. In particular, period increases in the provision of oral health education by dental professionals and oral health messaging in the media may have resulted in an increased prominence of such influences in more contemporary populations. Furthermore, improvements in dentists' chairside manners and dental technologies may have reduced the negative and enhanced the positive impact of the dental profession on dental anxiety.

Chapter 5: Quantitative path analysis results

This chapter presents the results of the quantitative study – a life course path analysis of the determinants of age 63 tooth retention in the NTFS cohort. In accordance with the methods described in Section 3.7, this chapter firstly presents summary statistics for all of the variables to be included in the path model building process, followed by univariable and multivariable regression analyses of the associations between the potential predictor variables and age 63 tooth retention. Subsequently, the final path model is presented, constructed using the sample of 198 individuals with complete data, along with tests of its goodness-of-fit. Finally, the testing of this final path model on the two larger samples (n = 245 and 233), as outlined in sub-section 3.7.17, is reported.

5.1: Summary statistics

Table 23 presents the summary statistics for all variables, calculated from the full eligible sample for the path analysis (n=245). Median tooth retention at age 63 was 25, with an interquartile range between 21 and 27. There were more females in the sample than males (58%); 19% belonged to a partly skilled/unskilled social class at birth, but only 10% remained in this social class at age 50; and only 39% of the sample achieved A-levels or above.

Tooth brushing frequency was poor in adolescence but improved across the life course, with 43%, 67% and 72% reporting brushing at least twice daily at ages 15, 35 and 50 respectively. Dental attendance was poor at age 15, with only 57% attending for a check-up at least yearly. By ages 35 and 50, 86% and 89%, respectively, were attending the dentist for a check-up every two years. Between the ages of 10 and 29, 45.7% of participants smoked; the median pack-years smoked by this group over this nineteen-year period was six. Between the ages of 30 and 62, 33.1% of participants smoked; the median pack-years smoked by this group over this 32-year period was 11.5. At age 50, mean daily total sugar consumption for men was 116g (similar to the current UK Guideline Daily Amount for Men, which is 120g (Food and Drink Federation 2013)). For women, the mean intake of 117g was higher than the UK Guideline Daily Amount for women, which is 90g (Food and Drink Federation 2013). Just over half (52.5%) of the sample were in the higher quantile for daily sugar intake, in relation to the full NTFS dataset (n=541). Almost two-thirds (61%) reported that they received strong or moderate encouragement from their parents/guardians to look after their teeth in childhood.

Dental anxiety was not uncommon. In late adulthood, participants scored a median of 9 on the MDAS (which ranges from 5 to 25 (Humphris et al. 1995)); 7.9% of individuals also scored 19 or above, so would be classified as dentally phobic (King and Humphris 2010). The median score for dental anxiety in early adulthood was slightly higher, being 7 on a scale from three to fifteen.

Independent variable	**n**	**Mean (SD)**
Standardised birth weight	245	-0.1 (1.1)
		Median (IQR)
Years married	233	38 (34-41)
Pack-years 10-29	245	0.0 (0.0-5.1)
Pack-years 30-62	242	0.0 (0.0-5.0)
Dental anxiety (early adulthood)	242	7 (5-10)
Dental anxiety (late adulthood)	242	9 (7-12)
Tooth count age 63	245	25 (21-27)
		n (%)
Sex	245	
Male		103 (42.0)
Female		142 (58.0)
Social class birth	241	
Partly skilled/unskilled		45 (18.7)
Skilled/managerial & technical/professional		196 (81.3)
Social class 50	241	
Partly skilled/unskilled		25 (10.4)
Skilled/managerial & technical/professional		216 (89.6)
Education level	238	
Below A-levels		145 (60.9)
A-levels or above		93 (39.1)
Parental encouragement	244	
Little/none		95 (38.9)
Strong/mod		149 (61.1)
Illness limiting daily activity (age 50)	242	
No		213 (88.0)
Yes		29 (12.0)
Sugar consumption 50	242	
<109.86g/day (Quantile 1)		115 (47.5)
>109.86g/day (Quantile 2)		127 (52.5)
Dental attendance 15	237	
Less than once per year		103 (43.5)
At least once per year		134 (56.5)
Dental attendance 35	236	
Less than once every 2 years		34 (14.4)
At least once every 2 years		202 (85.6)
Dental attendance 50	239	
Less than once every 2 years		26 (10.9)

At least once every 2 years		213 (89.1)
Tooth brushing 15 Once daily or less Twice daily or more	235	 133 (56.6) 102 (43.4)
Tooth brushing 35 Once daily or less Twice daily or more	234	 77 (32.9) 157 (67.1)
Tooth brushing 50 Once daily or less Twice daily or more	233	 66 (28.3) 167 (71.7)

Table 23: Summary statistics of the final eligible sample for the path analysis (n=245).

Comparing this sample to the rest of the UK population of the same generation is challenging due to the lack of available comparable data but, where comparisons are possible, these are presented in Appendix N. The sample appears representative in terms of age 63 tooth retention (Fuller et al. 2011), age 69 dental anxiety (Nuttall et al. 2011a) and age 50 tooth brushing frequency (Kelly et al. 2000). However, this NTFS sample had a higher proportion of females (58% compared to 51%), regular dental attendance at age 50 (73% compared to 64%) and a lower proportion of smokers at age 50 (16% compared to 27%). This potential bias of the sample towards females and those with better health behaviours is likely the result of loss to follow-up bias and, possibly, also the Hawthorne effect (as introduced in sub-section 3.7.1) (French and Sutton 2010; Godin et al. 2008). The potential impact of this on the interpretation of the results is addressed in the discussion (sub-section 6.2.4).

5.2: Univariable regression analyses

Table 24 shows the results of unadjusted univariable regression analyses between potential life course predictor variables and tooth count aged 63. Greater parental encouragement to look after one's teeth in childhood, higher educational attainment, higher age 50 social class, lower pack-years of smoking between ages 10 and 29 and ages 30 and 62, lower dental anxiety in early and late adulthood, more frequent dental attendance at age 50, and more frequent tooth brushing at ages 15, 35 and 50 were all significantly associated with higher tooth counts at age 63 (at least at the 5% significance level).

Independent variable	**β**	**95% CI**	**p-value**
Sex Male (ref) Female	 -0.870	 (-2.223, 0.484)	 0.207

Independent variable	**β**	**95% CI**	**p-value**
Standardised birth weight	-0.129	(-0.767, 0.508)	0.691
Parental encouragement Little/none (ref) Strong/mod	 1.458	 (0.096, 2.819)	 0.036*
Education level Below A-levels (ref) A-levels or above	 2.951	 (1.628, 4.274)	 <0.001**
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	 1.200	 (-0.500, 2.899)	 0.166
Social class 50 Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	 2.453	 (0.278, 4.629)	 0.027*
Years married	-0.046	(-0.107, 0.015)	0.140
Illness limiting daily activity (age 50) No (ref) Yes	 -0.717	 (-2.752, 1.318)	 0.488
Pack-years 10-29	-0.146	(-0.273, -0.019)	0.024*
Pack-years 30-62	-0.116	(-0.185, -0.048)	0.001**
Dental anxiety (early adulthood)	-0.436	(-0.644, -0.227)	<0.001**
Dental anxiety (late adulthood)	-0.429	(-0.566, -0.292)	<0.001**
Sugar consumption 50 <109.86g/day (Quantile 1) (ref) >109.86g/day (Quantile 2)	 -0.554	 (-1.907, 0.798)	 0.420
Dental attendance 15 Less than once per year (ref) At least once per year	 1.108	 (-0.267, 2.483)	 0.114
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	 1.257	 (-0.696, 3.210)	 0.206
Dental attendance 50 Less than once every 2 years (ref) At least once every 2 years	 3.595	 (1.454, 5.735)	 0.001**
Tooth brushing 15 Once daily or less (ref) Twice daily or more	 1.768	 (0.390, 3.146)	 0.012*
Tooth brushing 35 Once daily or less (ref) Twice daily or more	 2.011	 (0.554, 3.469)	 0.007**
Tooth brushing 50 Once daily or less (ref) Twice daily or more	 1.960	 (0.490, 3.429)	 0.009**

Table 24: Results of univariable regression analyses between life course predictor variables and tooth count aged 63.
** p<0.05, **p<0.01*

5.3: Full multivariable regression analysis

Table 25 reports the results of the adjusted multivariable regression analysis between all potential life course predictor variables and tooth count aged 63. Lower levels of dental anxiety in late adulthood and more frequent dental attendance at age 50 remained significantly associated with higher tooth retention at age 63 (p<0.01 and <0.05 respectively). However, less frequent dental attendance at age 35 was now also associated with greater tooth retention at age 63 (p<0.01).

Independent variable	**β**	**95% CI**	**p-value**
Sex Male (ref) Female	-0.103	(-1.656, 1.450)	0.896
Standardised birth weight	0.074	(-0.534, 0.682)	0.811
Parental encouragement Little/none (ref) Strong/mod	0.548	(-0.969, 2.064)	0.477
Education level Below A-levels (ref) A-levels or above	1.415	(-0.079, 2.909)	0.063
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	-0.223	(-2.106, 1.660)	0.816
Social class 50 Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	0.433	(-1.912, 2.778)	0.716
Years married	-0.016	(-0.073, 0.041)	0.581
Illness limiting daily activity (age 50) No (ref) Yes	-0.381	(-2.339, 1.578)	0.702
Pack-years 10-29	0.020	(-0.178,0.217)	0.845
Pack-years 30-62	-0.068	(-0.168, 0.033)	0.187
Dental anxiety (early adulthood)	-0.178	(-0.443, 0.087)	0.186
Dental anxiety (late adulthood)	-0.271	(-0.453, -0.088)	0.004**
Sugar consumption 50 <109.86g/day (Quantile 1) (ref) >109.86g/day (Quantile 2)	-0.987	(-2.308, 0.333)	0.142
Dental attendance 15 Less than once per year (ref) At least once per year	1.022	(-0.637, 2.681)	0.226
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	-3.382	(-5.717, -1.047)	0.005**
Dental attendance 50 Less than once every 2 years (ref)			

Independent variable	β	95% CI	p-value
At least once every 2 years	2.583	(-0.006, 5.171)	0.050*
Tooth brushing 15 Once daily or less (ref) Twice daily or more	-0.659	(-2.331, 1.012)	0.438
Tooth brushing 35 Once daily or less (ref) Twice daily or more	1.035	(-1.312, 3.382)	0.385
Tooth brushing 50 Once daily or less (ref) Twice daily or more	0.579	(-1.689, 2.847)	0.615

Table 25: Results of a multivariable regression analysis between life course predictor variables and tooth count aged 63 (n=198).
** p<0.05, **p<0.01*

5.4: Reduced multivariable regression analysis

Table 26 reports the results of a reduced multivariable regression model, including only the predictor variables significantly associated with tooth count age 63 in the preceding full multivariable regression analysis. As described in sub-section 3.7.13, this reduced model was produced to form the basis of the path model building process. Lower dental anxiety in late adulthood, more frequent dental attendance at age 50 and less frequent dental attendance at age 35 continued to be significantly associated with higher tooth retention at age 63 ($p<0.01$, <0.05 and <0.05 respectively).

Independent variable	β	95% CI	p-value
Dental anxiety (late adulthood)	-0.363	(-0.509, -0.216)	<0.001**
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	-2.285	(-4.435, -0.134)	0.037*
Dental attendance 50 Less than once every 2 years (ref) At least once every 2 years	2.845	(0.389, 5.301)	0.023*

Table 26: Results of a reduced multivariable regression analysis between life course predictor variables and tooth count aged 63 (n=198).
** p<0.05, **p<0.01*

5.5: Final path model

As discussed in sub-section 3.7.13 and presented in Appendix L, the path model building process involved 54 model iterations. This was developed via a process of model building and model trimming, starting with the above reduced multivariable regression model reformatted as a path model. Figure 13 presents the final path model for the life course determinants of tooth count at age 63, produced as a result of this process. Significant regression paths (p<0.05) are represented in the figure by arrows, with solid arrows and dotted arrows representing direct and indirect pathways to tooth count age 63, respectively. Values attached to arrows are standardised regression coefficients, which represent the standard deviation change in the dependent variable given a one standard deviation change in the predictor variable (Lei and Wu 2007). Values in boxes are the standardised total effects of variables on tooth count age 63. These represent the overall standard deviation change in tooth count at age 63, given a one standard deviation change in the predictor variable (mediated via both direct and indirect pathways) (Lei and Wu 2007).

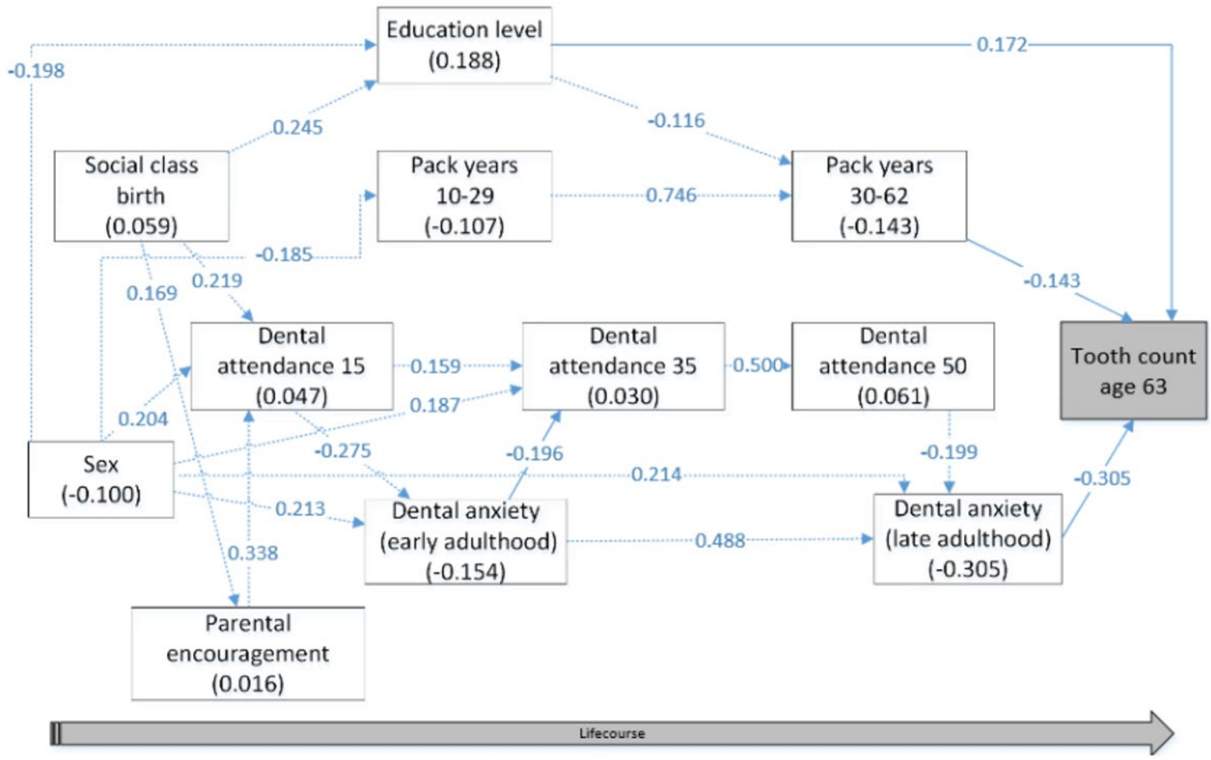

Figure 13: Final path model of the relationships between life course predictor variables and tooth count age 63 (n=198).
Arrows represent significant regression paths between variables (p<0.05), according to bootstrapped estimates (based on 50,000 samples). Solid arrows and dotted arrows represent direct and indirect pathways to tooth count age 63, respectively. Values attached to arrows are standardised regression coefficients. Values in boxes are standardised total effects of variables on tooth count age 63 (via direct and indirect pathways).

Table 27 also tabulates the standardised total effects of each variable on age 63 tooth count, but also reports corresponding unstandardised total effects (representing the unit change in age 63 tooth retention given a one unit change in each predictor variable). In addition, it breaks down these standardised and unstandardised total effects into standardised and unstandardised direct effects (if a path passes directly from a predictor variable to tooth retention) and indirect effects (if the effects of predictor variables on tooth retention are mediated through other variables). 95% confidence intervals and significance values for all effects are also presented, according to bootstrapped estimates. For example, Table 27 shows that being educated to A-level standard or above, compared to below A-level standard, is associated with retaining 1.819 more teeth at age 63 (unstandardised total effect). The equivalent standardised total effect is 0.188 (Figure 13 and Table 27), meaning that a one standard deviation improvement in education level is associated with a 0.188 standard deviation improvement in age 63 tooth retention. Figure 13 and Table 27 further show that this total effect of education level on age 63 tooth retention is primarily via a direct route (91%), with only 9% of this total effect being indirect (mediated by pack-years smoking age 30 to 62).

For completeness, Appendix O further tabulates the standardised regression coefficients for every individual regression path between all variables (the values attached to arrows in Figure 13), but also presents the unstandardised versions of these coefficients, alongside 95% confidence intervals and p-values for all coefficients.

	Direct effects						Indirect effects						Total effects				
Predictor variable	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**	**% of total effect**	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**	**% of total effect**	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**
Sex Male (ref) Female							-0.978	(-1.771, -0.294)	-0.100	(-0.169, -0.032)	0.003	100	-0.978	(-1.771, -0.294)	-0.100	(-0.169, -0.032)	0.003
Parental encouragement Little/none (ref) Strong/moderate							0.159	(0.055, 0.323)	0.016	(0.006, 0.031)	<0.001	100	0.159	(0.055, 0.323)	0.016	(0.006, 0.031)	<0.001
Education level Below A-levels (ref) A-levels or above	1.658	(0.463, 2.896)	0.172	(0.050, 0.293)	0.006	91	0.161	(0.010, 0.376)	0.017	(0.001, 0.039)	0.031	9	1.819	(0.634, 3.036)	0.188	(0.069, 0.306)	0.003
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional							0.761	(0.293, 1.367)	0.059	(0.024, 0.102)	<0.001	100	0.761	(0.293, 1.367)	0.059	(0.024, 0.102)	<0.001
Pack-years 10-29							-0.103	(-0.202, -0.014)	-0.107	(-0.204, -0.014)	0.023	100	-0.103	(-0.202, -0.014)	-0.107	(-0.204, -0.014)	0.023
Pack-years 30-62	-0.072	(-0.141, -0.010)	-0.143	(-0.270, -0.020)	0.023	100							-0.072	(-0.141, -0.010)	-0.143	(-0.270, -0.020)	0.023
Dental anxiety (early adulthood)							-0.242	(-0.411, -0.106)	-0.154	(-0.242, -0.073)	<0.001	100	-0.242	(-0.411, -0.106)	-0.154	(-0.242, -0.073)	<0.001
Dental anxiety (late adulthood)	-0.325	(-0.517, -0.154)	-0.305	(-0.441, -0.156)	<0.001	100							-0.325	(-0.517, -0.154)	-0.305	(-0.441, -0.156)	<0.001

	Direct effects						Indirect effects						Total effects				
Predictor variable	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**	**% of total effect**	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**	**% of total effect**	**Unstandardised beta**	**95% CI**	**Standardised beta**	**95% CI**	**p-value**
Dental attendance 15 Less than once per year (ref) At least once per year							0.468	(0.188, 0.848)	0.047	(0.020, 0.080)	<0.001	100	0.468	(0.188, 0.848)	0.047	(0.020, 0.080)	<0.001
Dental attendance 35 Less than once per 2 years (ref) At least once per 2 years							0.425	(0.098, 0.919)	0.030	(0.007, 0.063)	0.003	100	0.425	(0.098, 0.919)	0.030	(0.007, 0.063)	0.003
Dental attendance 50 Less than once per 2 years (ref) At least once per 2 years							0.965	(0.276, 1.885)	0.061	(0.017, 0.111)	0.003	100	0.965	(0.276, 1.885)	0.061	(0.017, 0.111)	0.003

Table 27: Unstandardised and standardised direct, indirect and total effects of life course variables on tooth count age 63, according to the final path model (n=198).

The primary finding in relation to this final path model relates to which predictor variables have a significant overall effect (total effect) on the outcome of age 63 tooth retention. Figure 13 and Table 27 show that greater parental encouragement to look after one's teeth in childhood, education to A-level standard or above, being from a higher social class at birth and attending the dentist regularly for check-ups at ages 15, 35 and 50 all had a positive influence on age 63 tooth retention. Conversely, female sex, higher pack-years of smoking between ages 10 and 29, and ages 30 and 62, and greater dental anxiety in early and late adulthood had a negative influence on tooth retention (Figure 13 and Table 27). Standardised birth weight, age 50 social class, the presence of illness limiting daily activities at age 50, the number of years married, sugar consumption at age 50, and tooth brushing frequencies at ages 15, 35 and 50 did not significantly influence tooth retention.

The second key finding relates to the size of the overall effects of each variable on age 63 tooth retention. According to standardised estimates – which facilitate relative comparisons between variables with different units (Lei and Wu 2007), but can be misleadingly influenced by a variable's sample variance (Frone 2012; Greenland et al. 1991) (sub-section 3.7.15) – higher dental anxiety in late adulthood had the greatest effect on age 63 tooth retention (standardised total effect: -0.305; 95% CI: -0.441, -0.156), followed by being educated to degree level or above (+0.188; 95% CI: 0.069, 0.306), higher dental anxiety in early adulthood (-0.154; 95% CI|: -0.242, -0.073), higher pack-years of smoking between ages 30 and 62 (-0.143; 95% CI: -0.270, -0.020), higher pack-years of smoking between ages 10 and 29 (-0.107; 95% CI: -0.204, -0.014), being female (-0.100; 95% CI: -0.169, -0.032), regular dental attendance at age 50 (+0.061; 95% CI: 0.017, 0.111), being in a higher social class at birth (+0.059; 95% CI: 0.024, 0.102), regular dental attendance at age 15 (+0.047; 95% CI: 0.020, 0.080), regular dental attendance at age 35 (+0.030; 95% CI: 0.007, 0.063) and, finally, receiving strong or moderate parental encouragement to look after one's teeth in childhood (+0.016; 95% CI: 0.006, 0.031).

To put these standardised total effects into context and avoid the potentially misleading influence of a variable's sample variance on standardised estimates (Frone 2012; Greenland et al. 1991), unstandardised total effects showed that being educated to degree level or above changed age 63 tooth retention by +1.819 (95% CI: 0.634, 3.036), being female by -0.978 (95% CI: -1.771, -0.294), regular dental attendance at age 50 by +0.965 (95% CI: 0.276, 1.885), being in a higher social class at birth by +0.761 (95% CI: 0.293, 1.367), regular dental attendance at age 15 by +0.468 (95% CI: 0.188, 0.848), regular dental attendance at age 35 by +0.425 (95% CI: 0.098, 0.919) and, finally, receiving strong or moderate parental encouragement to look after one's teeth in childhood by +0.159 (95% CI: 0.055, 0.323). Reassuringly, the order of the size of the unstandardised total effects for the binary variables was the same as for the standardised total effects; hence, the latter have not been misleadingly affected by the variances of the sample variables. Comparing the relative unstandardised total effects of the continuous variables (which is less intuitive, as the units differ significantly from the binary variables – hence the benefits of standardised total effects) found that an increased score of 5.6 in dental anxiety in late adulthood (28% of the twenty point scoring scale) resulted in the same effect as education level (unstandardised total effect of -1.819). Furthermore, an increased score of 4.0 in dental anxiety in early adulthood (33% on a twelve point scoring scale), an increase of 13.6 pack-years of smoking between the ages of 30 and 62 (0.43 pack-years per year) and an increase of 9.5 pack-years of smoking between the ages of 10 and 29 (0.50 pack-years per year) resulted in the same effect as sex (unstandardised total effect of -0.978).

Figure 14 is presented to further help contextualise these unstandardised total effects on age 63 tooth retention. The positions of the variables in this figure mimic those in the final path diagram (Figure 13) for consistency. The values attached to circles indicate the unstandardised change in age 63 tooth retention for the indicated change in each variable (compared to the reference category for binary variables). The areas of the circles visually represent the size of this change. For example, this figure visually shows that being educated to A-level standard or above has a greater overall effect on age 63 tooth retention than being in social class group I, II or III at birth (increasing tooth retention by 1.819, compared to 0.761 respectively). Furthermore, this figure shows that being educated to A-level standard or above has the same effect on tooth retention as moving 28% down the dental anxiety scale in late adulthood.

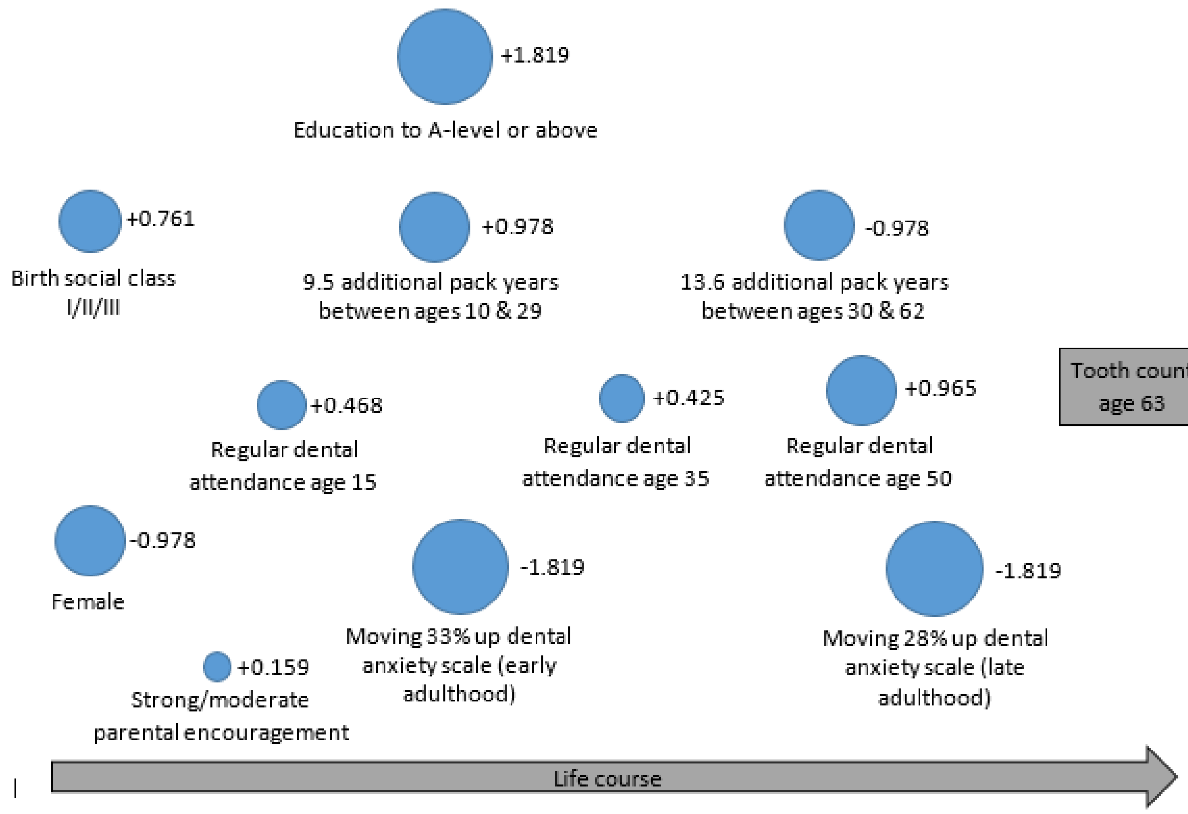

Figure 14: Visual representation of the sizes of the unstandardised total effects of predictor variables on age 63 tooth retention (n=198).
Values attached to circles indicate the change in age 63 tooth count for the indicated change in each variable (compared to the reference category for binary variables). The areas of the circles visually represent the size of this change.

The third and final key finding in relation to the final path model relates to the pathways of influence of the predictor variables on age 63 tooth retention. To supplement the breakdown of total effects into direct and indirect effects, provided in Table 27, Table 28 additionally breaks down these indirect effects by individual pathways. These tables show that the negative effects on tooth retention of pack-years smoking between ages 30 and 62 and dental anxiety in late adulthood were direct effects, not mediated by intermediate variables. The positive effect of education on tooth retention was also mainly direct (91%), but a small component was indirect via its influence on smoking between ages 30 and 62 (9%). The effects of all other variables on age 63 tooth retention, however, were purely indirect; pack-years of smoking between ages 10 and 29 exerted its effects via its influence on pack-years of smoking between ages 30 and 62; the effect of dental anxiety in early adulthood was predominantly indirect via dental anxiety in late adulthood (96%), but also via age 35 dental attendance (4%); the positive effect of parental encouragement to look after one's teeth in childhood was mediated by its effect on dental attendance at age 15; the positive effect of being in a higher social class at birth was predominantly mediated by its effect on education (78%), but also via its effects on age 15 dental attendance and parental encouragement; the effects of being female were predominantly mediated via detrimental influences on dental anxiety in early and later adulthood, but also detrimental effects on education; and, finally, the effects of dental attendance at each age were completely mediated via dental anxiety or dental attendance at subsequent ages. Breaking down the latter, the effect of dental attendance at age 15 was predominantly via dental anxiety in early adulthood (90%), but also via dental attendance at age 35 (10%); the effect of dental attendance at age 35 was completely mediated via dental attendance age 50; and the effect of dental attendance at age 50 was completely mediated via its decreasing effect on dental anxiety in late adulthood.

Indirect pathway	Unstandardised beta
Sex	
→ dental anxiety (late adulthood) → tooth count age 63	-0.635
→ education level → tooth count age 63	-0.332
→ dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63	-0.309
→ pack-years 10-29 → pack-years 30-62 → tooth count age 63	0.194
→ Dental attendance 15 → dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63	0.081
→ dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.055
→ education level → pack-years 30-62 → tooth count age 63	-0.032
→ Dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	-0.012
→ dental attendance 15 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.010
→ dental attendance 15 → dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.003
Parental encouragement	
→ dental attendance 15 → dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63	0.137
→ dental attendance 15 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.016
→ dental attendance 15 → dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.006
Education level	
→ pack-years 30-62 → tooth count age 63	0.161
Social class birth	
→ education level → tooth count age 63	0.541
→ dental attendance 15 → dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63	0.115
→ education level → pack-years 30-62 → tooth count age 63	0.053
→ parental encouragement → dental attendance 15 → dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63	0.030
→ dental attendance 15 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.014
→ dental attendance 15 → dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.005
→ parental encouragement → dental attendance 15 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.004
→ parental encouragement → dental attendance 15 → dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	0.001

Indirect pathway	Unstandardised beta
Pack-years 10-29 → pack-years 30-62 → tooth count age 63	 -0.103
Dental Anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	 -0.233 -0.009
Dental attendance 15 → dental anxiety (early adulthood) → dental anxiety (late adulthood) → tooth count age 63 → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63 → dental anxiety (early adulthood) → dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	 0.404 0.048 0.016
Dental attendance 35 → dental attendance 50 → dental anxiety (late adulthood) → tooth count age 63	 0.426
Dental Attendance 50 → dental anxiety (late adulthood) → tooth count age 63	 0.966

Table 28: Indirect pathways from predictor variables to tooth count age 63, according to the final path model (n=198).

5.6: Goodness-of-fit statistics

Table 29 reports several goodness-of-fit statistics for the final path model. As evidence to reject the assumption of multivariate normality was demonstrated (Table 19, page 134), use of the robust goodness-of-fit statistics is most appropriate, as discussed in sub-section 3.7.16.

The unadjusted model chi-squared statistic was significant at the 1% level, but the robust model chi-squared p-value was above 0.05 (p=0.097). This suggests that, when taking into account non-normality of the data, there was no evidence at the 5% level to reject the path model. Furthermore, the unadjusted and robust normed chi-squared values, which are less sensitive to sample size, were 1.73 and 1.28 respectively. Both of these values are well below recommended upper thresholds for acceptable model fit (ranging from 2 to 5) (Hooper et al. 2008), indicating a good model fit.

Evaluating the approximate fit statistics reported, the unadjusted and robust CFI values were 0.933 and 0.974 respectively. According to previously suggested thresholds of 0.95 for good fit and 0.9 for adequate fit (Garson 2015), these statistics suggest adequate or even good model fit. The unadjusted and robust RMSEA values of 0.061 and 0.038 also suggest adequate or even good model fit, based on suggested thresholds of 0.05 or 0.06 for good fit and 0.08 for adequate fit (Garson 2015).

The R-squared statistic suggests fifteen percent of the variation in tooth count age 63 was explained by the final path model.

Goodness-of-fit statistics	Value
Model chi-squared statistic (p-value)	77.65 (0.002)
Robust model chi-squared statistic (p-value)	57.70 (0.097)
Normed chi-squared value (unadjusted/robust)	1.73/1.28
Comparative fit index (CFI) (unadjusted/robust)	0.933/0.974
Root mean square error of approximation (RMSEA) (unadjusted/robust)	0.061/0.038
R-squared (tooth count age 63)	0.151

Table 29: Goodness-of-fit statistics for the final path model of the life course determinants of age 63 tooth retention (n=198).

5.7: Testing model on full sample (n=245)

The final path model, derived from the sample of 198 individuals with complete data, was tested on the full eligible sample for the path analysis (n=245), to assess the fit of this model when individuals with missing data were included. As described in sub-section 3.7.17, full-information maximum likelihood estimation allowed testing of this model in the presence of missing data, even though model building in the presence of missing data was not possible (Arbuckle 2016). The use of bootstrapping, however, was not possible, as AMOS does not permit this function when data is missing (Arbuckle 2016).

Application of the model to this full sample resulted in two of the model paths becoming non-significant at the 5% level (sex to dental attendance age 35 and dental anxiety (early adulthood) to dental attendance age 35). Following removal of these paths, one further path became non-significant (education level to pack-years age 30-62). Following removal of this path, all other direct paths remained significant at the 5% level.

Changes to unstandardised and standardised total effects on age 63 tooth retention were substantial for sex (increasing from -0.978 and -0.100 to -1.492 and -0.141, respectively), negligible for pack-years 10-29 and modest for all other variables (Table 30).

Predictor variable	Unstandardised beta	Standardised beta
Sex Male (ref) Female	-1.492	-0.141
Parental encouragement Little/none (ref) Strong/moderate	0.171	0.016
Education level Below A-levels (ref) A-levels or above	2.113	0.200
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	0.874	0.065
Pack-years 10-29	-0.104	-0.104
Pack-years 30-62	-0.080	-0.147
Dental anxiety (early adulthood)	-0.279	-0.168
Dental anxiety (late adulthood)	-0.364	-0.324
Dental attendance 15 Less than once per year (ref) At least once per year	0.456	0.043
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	0.490	0.033
Dental attendance 50 Less than once every 2 years (ref) At least once every 2 years	1.087	0.065

Table 30: Unstandardised and standardised total effects of life course variables on tooth count age 63, when the final path model was tested on the full eligible sample (n=245)

Regarding goodness-of-fit statistics, the model chi-squared statistic increased to 92.271 and remained highly significant (p<0.001), suggesting a worse model fit. However, as the robust model chi-squared p-value could not be produced – as missing values were present (Arbuckle 2016) – it was not possible to reliably assess the fit of this model according to the chi-squared p-value.

According to supplementary fit statistics, the unadjusted normed chi-squared value increased to 1.92, which remains below recommended thresholds for good fit (Hooper et al. 2008). The unadjusted CFI also reduced minimally from 0.933 to 0.923 and the unadjusted

RMSEA remained the same at 0.061, suggesting the model remains an adequate fit (Garson 2015). However, again, robust values could not be calculated.

The proportion of variance in tooth count age 63 explained by this model increased from 0.151 to 0.173.

5.8: Testing model on larger sample (n=223)

As bootstrapping and the production of robust goodness-of-fit measures were not permitted when testing the final path model on the full sample (n=245), due to missing data, the final path model was also tested on the sample of 223 individuals, who had complete data for all of the predictor variables in the final model.

Two of the model paths became non-significant at the 5% level (sex to dental attendance age 35 and dental anxiety (early adulthood) to dental attendance age 35). Following removal of these non-significant paths, all other direct paths remained significant at the 5% level.

Changes to unstandardised and standardised total effects on age 63 tooth retention were substantial for sex (increasing from -0.978 and -0.100 to -1.410 and -0.136, respectively) and modest for all other variables (Table 31).

Predictor variable	Unstandardised beta	Standardised beta
Sex Male (ref) Female	-1.410	-0.136
Parental encouragement Little/none (ref) Strong/moderate	0.175	0.017
Education level Below A-levels (ref) A-levels or above	2.111	0.205
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	-0.874	-0.066
Pack-years 10-29	-0.081	-0.082
Pack-years 30-62	-0.065	-0.121
Dental anxiety (early adulthood)	-0.260	-0.159
Dental anxiety (late adulthood)	-0.349	-0.317
Dental attendance 15 Less than once per year (ref) At least once per year	0.482	0.046
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	0.522	0.036
Dental attendance 50 Less than once every 2 years (ref) At least once every 2 years	1.139	0.069

Table 31: Unstandardised and standardised total effects of life course variables on tooth count age 63, when the final path model was tested on the larger sample (with complete data for those variables included in the final path analysis) (n=233).

Regarding goodness-of-fit statistics, the model chi-squared statistic increased to 100.197 and remained highly significant (p<0.001). The robust model chi-squared p-value decreased to below 0.05, from 0.097 to 0.013, suggesting there is significant evidence that this model is not an appropriate fit to the data.

The normed chi-square value, however, suggested a worsening but still adequate or even good model fit (Hooper et al. 2008) – the unadjusted and robust normed chi-squared values increased to 2.13 and 1.51 respectively. Equally, the CFI and RMSEA values suggest a worsening but still adequate or even good model fit (Garson 2015) – the unadjusted and robust CFI values reduced to 0.902 and 0.956, respectively, whilst the unadjusted and adjusted RMSEA values increased to 0.071 and 0.048, respectively.

The proportion of variance in age 63 tooth count explained by this model increased from 0.151 to 0.164.

5.9: Summary of quantitative results

According to the final path model constructed using the sample of 198 individuals with complete data, factors across the whole life course, including social, behavioural and psychological factors, influenced tooth retention at age 63.

Comparing unstandardised total effects for binary variables, being educated to degree level or above had the greatest effect on age 63 tooth retention (+1.819), followed by being female (-0.978), regular dental attendance at age 50 (+0.965), being in a higher social class at birth (+0.761), regular dental attendance at age 15 (+0.468), regular dental attendance at age 35 (+0.425) and, finally, receiving strong or moderate parental encouragement to look after one's teeth in childhood (+0.159). Regarding relative comparisons for continuous variables, standardised total effects suggested that higher dental anxiety in late adulthood resulted in a greater negative effect than being educated to below degree level, and that higher dental anxiety in early adulthood, pack-years of smoking between ages 30 and 62 and pack-years of smoking between ages 10 and 29 resulted in greater negative effects than being female (in order of greatest effects), but lesser effects than education level. Using unstandardised effects to provide context for these continuous variables, an increased score of 5.6 in dental anxiety in late adulthood (28% of the twenty point scoring scale) resulted in the same effect as education level (unstandardised total effect of -1.819). Furthermore, an increased score of 4.0 in dental anxiety in early adulthood (33% on a twelve point scoring scale), an increase of 13.6 pack-years of smoking between the ages of 30 and 62 (0.43 pack-years per year) and an increase of 9.5 pack-years of smoking between the ages of 10 and 29 (0.50 pack-years per year) resulted in the same effect as sex (unstandardised total effect of -0.978).

In contrast, standardised birth weight, age 50 social class, the presence of illness limiting daily activities at age 50, the number of years married, sugar consumption at age 50 and tooth brushing frequencies at ages 15, 35 and 50 did not significantly influence tooth retention.

Regarding pathways of influence, the effects of pack-years of smoking between ages 30 and 62 and dental anxiety in late adulthood were direct, as were the majority of the effects of education level. However, the effects of all other factors on age 63 tooth retention were entirely mediated by intermediate variables.

There was some evidence that the path model derived from the sample of 198 individuals was slightly different to the path model that would have been produced on the full eligible sample of 245 individuals, if missing data had not prevented model building using this latter sample. Application of the final path model to the larger samples (n=245 and n=233) resulted in the loss of significance of a small number of direct paths and generally modest changes in the total effects of predictor variables on age 63 tooth retention (apart from substantial increases for sex). There was also uncertainty regarding the acceptability of model fit according to goodness-of-fit statistics.

Chapter 6: Discussion

This mixed-methods research comprised two separate but related studies. Both addressed the overarching aim of this project – to investigate the life course determinants of oral health in the UK – but each focused on distinct objectives: the first explored the factors across the life course determining how and why people look after their oral health (using a qualitative methodology); and the second quantitatively modelled the contributions of determinant factors across the life course on oral health (specifically tooth retention).

Section 6.1 and 6.2 of this Discussion chapter will firstly discuss the findings of these two studies independently from each other, considering their contributions to the existing literature in the context of their strengths and limitations. Section 6.3 subsequently draws together these two studies, comparing their findings where their remits overlapped and reviewing their joint contribution to the overarching research aim, in the context of existing knowledge. This third section also discusses the implications of this mixed-methods research for policy and practice and concludes by considering the implications of this project for future research.

6.1: Qualitative Study

6.1.1: Key findings

A comprehensive summary of the findings of the qualitative interviews was provided in Chapter 4. Hence, only a concise summary will be provided here to re-orient the reader whilst avoiding repetition.

In brief, this research suggested that:

- Multiple factors determined how and why interviewees looked after their oral health across the life course, and these particularly grouped around the following sources: the dental profession, society, family members and the individuals themselves.
- Influences appeared to vary between different behaviours. Broadly speaking, dental attendance, oral hygiene and dietary practices seemingly shared many similar influences, although dental attendance was additionally heavily influenced by dental anxiety, and dietary practices additionally influenced by enjoyment and, moreover, systemic health concerns. In relation to smoking behaviours, the predominant influencing factors discussed were more specific, with initiation being predominantly

attributed to peer influences, and cessation primarily attributed to systemic health but also financial concerns.

- Influences changed across the life course. Parents were seemingly the predominant influencers in childhood, although schools, siblings and the dental profession also reportedly played a role, the latter especially in relation to shaping dental anxiety. During the transition to independent adulthood, the influence of childhood authorities seemed to persist, but individual-level factors and peers also began to play a predominant role. Finally, in independent adulthood, a central role of individual-level factors, society (particularly peers and media sources) and the dental profession generally appeared to persist. However, the predominant influence of family members often transferred from parents to spouses and children, especially the former.
- The interplay between competing influences of behaviours was complex. In support of the PRIME theory of motivation (West 2006), motivation for performing a certain behaviour seemed to be determined by the balance of all positive and negative motivators at a particular time. Notably, dominant negative motivators appeared to be the pleasure of enjoyment, dental anxiety and a lack of time. In support of the COM-B theory of behaviour (Michie et al. 2011), determinants of behaviours seemed to influence capability and opportunity as well as motivation. Moreover, there was evidence that the absence of capability or opportunity impeded OHBs even if motivation was high, whilst the presence of capability or opportunity was often insufficient to affect behaviour in the absence of motivation.
- There are likely some differences between the factors determining how and why this 1947 cohort looked after their teeth and those influencing contemporary UK populations, relating to changes in factors such as media influences, the provision of oral health education by dentists and the anxiety-provoking nature of dental visits, amongst other things.

6.1.2: Research strengths

This qualitative research study had multiple strengths. Firstly, as comprehensively reviewed in Section 2.14 of the literature review, it was the first qualitative study in the UK to focus specifically upon the determinants of people's oral health-related behaviours from a life course perspective. One previous UK study had used a qualitative life course approach to explore the development of oral health in older adults, but the focus of this research was broader than that of the present study, and the published findings to date, of relevance to the aim of the present study, have been reasonably limited (Gibson et al. 2019; Kettle et al. 2019). Of note, this study was also published after the qualitative component of this PhD research was undertaken. Other qualitative studies in the UK have focused mainly on the cross-sectional determinants of oral health and related behaviours at various ages (Amos and Bostock 2008; Borreani et al. 2010; Daly et al. 2010; Delaney et al. 2018; Gibson et al. 2019; Gill et al. 2011; Gregory et al. 2007; Hall-Scullin et al. 2015; Hill et al. 2003; Kerr et al. 2006; Marshman et al. 2016; Stokes et al. 2006). In addition, a few qualitative studies have used a life course approach to study the determinants of oral health outcomes and behaviours in other countries, but these are scarce (Delaney and McCarthy 2011; MacEntee et al. 2019; Thomeer et al. 2019), and their applicability to UK populations is sometimes limited (MacEntee et al. 2019).

Secondly, the methods used in the qualitative component of this research were generally very robust (as discussed in detail in Chapter 3). Briefly, the sampling strategy used was purposeful and iterative, ensuring the sample reflected a diversity of individuals and allowing confirmation or disconfirmation of emerging ideas. The sample size was also reasonable and allowed a pragmatic point of data saturation to be achieved. Regarding the interviews, they were in-depth, allowing participants' accounts to be thoroughly explored. Questioning was also primarily inductive, which enabled interviewees to explore issues of relevance to them, rather than pre-conceived topics. However, elements of a deductive approach were also included, particularly to guide participants to discuss key, established OHBs if they did not do so voluntarily. Finally, the data analysis process was robust, being methodical and systematic and involving a second researcher to improve validity. Data analysis was also primarily inductive, meaning the findings were primarily generated from participants' accounts. However, importantly, deductive approaches also allowed these findings to be situated in the context of previous research and theory.

6.1.3: Research limitations

The limitations associated with this qualitative research have been discussed in detail in Chapter 3. Hence, the intention of this section is purely to summarise the effects of these limitations on the validity and usefulness of the research findings.

A small number of limitations were considered to have had a moderate effect on the findings of this research. Firstly, the reliance on interviewees' retrospective recall of life course events has likely compromised the robustness of this research to a certain extent, especially the findings relating to earlier in the life course. As discussed in sub-section 3.6.9, issues with memory recall were expressed in many interviews. Fortunately, such issues were not widespread across whole accounts and the contribution of recollections explicitly affected by memory issues were modified accordingly during the data analysis process. Nonetheless, the extent to which recall issues may have imperceptibly affected participants' responses is unknown and, therefore, the research findings should be treated with some level of caution.

Secondly, the application of the research findings from a 1947 birth cohort to more contemporary generations is a further considerable limitation. As discussed in sub-section 3.6.9, period changes in the determinants of people's behaviours were frequently recognised in the interviews, as would be expected according to current knowledge (Fielding 1999; Glenn 2005; Oláh et al. 2018). However, to mitigate for this limitation, such period changes were openly considered during the data analysis process (Section 4.3), and any proposed contemporary application of this research (sub-section 6.3.3) takes account of these issues. Nonetheless, it must be borne in mind that this process relied to a certain extent on conjecture and postulation.

All other limitations associated with this research must still be acknowledged, but it is likely that their effects on the robustness and utilisation of the research findings is more modest. Such limitations include: the reliance on participants' subjective accounts as evidence, rather than observational methods, which is a recognised disadvantage of interview methodologies (Green and Thorogood 2018; Stimson and Webb 1975); the effect of myself as the researcher on the research process (see sub-section 3.6.8); and the generalisability of findings from a North-East England cohort, also biased by loss to follow-up, to the UK population. As discussed in sub-section 3.6.1, the effects of the latter should have been minimised by the purposive sampling strategy, which actively sought out participants based upon specific characteristics, including current residence outside of North-East England. Furthermore, this study covered a very broad topic area – the focus being on the determinants of a range of different behaviours across the whole life course. Although this was a strength of the study, this broad scope also sometimes limited the depth of detail that could be reached on specific topics, such as the determinants of smoking initiation or cessation, which could themselves be substantial research topics in their own right (Pourtau et al. 2019; Tombor et al. 2017). The findings of this study, therefore, must be utilised alongside other research within this field. Lastly, the use of a primarily inductive approach to interviewing and data analysis (sub-sections 3.6.5 and 3.6.6), although identified as a strength of this research, could also be considered a limitation. In particular, the decision not to base the interview topic guide and data analysis process around established health behaviour theories (such as the TDF and COM-B models (Cane et al. 2012; Michie et al. 2011)) may have limited the exploration of more subtle influences, perhaps outside of an interviewees' immediate awareness.

6.1.4: Contribution to existing knowledge

The findings of this qualitative research accord with well-accepted contemporary beliefs about the wider determinants of oral health (DoH 2005; Marmot and Bell 2011; Watt et al. 2015; Watt 2007) – specifically that a diverse range of factors at the level of the individual and beyond determine oral health and related behaviours. Perhaps understandably, however, given the reliance upon interviewees' personal accounts, the findings of this research focused to a greater extent on more intermediate level determinants of people's behaviours, such as social relationships and health service influences, rather than more upstream structural determinants, such as trade, economic policies or globalisation (Watt et al. 2015).

Broadly speaking, the determinants of how and why people looked after their teeth, identified within this research, have been supported by previous evidence. For example, prior research has suggested that individuals' oral health beliefs and oral health-related behaviours are influenced by dental professionals – both via the provision of education (Gibson et al. 2019; Hall-Scullin et al. 2015; Jensen et al. 2011) and their contribution to dental anxiety (Borreani et al. 2010; Dahlander et al. 2019; Gregory et al. 2012); their parents (Gill et al. 2011; Kettle et al. 2019; Stokes et al. 2006), spouses (Lewis and Butterfield 2007; Markey et al. 2008; Thomeer et al. 2019), siblings (McGee et al. 2015; Puri et al. 2019; Ragelienė and Grønhøj 2020) and children (Delaney and McCarthy 2011; Jarvis 1996; Kettle et al. 2019; Thomeer et al. 2019); the school environment (Bonell et al. 2019; Duijster et al. 2015; Gibson et al. 2019; West et al. 2004); peer groups (Gibson et al. 2019; Hall-Scullin et al. 2015; Hoffman et al. 2007; Rawahi et al. 2018); media and marketing sources (Bala et al.

2017; Fitzgerald et al. 2004; Jensen et al. 2011; Rawahi et al. 2018); and individual-level factors, such as health knowledge (Jensen et al. 2011; Rawahi et al. 2018; Syrjala et al. 2001) and beliefs about the value of health (Block et al. 2013; Fitzgerald et al. 2004; Gibson et al. 2019; Gregory et al. 2007; Ostberg et al. 2002).

Previous studies have also highlighted both similarities and differences between the determinants of different OHBs. Like the present research, prior studies have identified many shared determinants between oral hygiene and dental attendance behaviours, but also some differences, such as dental anxiety. However, the ability for detailed comparisons is limited by the small number of qualitative studies that distinguish between the determinants of these two behaviours, especially in mainstream populations in the UK (Gill et al. 2011; Gregory et al. 2007; Hill et al. 2003; Marshman et al. 2016).

In relation to dietary behaviours, particularly sugar consumption, the present study also supports the prevailing view that the profile of influencing factors is very broad. The ecological framework depicted in Figure 15 was constructed by Story et al. (2008) and outlines the multiple potential influences of people's diets. Individual studies examining influences of food choice in general (Bloom et al. 2017; Delaney and McCarthy 2011; Goldthorpe et al. 2018; Host et al. 2016; Wham and Bowden 2011; Whitelock and Ensaff 2018), and influences of sugar consumption (Battram et al. 2016; Block et al. 2013; Graham et al. 2013; Krukowski et al. 2016; Rawahi et al. 2018), also evidence such broad arrays of determinants. Of particular relevance, the importance of health concerns as a key influence of diet is widely recognised in the literature (Battram et al. 2016; Delaney and McCarthy 2011; Goldthorpe et al. 2018; Host et al. 2016; Rawahi et al. 2018). In particular, studies have shown that major health events are one of few factors generally sufficient to bring about substantial changes in dietary trajectories (Devine 2005; Edstrom and Devine 2001). However, limited research to date has explored the contribution of oral health concerns to dietary behaviour change (Rawahi et al. 2018), highlighting the important contribution of the present research. Notably, the existing evidence to date supports the suggestion of the present study that oral health concerns are generally of secondary importance to systemic health concerns (Rawahi et al. 2018).

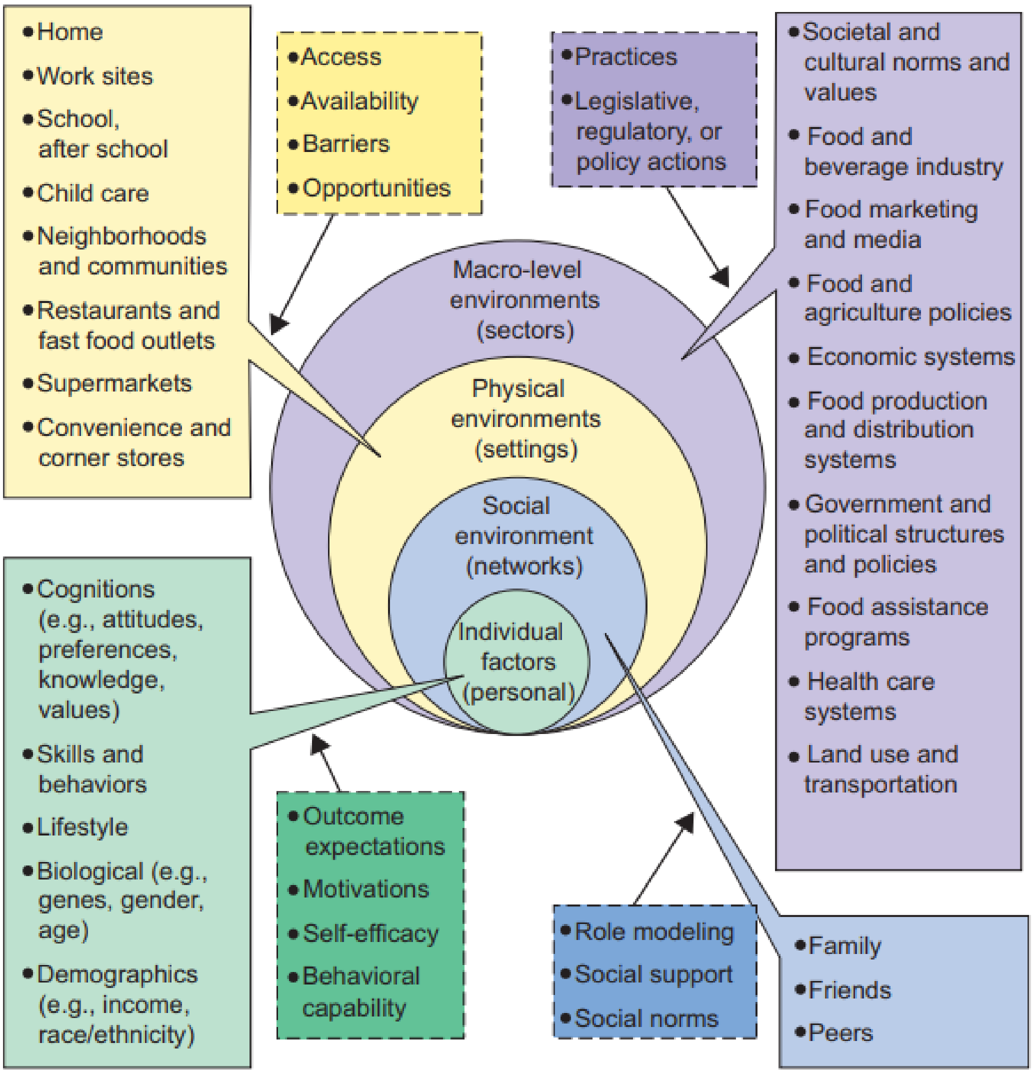

Figure 15: An ecological framework depicting the multiple influences on what people eat. Reproduced from (Story et al. 2008).

With regards to smoking behaviours, this study revealed only a few of the diverse determinants of smoking initiation proposed by previous research (Figure 16) (Wood et al. 2019) – predominantly the role of peers and, secondarily, parents. Such influences have previously been identified as particularly central determinants of smoking initiation (Hoffman et al. 2007; Simons-Morton and Farhat 2010), likely explaining their dominance within the present study. The recognition of other potential influencing factors in this research may have been limited by the retrospective nature of people's recollections about smoking initiation, which relied upon recall from at least forty years earlier, and also the broad focus of this research study, which limited the depth to which each individual topic could be explored. Period changes may also partly explain differences in the determinants of smoking initiation identified in the present study compared to contemporary research

(Wood et al. 2019), for example changes in exposure to media sources since the mid-twentieth century (see sub-section 4.3.4) (Ortiz-Ospina 2019; Roser et al. 2015).

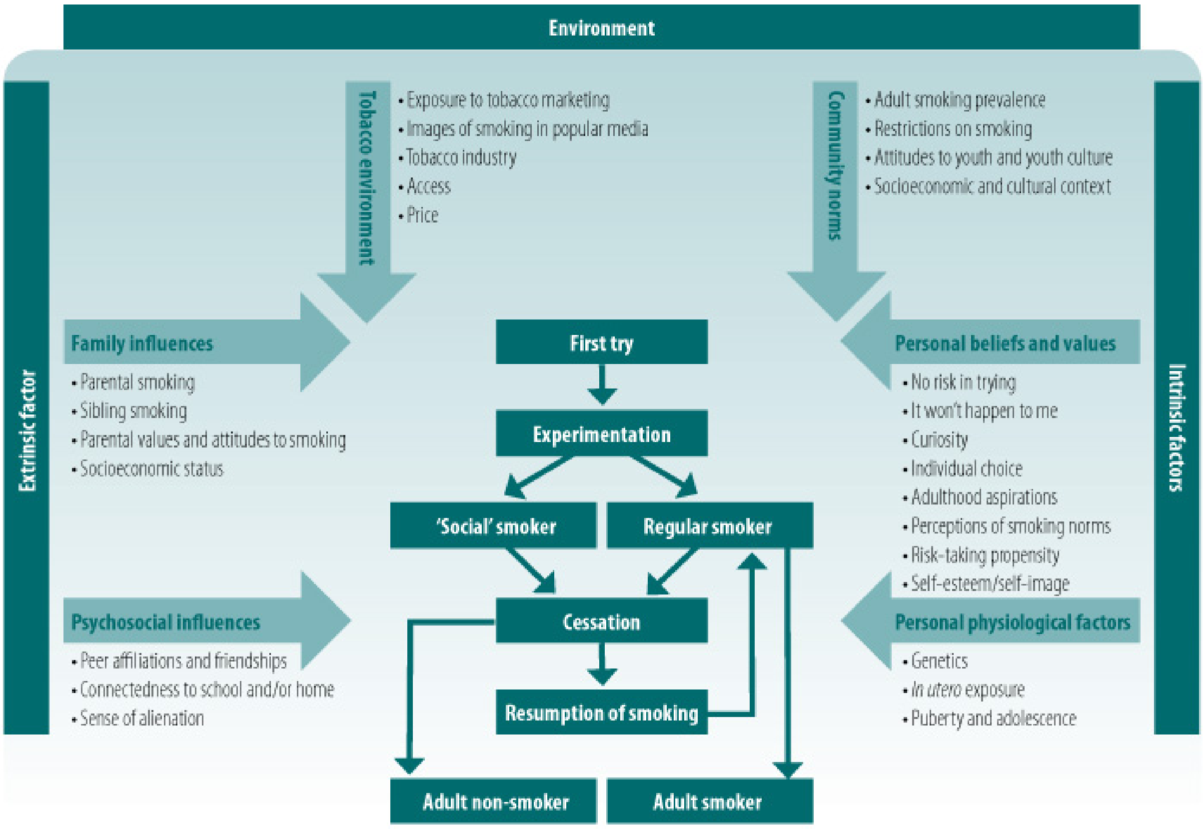

Figure 16: Illustration of the multiple influences of smoking initiation. Reproduced from (Wood et al. 2019).

With respect to smoking cessation, it is notable that existing research has identified health concerns as the predominant motivation for cessation (McCaul et al. 2006; Oral Health Foundation 2019), and financial concerns as an important secondary motivation (McCaul et al. 2006), supporting the present research. In agreement with the present study, psychological characteristics have also been recognised as central to smoking cessation success (Grassi et al. 2014; Greenhalgh et al. 2016; Hitsman et al. 2013; Zvolensky et al. 2007), especially the role of self-efficacy (Castro et al. 2014; Elshatarat et al. 2016; Gwaltney et al. 2009). However, this study adds novel evidence regarding the (seemingly limited) contribution of oral health concerns to smoking cessation. Existing research directly addressing this topic is scarce and conflicting (Andersson and Johannsen 2016; Rosseel et al. 2010). In addition, where evidence suggests that oral health motivations may be reasonable important, the validity of this research is in doubt (Andersson and Johannsen 2016). Specifically, this study in question measured hypothetical reasons for smoking cessation in smokers, regardless of their actual intentions to quit, and was conducted in a dental setting, likely biasing participants' responses. Of note, previous research in the UK has shown that knowledge about the negative oral health effects of smoking is poor, and certainly inferior compared to knowledge about its systemic health effects (Lung et al. 2005; Terrades et al. 2009). This may at least partially explain a potentially more limited role of oral health, compared to general health, in reasons for smoking cessation.

Regarding how the determinants of OHBs changed across the life course, previous research has generally agreed that parental influence is a central determinant of behaviours in childhood (Battram et al. 2016; Duijster et al. 2015; Gill et al. 2011; Goldthorpe et al. 2018; Kettle et al. 2019) and that schools (Duijster et al. 2015; Gibson et al. 2019; Gill et al. 2011), siblings (Puri et al. 2019; Ragelienė and Grønhøj 2020) and the dental profession can also be influential, the latter particularly via their contribution to dental anxiety (De Oliveira et al. 2006; Gao et al. 2013; Townend et al. 2000). Pertaining to the period of transition to independent adulthood, the increasing importance of peers and individual-level factors is also well documented, alongside a persisting (although generally lesser) influence of parents (Alves et al. 2016; Amos and Bostock 2008; Hall-Scullin et al. 2015; Hoffman et al. 2007; Ostberg et al. 2002; Scalici and Schulz 2014; Shepherd et al. 2006; Simons-Morton and Farhat 2010; Stead et al. 2011; Stokes et al. 2006). In particular, like the present study, prior research suggests that the desire to conform to peer behavioural norms (Amos and Bostock 2008; Simons-Morton and Farhat 2010; Stead et al. 2011) and concerns about the social acceptability of oral health (Hall-Scullin et al. 2015; Ostberg et al. 2002; Stokes et al. 2006) are particularly strong at this age.

Considering the period of established independent adulthood, past research has similarly demonstrated that adulthood oral health beliefs and behaviours are influenced by a wide array of factors, including the long-lasting effects of parental influences in childhood, dental professionals, media and marketing sources, peers, and various individual-level factors, such as health knowledge, dental anxiety and cost (Delaney and McCarthy 2011; Gibson et al. 2019; Gregory et al. 2007; Hill et al. 2003; Jensen et al. 2011; McCaul et al. 2006; Rawahi et al. 2018; Syrjala et al. 2001; Uppal et al. 2013). However, in-depth qualitative investigations of the determinants of OHBs in adulthood have been much more limited than those focusing on other life course stages, particularly those relating to behaviours mainly of relevance to oral, rather than general, health (i.e. dental attendance and oral hygiene behaviours)

(Gibson et al. 2019; Gregory et al. 2007; Hill et al. 2003; Jensen et al. 2011; Kettle et al. 2019; Syrjala et al. 2001). Consequently, the present study adds substantial value to this evidence base. For example, only very limited evidence to date has recognised the impact of having children on adulthood dental attendance and oral hygiene behaviours (Kettle et al. 2019). Moreover, although several studies demonstrate an influence of spouses on adult smoking and dietary behaviours (Lewis and Butterfield 2007; Markey et al. 2008; Thomeer et al. 2019), the present study is the first to provide any substantial evidence of their impact upon dental attendance and oral hygiene practices.

Finally, as previously mentioned (sub-section 3.6.5), the two comprehensive, contemporary health behaviour theories presently considered most applicable to oral health (Asimakopoulou and Newton 2015) are the linked TDF (Cane et al. 2012) and COM-B models (Michie et al. 2011). It is therefore useful to reflect upon the findings of the present study in the context of such theories. As outlined in Appendix P, the findings of this study can be related very clearly to the majority of the fourteen domains of the TDF framework, especially the following ten domains: knowledge; social influences; environmental context and resources; social/professional role and identity; beliefs about capabilities; beliefs about consequences; intentions; goals; reinforcement; and emotion. For example, the frequently recalled influence of oral health knowledge on how people looked after their teeth clearly maps to the 'knowledge' domain of the TDF. Relationships to the remaining four domains (skills; behavioural regulation; memory, attention and decision processes; and optimism) were more limited, especially for the latter two domains (Appendix P). This does not necessarily infer that such domains are not relevant to OHBs, however, but rather that they were not identified by the interviewees in this research process. As acknowledged as a limitation of this research (sub-section 6.1.3), it may be that some of the above potential influences were not uncovered via the primarily inductive approach to interviewing used in this research, perhaps due to their subtlety and, therefore, position outside of a participant's immediate awareness.

According to the proposed mapping of the domains of the TDF to the COM-B model (Cane et al. 2012), it is also clear that the findings of this research can be related to each component of the latter model – capability (psychological and physical), opportunity (social and physical) and motivation (reflective and automatic) (Appendix P). Furthermore, as presented in Section 4.4, this research also supports the premise of the COM-B model that capability, opportunity and motivation need to be present simultaneously for a behaviour to be performed (Michie et al. 2011).

The alignment of the findings of this research in many ways to the TDF and COM-B health behaviour theories is encouraging from two perspectives: firstly, this research further supports the validity of the above theories to the field of oral health, an argument supported by only a small amount of empirical research to date (Marshman et al. 2016; Rawahi et al. 2018); vice versa, the consideration of these health behaviour theories as the most applicable to oral health today (Asimakopoulou and Newton 2015) adds credibility to the findings of this research.

6.2: Quantitative Study

6.2.1: Key findings

The quantitative analysis suggested that factors across the whole life course influenced tooth retention at age 63 in the NTFS, including behavioural practices (smoking and dental attendance), demographic factors (sex), social determinants (education, social class and parental encouragement), and psychological factors (dental anxiety).

In terms of the relative importance of the factors investigated, this research suggested that dental anxiety across the whole life course had the greatest overall effect on age 63 tooth retention, being particularly important in later adulthood (higher anxiety being associated with lower tooth retention). Following this, being educated to degree level had the next greatest effect (with higher education associated with higher tooth retention). Smoking behaviours across the whole life course, sex, life course dental attendance patterns and social class at birth were associated with the next greatest effects (with higher smoking, female sex, irregular attendance patterns and lower social class associated with lower tooth retention). Lastly, parental encouragement in childhood to look after one's teeth was associated with the smallest effect.

In the context of actual tooth numbers, the size of most of the above effects were clinically meaningful. For example, being educated to degree level or above was associated with almost two (1.819) additional retained teeth, being female with almost one less tooth, and regular dental attendance at age 50 with almost one additional tooth. Even at the lower end of effects, regular dental attendance at age 15 or at age 35 were associated with almost half an additional tooth, on average. Below this, however, strong or moderate parental encouragement to look after one's teeth in childhood was only associated with 0.159 additional retained teeth, which is perhaps less clinically relevant.

In contrast, this research suggested that birth weight, the number of years married, tooth brushing frequencies across the life course, and social class, the presence of illness and sugar consumption in later adulthood (at age 50) were not significantly associated with age 63 tooth retention.

This analysis also provided information regarding the potential pathways of influence of different determinants on tooth retention. Most importantly, the effects of education level were direct and not mediated by any of the other variables included in the model; social class at birth effects were predominantly mediated via education (78%) but also dental attendance at age 15 and parental encouragement; the negative effects of being female were predominantly mediated via detrimental influences on dental anxiety but also detrimental effects on education; the effect of smoking in earlier life (age 10-29) was entirely mediated by smoking in later adulthood (age 30-62); and the effects of dental anxiety were predominantly direct and not mediated by the other variables included in the model.

6.2.2: Research strengths

This quantitative study had many strengths, particularly relating to its unprecedented aim and the statistical modelling techniques employed.

This research involved the most comprehensive attempt to date to model the life course determinants of oral health using data from the UK. Such evidence is vital for the development of appropriate and effective life course interventions. As discussed in the literature review (sub-sections 2.12.3 and 2.13.4), two previous analyses have used data from the same NTFS cohort to model the life course determinants of tooth retention and OHRQoL at age 50 (Mason et al. 2006; Pearce et al. 2004). However, these analyses were limited by a lack of information on several potentially important determinants (that were included in the present research) – particularly education, marital history, general health, dental anxiety, dental attendance and tooth brushing – and did not include oral health outcomes beyond the age of 50. They also did not employ full path analyses approaches but relied only upon hierarchical regression modelling and, hence, were unable to model pathways between, or estimate the relative effects of, individual variables (Newton and Bower 2005). Beyond the NTFS cohort, only four other prospective birth cohort studies with dental data exist in the UK (Connelly and Platt 2014; Delgado-Angulo and Bernabe 2015a; Dudding et al. 2018; Skafida and Chambers 2018). However, these cohorts are generally much younger than the NTFS cohort – oral health data is available at the oldest age of 33 only (Delgado-Angulo and Bernabe 2015b) – and all but one of these studies (Dudding et al. 2018) include solely self-reported oral health outcomes. Furthermore, other UK longitudinal studies with oral health data are limited to two prospective studies starting only around midlife (Lennon et al. 2015; Steptoe et al. 2013). Comprehensive attempts to model the life course determinants of oral health outcomes using data from the above cohorts are limited to one analysis of self-reported caries outcomes at age five (Skafida and Chambers 2018).

The present research is also unprecedented on a global scale in several ways. Firstly, no other prospective birth cohort studies worldwide have attempted to comprehensively model the life course determinants of oral health past the age of 38 (Broadbent et al. 2016). Although this has been attempted in a small number of retrospective studies (Holst and Schuller 2012; Listl et al. 2018; Thorstensson and Johansson 2010), the oldest prospective birth cohort study with dental data outside of the UK is the Dunedin study and this is currently only in its fifth decade (Poulton et al. 2015). The oldest prospective birth cohort behind this is a further ten years younger (Peres et al. 2011a). Secondly, the present study is only the third study globally (to the author's knowledge) to use path analyses or SEM approaches to comprehensively model the life course determinants of oral health. Previous attempts are limited to one investigation of oral health outcomes using Dunedin study data (Broadbent et al. 2016) and one investigation of caries outcomes using data from the USA Iowa Fluoride study (Curtis et al. 2018a). However, outcomes in these studies relate only to the younger ages of 38 and 17, respectively.

Beyond the above, the detail of the methods employed in this study also had additional strengths. Although the absence of some potentially relevant determinant variables can be considered a limitation of this study (sub-section 6.2.3), the inclusion of a large number of potential determinant variables from across the whole life course, including birth, demographic, social, psychological, general health and behavioural factors can also be considered a strength, at least compared to previous studies (Broadbent et al. 2016; Curtis et al. 2018a; Mason et al. 2006; Pearce et al. 2004). A further strength is related to the detail of some of these variables, such as the use of pack-years of smoking (rather than purely the presence or absence of smoking) and the number of years married (rather than cruder measures of marital status), which will have facilitated a greater level of discrimination regarding the effects of these variables. Furthermore, multiple specific techniques were employed to ensure the statistical path analyses were robust: the model building process was methodical and comprehensive, and only theoretically sound and justifiable paths were included; the assumption of low multicollinearity was checked and upheld (Garson 2014); the assumption of multivariate normality was checked and, as this assumption was violated, robust significance values, confidence intervals and goodness-of-fit measures were calculated where possible (Bollen and Stine 1992; Shipley 2016; Walker and Smith 2017); chi-squared statistics were used as the primary measures of goodness-of-fit, as recommended (Kline 2016); normed chi-squared statistics were also calculated, as they are less sensitive to sample size (Hooper et al. 2008); and, finally, approximate fit indices were only used secondarily to the chi-squared statistics, as they do not distinguish between what may be sampling error and what may be real covariance evidence against the model (Kline 2016).

6.2.3: Limitations relating to the study variables

Although this quantitative research study had many strengths, it also unfortunately had several limitations. Many of these limitations have already been introduced in the Methodology and Methods chapter (Chapter 3), but their impact on the usefulness and applicability of the study findings will now be discussed. This sub-section, firstly, considers the limitations related to the study variables, whilst sub-sections 6.2.4 and 6.2.5 consider other limitations.

The lack of inclusion of several potential determinants of tooth retention was the first key limitation of this research. In particular, the absence of sugar consumption data prior to the age of 50 was a concern, given the central role of sugar in caries development (Moynihan and Kelly 2014; Selwitz et al. 2007). The absence of such information meant that the effect of sugar consumption on tooth retention could not be determined, but also that the effects of other determinants, such as smoking and dental attendance, were potentially overestimated due to confounding relationships (Bennett et al. 1970; Singh et al. 2013). Furthermore, the absence of social class information and general health information prior to the age of 50 was not ideal, given previous evidence of the effect on oral health of general health (Albandar et al. 2018; Anders and Davis 2010; Mathews et al. 2008) and social class across the whole life course (Pearce et al. 2009a; Poulton et al. 2002; Thomson et al. 2004).

The implications of the absence of the above determinants, again, is that their own effects could not be determined, but also that the effects of other variables may have been falsely distorted. For example, the lack of social class data may have resulted in the role of education being overestimated, given the close relationship between these factors (Thompson 2019).

Beyond the above specific examples, the path analysis was also limited in many other ways by the scope of potential determinants that could be considered. As with much epidemiological research, the number and range of included predictor variables was limited by sample size restrictions, the data available and the ability to actually measure certain determinants. It is not practical, or even possible, to list all potentially relevant excluded information, due to the known diversity and complexity of the determinants of oral health (Marmot and Bell 2011; Watt et al. 2015). However, such factors include information about supplementary oral hygiene techniques beyond tooth brushing, aspects of dental attendance beyond regularity of dental check-ups, fluoride exposure via water and other mediums (Iheozor-Ejiofor et al. 2015; Marinho et al. 2003b), and social relationships and networks (Kettle et al. 2019; Rouxel et al. 2015b).

A further central limitation relates to the robustness of several of the independent variables utilised, which means a level of caution needs to be applied to the study findings. In particular, it is important to note that concerns affecting one variable can affect the study findings relating also to other variables, due to issues of confounding.

Specifically, the robustness of the retrospective collection of tooth brushing and dental attendance data was uncertain, as this has not been explored in prior research. As discussed previously, confidence in recalling such information was generally good during the piloting of the age 69 dental questionnaire (sub-section 3.7.6), whilst a test of criterion validity for the age 50 measure of dental attendance showed reasonable concordance with prospectively collected information (sub-section 3.7.8). However, such assessments are by no means comprehensive, and a few respondents did express concern about their ability to accurately recall such information during the process of definitive data collection (see Table 17, Page 118).

Concerns also exist about the robustness of the assessment of early adulthood dental anxiety, as discussed in sub-section 3.7.6. To recap, this was assessed via a single summary question from the normally five-question MDAS questionnaire (Humphris et al. 1995), the latter of which has been extensively validated for use in the UK (Humphris et al. 2009; Humphris et al. 2000; Humphris et al. 1995; Newton and Edwards 2005). However, it is acknowledged that use of the single question independently was unvalidated, and that it may not have captured all dimensions of dental anxiety. Moreover, as this question was asked retrospectively at age 69 (pertaining to ages 15, 25 and 35), recall issues may have introduced inaccuracies or bias into this data. For example, respondents' perceptions of their past anxiety may have been influenced by their current anxiety (Tourangeau et al. 2000). Unfortunately, no formal evidence is available regarding the retrospective application of the MDAS questionnaire.

Further concerns relate to the retrospective and subjective nature of the assessment of parental encouragement (assessed via self-report at age 69 but pertaining to childhood). Although research has suggested that simple information regarding parental factors in childhood is accurately recalled across adulthood (Berney and Blane 1997; Krieger et al. 1998), it is still very possible that memory issues may have led to inaccurate recall, or that more recent events, such as later life relationships with parents, may have resulted in biased recall. Furthermore, it must be acknowledged that this variable reflects only perceived rather than objective levels of childhood parental encouragement.

The robustness of the EPIC-Norfolk FFQ (Bingham et al. 2001) for assessing daily sugar consumption at age 50 was also a potential concern. As discussed (sub-section 3.7.9), this questionnaire has been subjected to extensive validation studies. Although these have generally demonstrated good reliability in relation to sugar intake, they have only demonstrated average validity in relation to this measure (Bingham et al. 2007; Bingham et al. 1997; Bingham et al. 2001; McKeown et al. 2001).

Lastly, there are some minor concerns about the retrospective collection of self-reported life course smoking data at age 50. Research has generally shown that self-reporting of numbers of cigarettes smoked is relatively accurate, although it has been demonstrated that under-reporting can sometimes be a problem (Blank et al. 2016; Connor Gorber et al. 2009). Reassuringly, however, the long-term recall of the number of cigarettes smoked has been shown to be reasonably robust (Bernaards et al. 2001; Brigham et al. 2009; Brigham et al. 2010; Brigham et al. 2008).

In addition to the above limitations, a further disadvantage relating to the independent variables was the need to condense many of the categorical variables into binary variables, to satisfy the sample size requirements of path analysis (Bentler and Chou 1987; Kline 2016) (see sub-section 3.7.9). Specifically, this allowed this research only to discriminate between the effects of two different levels of each variable.

Finally, there were some limitations associated with the use of tooth retention as the only oral health outcome. Sub-section 3.7.3 provides a detailed discussion of the rationale for using this outcome variable, notably due to its role as a meaningful, cumulative and broad measure of oral health experience across the life course. However, as well as being a strength of this research, the broad reflection of tooth loss of multiple diseases was also a disadvantage. Previous research suggests tooth loss in this cohort was most likely due to caries and periodontal disease (Hull et al. 1997; McCaul et al. 2001; Richards et al. 2005), but this research could not distinguish between the determinants of these different diseases. Therefore, its findings are not useful for addressing these individual component causes. Furthermore, the outcome of tooth loss would only have captured the more severe experiences of caries and periodontal disease (Hirschfeld and Wasserman 1978; McLeod et al. 1997; Ramseier et al. 2017; Wriedt et al. 2010) and, therefore, the determinants of milder disease will not have been reflected. In addition, as discussed in sub-section 3.7.3, the lack of inclusion of any other outcome measure means this research does not provide any information on PROMs or the determinants of other oral diseases for which tooth loss is not a frequent endpoint, such as oral cancer or temporomandibular diseases.

6.2.4: Limitations relating to the study sample and population

Several additional limitations relate to the use of the NTFS cohort as the setting for this quantitative study, which likely affected the robustness and generalisability of the research findings to a certain extent.

Firstly, loss to follow-up was a significant concern in the NTFS study (Table 11, Page 72), meaning that the sample involved in this quantitative research study was not entirely representative of the original study cohort. As detailed in sub-section 3.7.1, males and those born into lower social class households were under-represented by the age 63 follow-up. Loss to follow-up also may have biased the sample towards individuals with other characteristics, such as those who were more health conscious or lived nearer to Newcastle upon Tyne.

Secondly, the NTFS cohort is a North-East birth cohort and, therefore, may not be representative of populations born in the rest of the UK in 1947. Particular concerns are that the North-East has generally suffered a below average economic profile (ONS 2016), worse oral health outcomes and poorer oral health related behaviours compared to the rest of the UK (Chenery 2011; Kelly et al. 2000). It is worth noting, however, that this limitation would likely bias the sample in the opposite direction to the effects of loss to follow-up, thereby possibly diminishing the overall impacts of these two limitations.

The comparisons presented in Section 5.1 and Appendix N – between the full eligible sample for the path analysis (n=245) and the rest of the UK population of the same generation (where this was possible) – do provide some insight into the combined effects of the above two issues. As documented, the sample appeared representative in terms of age 63 tooth retention, age 69 dental anxiety and age 50 tooth brushing frequency, but biased towards females and those with more positive dental attendance and smoking behaviours at age 50. The implications of the above residual bias are that the study's findings may reflect the determinants of oral health in females, higher social classes and more health conscious individuals to a greater extent than in those without such characteristics.

A further limitation relating to the study sample was the exclusion of fourteen edentate individuals. Although the statistical justification for this has been discussed (sub-section 3.7.17), this may have resulted in an underestimation of the effects of predictor variables occurring prior to the point of edentulism in these fourteen individuals, and an overestimation of the effects of variables occurring after this point. As the age of becoming edentate varied across the life course for these fourteen individuals, in effect, the determinants occurring earliest in the life course are likely to have been underestimated to the greatest extent, and those occurring latest in the life course overestimated by the greatest extent.

Additional bias was likely introduced when the eligible sample for the path analysis (n=245) was further restricted to 198 individuals for the construction of the path model, due to the presence of missing data (see sub-section 3.7.17). As discussed, this further biased the sample towards females, higher social class and education groups, those generally exhibiting more positive OHBs and those retaining more teeth at age 63. The above sample restriction, however, did not appear to substantially affect the results of the path analysis. Testing of the path model on the larger samples of 223 and 245 individuals (Sections 5.7 and 5.8) demonstrated only modest changes in the total effects of most predictor variables, whilst substantial changes were only seen in relation to sex (the negative effect of being female was underestimated in the restricted sample). However, it is worth noting that, when applied to these larger samples, the goodness-of-fit of the final path model was uncertain, and that different results may have been obtained if the path models had been constructed, rather than purely tested, on these larger samples.

A final limitation relating to the use of the NTFS cohort is that it is a 1947 birth cohort and, hence, the findings of this research may not be completely applicable to more contemporary generations. In particular, it could be speculated that: the protective effect of tooth brushing may have increased in more recent generations due to dramatic increases in the availability of fluoride toothpaste between the 1960s and 1980s (Jones et al. 2005; Marinho et al. 2003a); the negative effects of dental anxiety could have diminished as anxiety management strategies have evolved; and that the positive effects of regular dental attendance may have increased as the provision of oral health education by dentists has become more widespread (as suggested by the qualitative study in this research). Furthermore, the effects of socio-economic factors on oral health behaviours and outcomes are likely changing over time (Bernabe and Sheiham 2014; Watt and Sheiham 1999). Therefore, although the application of this research to more contemporary generations is certainly not precluded, it should be applied with due regard to these changing patterns.

6.2.5: Other research limitations

One final limitation associated with this quantitative study relates to the sample size requirements for path analysis. Typical sample sizes in published studies using path analysis are often around 200, in line with this study (Kline 2016). However, when maximum likelihood estimation methods are used (as in this research), research suggests that the sample size should be at least five times the number of parameters to be estimated, if data distributions are normal, and at least ten times larger for more arbitrary distributions (Bentler and Chou 1987; Kline 2016). As the sample size used to construct the final path model in this research was only six times the number of parameters to be estimated (the sample size was 198 and 33 parameters required estimation) and the data did not demonstrate multivariate normality, these sample size requirements were not met. Such a limitation may have compromised the stability of the estimates of effects. This lack of certainty in the true value of effects must be considered when interpreting the research findings.

6.2.6: Overall implications of study limitations

Given the large number of limitations affecting this quantitative study, this sub-section will summate and clarify their bearing on the overall robustness and generalisability of the research findings.

Two limitations arguably had a very substantial impact on the robustness of the research findings. The first relates to the lack of inclusion of sugar consumption data prior to the age of 50, which means the effect of sugar consumption remains unknown, but also that the effects of other determinants may have been distorted. The second relates to the uncertainties surrounding the robustness of the tooth brushing, dental attendance, early adulthood dental anxiety and parental encouragement data, which reduces confidence in the accuracy and reliability of the path analysis. Despite the significance of these limitations, I would suggest that they do not completely preclude the application of the study's findings, if appropriate caution is applied. However, each finding must be considered individually in the context of these limitations.

Beyond the above concerns, the effects of all other limitations relating to the robustness of this research are considered to be more modest.

In relation to the generalisability of the study findings, the key limitation is that they are likely not completely applicable to contemporary generations. However, this is also considered a more modest concern and, provided due attention is paid to this issue, this should not preclude the contemporary applicability or usefulness of these findings.

6.2.7: Contribution to existing knowledge

Broadly speaking, the quantitative findings of this research support the contemporary view that social determinants, as well as more traditional biological and behavioural factors, are all key determinants of oral health (DoH 2005; Marmot and Bell 2011; Watt et al. 2015; Watt 2007), and that oral health is influenced across the whole life course (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015).

More specifically, with regards to the role of smoking and dental attendance, this research accords with previous research to some extent. Prior studies have demonstrated that such behaviours across the whole life course can contribute to tooth retention in later life (Albandar et al. 2000; Arora et al. 2010; Astrom et al. 2011b; Crocombe et al. 2012; Krall et al. 2006; Listl et al. 2018; Simila and Virtanen 2015; Thomson et al. 2000; Thomson et al. 2010; Thorstensson and Johansson 2010; Yanagisawa et al. 2009). Furthermore, prior evidence has also shown that past dental attendance influences future dental attendance (Lu et al. 2011) and future dental anxiety (Poulton et al. 2001). Several longitudinal studies have also suggested that levels of tooth loss in former smokers eventually return to levels observed in never smokers (Krall et al. 2006; Yanagisawa et al. 2009), supporting the present finding that smoking between ages 10 and 29 had no direct effect on tooth retention but completely imparted its effects via later adulthood smoking.

However, the present study also advances knowledge regarding the influence of dental attendance and smoking behaviours on oral health outcomes, by applying causal pathways modelling approaches to comprehensive life course data. The few prior studies achieving this have not included information on smoking behaviours and have been limited to much younger cohorts (Broadbent et al. 2016; Curtis et al. 2018a). In particular, this allowed the present study to elucidate the relative contributions of smoking and dental attendance behaviours across the life course on later life tooth retention, suggesting that the former makes a greater contribution. However, this finding must be treated with caution given the study limitations.

This research also advances knowledge regarding the role of tooth brushing frequency in oral health outcomes. Several longitudinal studies have previously explored relationships between this behaviour and caries outcomes but have produced conflicting results (Alm et al. 2008; Bastos et al. 2008; Broadbent et al. 2016; Chankanka et al. 2011; Curtis et al. 2018a; Holst and Schuller 2012; Peres et al. 2009). Moreover, previous longitudinal research exploring the effects of tooth brushing frequency on tooth retention is lacking.

The lack of influence of tooth brushing frequency on tooth retention observed in the present study is surprising, given the established association between plaque, fluoride and caries (Takahashi and Nyvad 2011; Walsh et al. 2019), and plaque and periodontal disease (Bartold and Van Dyke 2013). Possible explanations could be a poor correlation between tooth brushing frequency and the effectiveness of plaque control. Indeed, previous longitudinal studies have shown plaque control to be associated with subsequent oral health outcomes, including tooth loss (Alm et al. 2008; Broadbent et al. 2011; Thomson et al. 2007). Alternatively, a lack of correlation between tooth brushing frequency and the use of fluoride toothpaste could be an explanation. Fluoride is accepted as the key caries preventive component of toothpaste (Walsh et al. 2019) but was only introduced into toothpaste in the late 1960s (Jones et al. 2005). Furthermore, although fluoride-containing toothpastes have become increasingly widespread since then, their use has not been universal (Jones et al. 2005). It must also be borne in mind, however, that the lack of association between tooth brushing frequency and tooth retention may be partly attributable to the use of retrospective, and hence potentially unreliable, measurements of tooth brushing frequency across the life course.

With regards to sugar consumption, its role in caries development is well-established (Chankanka et al. 2016; Curtis et al. 2018a; Jamieson et al. 2010b; Moynihan and Kelly 2014; Peres et al. 2005; Skafida and Chambers 2018), although longitudinal evidence of its contribution to tooth retention is lacking. Therefore, this research furthers existing evidence in that it explores the role of sugar consumption at age 50 on age 63 tooth retention. This said, the lack of an association observed warrants further investigation. It may be that a true effect was not identified for several reasons: the validity of the EPIC-Norfolk FFQ for the measurement of sugar consumption is only considered 'average' (Bingham et al. 2007; Bingham et al. 1997; Bingham et al. 2001; McKeown et al. 2001) (sub-section 6.2.3); it assesses the amount rather than frequency of consumption, the latter of which is the key contributor to caries development (Van Loveren 2019); and the thirteen-year period between age 50 and age 63 may have been insufficient for the causal effects of sugar on tooth loss to be realised. Furthermore, this research still provides no further evidence on the role of sugar consumption across earlier stages of the life course.

The findings of this study that socio-economic factors (specifically social class and education) play a key role in determining tooth retention is supported by a substantial prior body of evidence (Bernabe et al. 2011; Broadbent et al. 2016; Listl et al. 2018; Pearce et al. 2009a; Ramsay et al. 2018; Tsakos et al. 2011; Vendrame et al. 2018; Vettore et al. 2016). However, existing evidence conflicts regarding the pathways via which such factors impart their effects (Broadbent et al. 2016; Donaldson et al. 2008; Peres et al. 2018b; Polk et al. 2010; Sabbah et al. 2015; Sabbah et al. 2009; Vendrame et al. 2018; Vettore et al. 2016), ranging from those suggesting socio-economic inequalities are almost entirely mediated by behavioural factors (Sabbah et al. 2015) to those suggesting that very little of such inequalities are mediated by behavioural factors (Peres et al. 2018b; Sabbah et al. 2009; Vendrame et al. 2018). Being one of only a small number of studies to investigate such pathways using longitudinal data (Broadbent et al. 2016; Peres et al. 2018b; Vendrame et al. 2018; Vettore et al. 2016), this research adds new evidence to this debate, supporting the latter argument. In explanation, previous evidence has demonstrated that physiological factors, such as the influence of physiological stress and poor nutrition on susceptibility to inflammation and disease, may alternatively mediate the effects of socio-economic inequalities (Buchwald et al. 2013; Gomaa et al. 2016). It must be acknowledged, however, that the present research, like most of the above existing research (Broadbent et al. 2016; Peres et al. 2018b; Polk et al. 2010; Sabbah et al. 2009; Vendrame et al. 2018), is limited by its lack of inclusion of data on all relevant OHBs. Hence, it is arguable that the effects of socio-economic factors may have been mediated by unmeasured behaviours, such as dental treatment decisions, sugar consumption prior to the age of 50 and oral hygiene behaviours apart from tooth brushing.

Given that previous longitudinal studies have demonstrated the importance of both childhood and adulthood socio-economic conditions in determining later life tooth retention (Bernabe et al. 2011; Pearce et al. 2009a; Ramsay et al. 2018; Vendrame et al. 2018), it is also notable that the lack of contribution of age 50 social class in the present study was perhaps unexpected. It is possible that this independent variable was too close in time to age 63 tooth retention for any negative effects to be realised. Furthermore, it is possible that any effects of social class between birth and age 50 were partially represented via the effects of education, given the lack of inclusion of any intermediary social class data. Previous research has recognised the complex interplay between different socio-economic indicators, including social class and education, and oral health outcomes (Steele et al. 2014).

In relation to the role of dental anxiety, this research supports previous evidence demonstrating its association with oral health outcomes (Heidari et al. 2017; Schuller et al. 2003; Zinke et al. 2018) and, more importantly, previous longitudinal research demonstrating its contribution to tooth retention and other outcomes (Crocombe et al. 2012; Thomson et al. 2000). However, this research was novel in its application of causal pathways modelling techniques to longitudinal dental anxiety data, alongside data on other determinants of oral health. Hence, it provides unique evidence regarding the effects of dental anxiety on tooth retention relative to other determinants, and also the relative effects of dental anxiety across different stages of the life course – specifically finding that the effects of dental anxiety across the whole life course were substantial but that the overall impact of dental anxiety in later adulthood was greatest. The reliability of this finding, however, may be compromised as a result of the retrospective measurement of early life dental anxiety. Furthermore, the absence of consideration of all potential predictor variables (in particular sugar consumption) may have resulted in an overestimation of the effects of dental anxiety, due to issues of confounding.

The indirect pathways of influence of dental anxiety suggested in this research – via dental attendance (Crocombe et al. 2011; Liinavuori et al. 2019; Pohjola et al. 2007; Schuller et al. 2003; Sohn and Ismail 2005) and future dental anxiety levels (Liinavuori et al. 2019; Thomson et al. 2009) – have also been evidenced in previous research. However, by more comprehensively modelling pathways between dental anxiety and oral health outcomes, this research advanced the above evidence, suggesting that the predominant effects of dental anxiety on tooth retention were in fact not explained by dental attendance, but were predominantly direct. Such pathways warrant further investigation, but it can be speculated that dental anxiety may influence treatment decisions; for example, dentally anxious patients may be more likely to opt for quicker, simpler treatment options, such as extractions, rather than more complicated, time-consuming conservative treatments (Heidari et al. 2017). Alternatively, dental anxiety may influence other aspects related to dental attendance, not captured by the variables utilised in this research, such as compliance at follow-up appointments after an initial check-up.

With regards to the role of gender, the finding of this research that being female resulted in the retention of almost one less tooth by the age of 63 is in agreement with gender patterns of tooth loss demonstrated in much previous research. Although not universally supported (Dye et al. 2007; Marcus et al. 1996; Todd et al. 1982), historical and contemporary research across many countries has predominantly found that females incur greater tooth loss than males (Dye et al. 2007; Fuller et al. 2011; Gray et al. 1970; Ismail et al. 1987; Kelly et al. 2000; Lukacs 2011; Russell et al. 2013; Todd and Lader 1991). It has been suggested that this relationship is mediated by two types of pathways (Ferraro and Vieira 2010; Russell et al. 2013): biological pathways, such as sex-linked genetic differences in caries susceptibility, or the effects of sex-linked hormones on inflammation and periodontal disease (Akcali et al. 2018; Ferraro and Vieira 2010; Russell et al. 2013; Shaffer et al. 2015); and non-biological pathways, such as gender differences in socio-economic opportunities, health behaviours and cultural practices (Chadwick et al. 2011; Ferraro and Vieira 2010; Forey et al. 2016; Morris et al. 2011; Russell et al. 2013). The present research provides further support for the latter pathway, finding that the effect of sex on tooth loss was completely accounted for by dental anxiety, education, smoking and dental attendance. Specifically, the effect of being female on tooth loss was predominantly mediated via its negative effect on dental anxiety (57%) and educational attainment (22%). However, smaller effects of being female were mediated via its positive effects on smoking behaviours (12%) and regularity of dental attendance (9%).

The above findings, however, may only be partially applicable to recent generations. Evidence suggests that the negative effect of female gender on tooth loss persists in the UK in contemporary populations (Fuller et al. 2011); that smoking rates (Forey et al. 2016) and dental attendance (Morris et al. 2011) continue to be worse in males; and that dental anxiety levels continue to be higher in females (unpublished analysis of 2009 Adult Dental Health Survey Data). However, the proportion of females attending university is now much higher than that of males (HESA 2019), which is in significant contrast to past generations, including the NTFS cohort. Therefore, education level may no longer mediate the effect of sex on tooth loss in more recent generations.

Considering the role of parental support, previous evidence has demonstrated its substantial contribution to children's OHBs and oral health outcomes (Berendsen et al. 2018; Hall-Scullin et al. 2015; Hooley et al. 2012; Kettle et al. 2019; Stokes et al. 2006). However, few studies have examined parental long-term influences on children's oral health and related-behaviours as they reach later adulthood. The most relevant research comes from the Dunedin study, which found that parental oral health status and oral health knowledge influenced participants' future OHBs and oral health outcomes up to the age of 38 (Broadbent et al. 2016; Shearer et al. 2011). Like the present research, however, the Dunedin study findings suggested that parental influence contributed to adulthood oral health outcomes to a much lesser extent than other factors, such as dental attendance and socio-economic status.

Finally, the findings of the present research – that general health at age 50 was not associated with age 63 tooth retention – conflicts with previous evidence, which has generally demonstrated a negative impact of poor general health on oral health (Albandar et al. 2018; Anders and Davis 2010; D'Aiuto et al. 2017). This may have been a result of the narrow focus of the general health variable included in the present study, which did not reflect all aspects of general health but involved only a crude assessment of whether somebody had a long-term illness which limited their daily activities at age 50.

The demonstrated lack of association between standardised birth weight and later life tooth retention also advances previous evidence regarding the effects of low birth weight on the permanent dentition. Although there is good evidence that low birth weight contributes to enamel defects in the primary dentition (Jacobsen et al. 2014), current evidence on the effects of low birth weight on the permanent dentition is scarce and inconclusive (Jacobsen et al. 2014; Nicolau et al. 2003a; Saraiva et al. 2007).

6.3: General Discussion

Having discussed the results of the qualitative and quantitative components of this research separately, this section will now integrate the results of these studies. Specifically, it will compare their results where their remits overlapped, review their joint contribution to the overarching research aim and discuss their joint implications for policy, practice and future research.

6.3.1: Comparison of qualitative and quantitative studies

Although the qualitative and quantitative components of this research addressed two different aspects of the life course determinants of oral health – the former focusing purely on the determinants of people's oral health behaviours and the latter addressing more broadly the determinants of oral health outcomes (specifically tooth retention) – there was some overlap in the study remits. This occurred where the quantitative study considered to some extent the determinants of people's behaviours within its broader model. Therefore, it is important to compare the findings of both studies where their remits overlapped.

There were several areas of relative agreement within the studies' findings. Firstly, both suggested that dental anxiety influenced dental attendance but also suggested that the influence of dental anxiety on oral health may be mediated by other pathways. The quantitative study suggested that the predominant influence of dental anxiety on tooth retention was not mediated via any of the factors considered in the model. In the qualitative research, participants discussed anxiety affecting their attendance patterns but also their treatment decisions, such as desires to avoid more complex treatments or to receive treatment under sedation. Such results of the qualitative study may, therefore, help to explain the quantitative results – treatment decisions increasing the likelihood of extractions, rather than more complex conservative treatments, may have mediated the effects of dental anxiety on tooth loss.

Furthermore, both studies suggested that behaviours in earlier life influenced behaviours in later life – in the qualitative study, participants frequently reported that their later life behaviours were influenced by behaviours established in their childhoods. Similarly, the quantitative study demonstrated clear pathways of influence between earlier and later life smoking and dental attendance behaviours.

In addition, both studies supported the role of parents in influencing OHBs in earlier life. In particular, both demonstrated parental influences on dental attendance and oral hygiene behaviours (Note: In the quantitative model, a statistically significant path was added between parental encouragement and age 15 tooth brushing during the path model building process (see Step 41, Appendix L) but was removed from the final model due to its lack of pathway to tooth retention).

Despite the above agreements, there were also some differing results between the two studies, for which potential explanations are considered. Continuing with the topic of parental influence, the qualitative study highlighted parental influences upon earlier life smoking and dietary practices, which were not replicated in the quantitative study. The lack of parental influence on dietary behaviours in the quantitative study, however, was very obviously explained by the absence of inclusion of earlier life dietary data. Additionally, the suggestion of the qualitative study that parents were only a minor influence on smoking behaviours (significantly overshadowed by peer influences) may partly explain the lack of effect of parental influence on smoking behaviours demonstrated in the quantitative study.

Furthermore, the qualitative study highlighted an important influence of spouses on participants' OHBs, generally according with the previously observed positive effects of marriage on health behaviours and outcomes (Duncan et al. 2006; Grundy and Tomassini 2010; Rendall et al. 2011; Tatangelo et al. 2017; Umberson et al. 2010; Waite and Gallagher

2000). However, in the quantitative path analysis, the number of years married was not significantly associated with tooth retention (or any other OHB – see Steps 45 and 50 of the path model building process, Appendix L). It may be that the number of years married was actually a poor correlate of spousal influence. In addition, biasing of the quantitative sample towards females (see sub-section 6.2.4) may partly explain this lack of association, given previous observations that males generally attempt to control others' health behaviours to a lesser extent than females (Lewis et al. 2004; Umberson 1992; Umberson et al. 2018).

Finally, the quantitative study did not demonstrate any effect of general health on OHBs (see Appendix L, Steps 14 and 5), whereas the qualitative study highlighted some positive effects of poor systemic health, i.e. systemic health concerns fuelling motivations to improve smoking and sugar consumption behaviours. Both positive (Boudreaux et al. 2012; Delaney and McCarthy 2011; McCaul et al. 2006) and negative (Chadwick et al. 2018; Lopez Silva et al. 2021) effects of poor general health on OHBs have also been noted in previous literature. The identification of only positive influences in the qualitative research may be explained by the limited sample size, which perhaps hindered the discovery of such negative influences. Furthermore, as discussed in sub-section 6.2.7 (Page 218), the lack of any influence detected in the quantitative study may have been the result of utilising a crude and only single measure of general health.

6.3.2: Overall findings from this mixed-methods research

Taking into consideration the separate discussions regarding the qualitative and quantitative research findings (Sections 6.1 and 6.2), and a reasoned comparison of their findings where their remits overlap (sub-section 6.3.1), this section will now summarise the overall contribution of this mixed-methods research to the current knowledge base regarding the life course determinants of oral health in the UK. Figure 17 has been constructed to support this process. This figure maps the findings from the qualitative study onto those of the quantitative study, but also highlights additional postulated determinants of oral health, not investigated or identified by the present study, but supported by previous evidence.

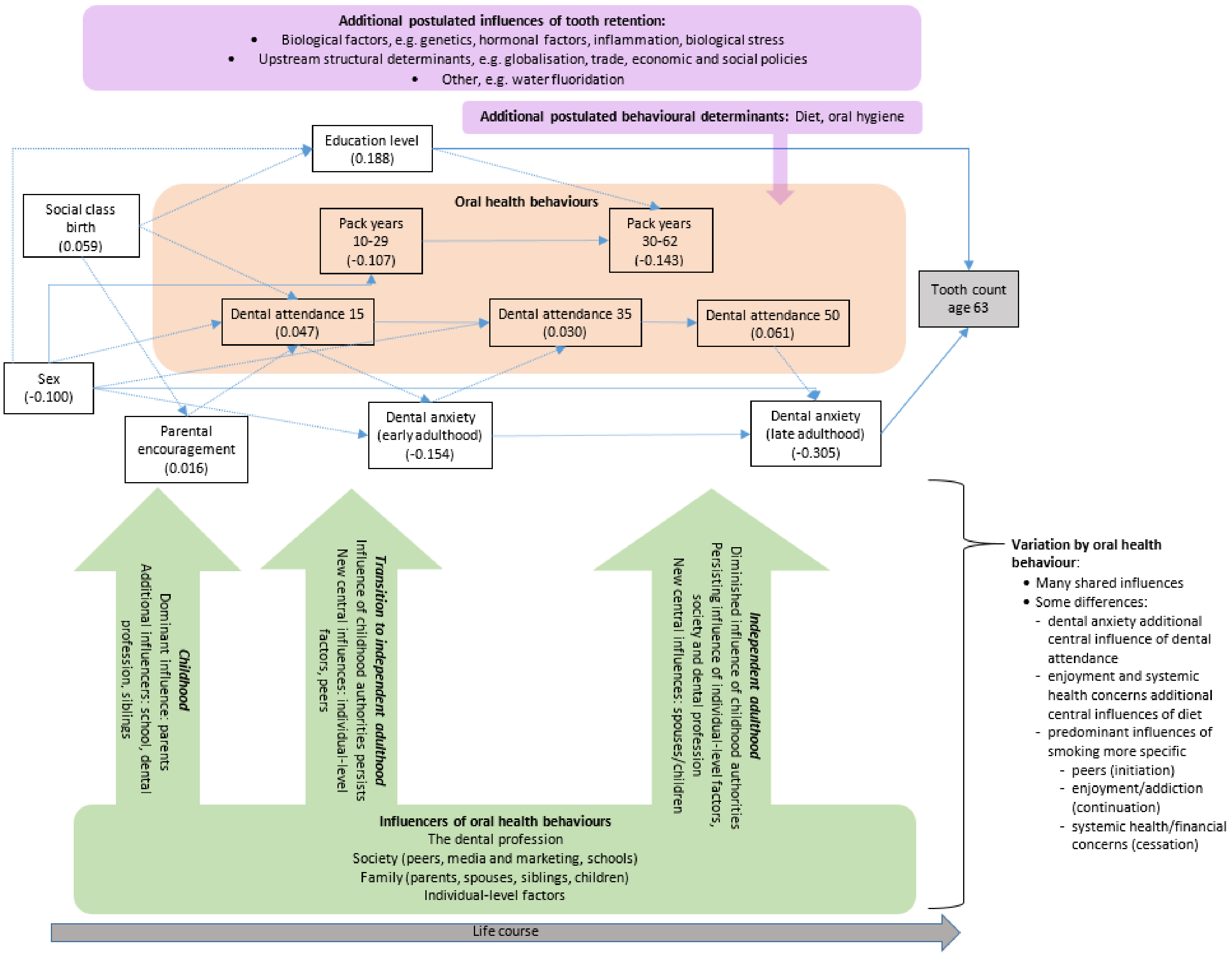

Figure 17: The life course determinants of oral health in the NTFS, according to this mixed-methods research study. The lower green section illustrates the complex influences of OHBs and how these changed across the life course, according to the qualitative study. The middle section presents the final path model of the life course determinants of tooth retention at age 63, according to the quantitative study (values are standardised total effects of each predictor on the outcome). The upper purple section illustrates additional postulated influences of tooth retention, not investigated or identified by the present study but suggested by previous evidence.

In summary, the quantitative component of this research suggested that a broad range of factors influence later life tooth retention, including socio-demographic factors, psychological factors and OHBs. It suggested that such factors all play a substantial role in determining tooth retention, although the more precise estimates of each factor's relative contribution should be treated with caution due to the research limitations (particularly relating to the inclusion and measurement of the independent variables and the generalisability of the findings to contemporary UK populations). It also demonstrated that such determinants play a role across the lifetime and that the development of tooth loss is a life course process.

The quantitative and qualitative research components also suggested that OHBs themselves are influenced by a broad range of factors at the level of the individual (e.g. sex, socio-economic background, psychological factors and general health), family (e.g. parents and spouses), society (e.g. peers, schools, media and marketing) and the dental profession. As summarised in Figure 17, this research also demonstrated how these factors might vary between different OHBs and change across the life course (subject to differences between this 1947 cohort and more recent generations, such as changes in the influence of the media and the dental profession).

This mixed-methods study accords with contemporary views about the contribution of the whole life course to the development of oral health (Crall and Forrest 2018; Heilmann et al. 2015; Nicolau et al. 2007b; Watt et al. 2015). For example, in relation to Figure 2 (Page 26) (Heilmann et al. 2015), this research supports the recurring relationships between wider social determinants, OHBs and oral health outcomes across the life course. However, as previously discussed, it also advances knowledge in this field, being the most comprehensive quantitative attempt to date to model the life course determinants of oral health outcomes using UK data (sub-section 6.2.7) and providing novel evidence regarding changes across the life course in how and why people look after their oral health (see sub-section 6.1.4).

This research also concurs broadly with contemporary beliefs about the wider determinants of oral health (DoH 2005; Marmot and Bell 2011; Watt et al. 2015; Watt 2007). For example, in accordance with Watt et al.'s (2019) depiction of the determinants of oral health (Figure 18), this research demonstrates the contribution of structural determinants (e.g. cultural and social norms), intermediate determinants (e.g. social class, education, social relationships, psychosocial factors and health services) and proximal determinants (e.g. behavioural factors). In relation to this framework (Figure 18), however, this research did not specifically explore biological determinants of oral health or provide much evidence relating to the more upstream structural determinants (e.g. economic and welfare policies). It also failed to demonstrate a role of diet and oral hygiene in tooth retention, most likely due to its limitations (sub-section 6.2.7). These potential determinants have therefore been added to Figure 17. The potential contribution of other additional unmeasured factors to poor oral health, such as exposure to fluoridated water (discussed in sub-section 6.2.3), are also recognised in Figure 17 for completion.

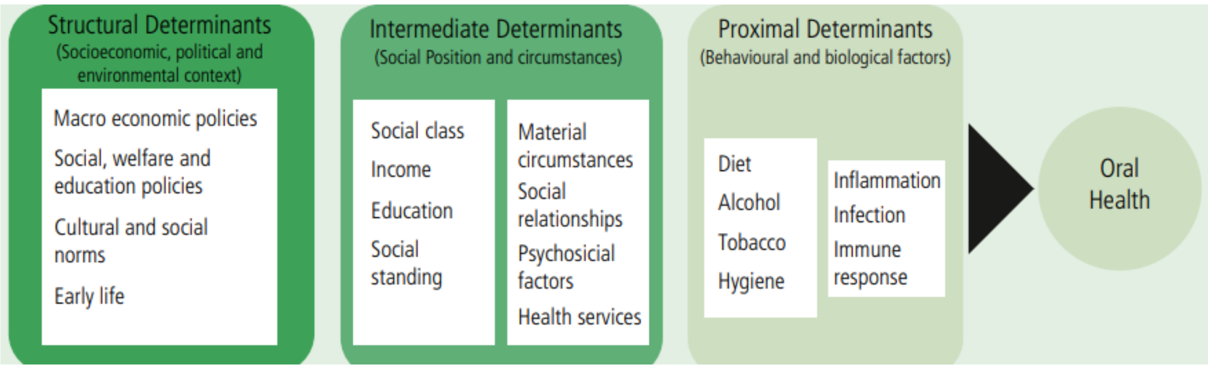

Figure 18: The determinants of oral health. Reproduced from (Watt et al. 2019).

Finally, it is also relevant to consider the findings of this research beyond oral health and within the broader field of health. Like oral health, the development of many general health conditions are also now considered within the context of the whole life course (Cullati 2014; Frilander et al. 2015; Halfon et al. 2018; Kuh and Ben-Shlomo 2004; Lu and Halfon 2003; Seo et al. 2010) and a wide variety of determinants have been implicated in their development (Banks et al. 2019; Commission on Social Determinants of Health 2008; Dahlgren and Whitehead 1991; Dunbar et al. 2008; Karaman et al. 2020; Kreatsoulas and Anand 2010; Marmot 2010; Reading et al. 1999; Tatangelo et al. 2017). Hence, the present study demonstrates many similarities between the development of oral and such general health conditions. Moreover, smoking and dietary behaviours, considered in this study as key determinants of oral health, are also common risk factors for many general health conditions, such as cardiovascular disease, cancer, obesity and diabetes (Peters et al. 2019), making the findings of this research also applicable in the general health field. Research also suggests that there is much overlap between the determinants of the oral health-related behaviours identified in this study and the determinants of other general health behaviours, such as physical activity – for example, the contribution of healthcare professionals, societal norms, schools, family members and individual factors (Artazcoz et al. 2009; Barnett et al. 2013; Cobb et al. 2015; Edwards et al. 2015; Hillsdon et al. 2005; Jepson et al. 2010; Salvy et al. 2012; Trost and Loprinzi 2011; Wakefield et al. 2010).

6.3.3: Implications for policy and practice

Taking into consideration the limitations of this research, its findings still have many implications for oral health improvement within contemporary UK populations (and also for general health improvement due to the status of smoking and dietary behaviours as common risk factors).

A central implication is that proximal OHBs – including dental attendance and smoking behaviours (as demonstrated in this research) but likely also sugar consumption and oral hygiene practices – are central determinants of oral health outcomes and, hence, must be a fundamental focus of oral health interventions.

However, such behaviours and oral health outcomes are, in turn, also strongly influenced by an array of more intermediate and upstream psycho-social determinants. Hence, these factors must also be targeted if meaningful oral and general health improvement is to be achieved.

Regarding such wider determinants, this research suggests that socio-economic health behaviour and oral health inequalities must be addressed, such as those associated with social class and education. It is arguable that such inequalities could be reduced by levelling up the socio-economic disparities themselves, such as by ensuring universal access to well-paid employment, education and good quality housing. However, the behavioural and biological pathways mediating such socio-economic inequalities could also be targeted, for example, by securing an affordable healthy food environment and equal access to health services, including removing financial barriers to access.

The value of social environments and social relationships must also be recognised. Specifically, this research provides evidence for using social environments, such as schools, workplaces and media sources, as part of health behaviour improvement strategies. Furthermore, the influence of social relationships both within and outside families (particularly relating to parents, spouses and peers) must be exploited.

The importance of targeting psychological determinants of health behaviours is also demonstrated by this research – specifically dental anxiety but also personality dispositions, such as self-efficacy and locus of control beliefs. In relation to dental anxiety, the role of the dental profession should not be underestimated. This research suggests that anxiety reduction should be a central consideration in future developments of dental technology and techniques and that fostering a supportive chairside manner should be a central focus of dental professionals' training.

Furthermore, it is evident from this research that providing preventive education should be a high priority for dental professionals, given its perceived importance in determining behaviours. Moreover, this research highlights that dental professionals must emphasise not only the oral health benefits, but also the general health benefits, of smoking cessation and dietary improvement. Given the potential importance of both general and oral health concerns in people's decisions around such behaviours, this also supports the argument for oral and general health services to work together, recognising that general health services can play a part in improving patients' oral health and vice versa.

A final implication of this research is that oral (and general) health improvement strategies should focus on the whole life course and target appropriate determinants at each life course stage. This research indicates that oral health behaviours are important across the life span, and it is likely that the influence of socio-economic determinants is also lifelong (Bernabe et al. 2011; Ramsay et al. 2018; Vendrame et al. 2018). However, many other influences may vary between life course stages. Specifically, this research suggests that harnessing parental support in childhood is key but that the potential impact of schools, dental professionals and siblings should not be overlooked. As individuals transition to independent adulthood, the influence of childhood authorities should still be targeted but a greater focus should now be placed on the individual, peer influences and possibly other aspects of the social environment, such as media and marketing sources (subject to the confirmation of differing influences between contemporary populations and this 1947 birth cohort). Subsequently, as individuals become established independent adults, the additional influence of spouses and children could be exploited.

6.3.4: Implications for policy and practice in the current UK policy context

The above implications for policy and practice must now be considered within the current UK oral health, general health and wider policy contexts. Before doing so, it is important to highlight that many aspects of governance, which have implications for health and oral health, have been devolved from UK central government to the Welsh, Scottish and Northern Ireland governments since 1999 (Devolution and You 2020). The complete list of devolved responsibilities is complex and varies between the devolved nations. However, to provide some examples, devolved responsibilities include health and social care, education, local government and some areas of social security and taxation (Devolution and You 2020). This section will therefore try to consider the different policy environments across the four nations, where relevant, but, for conciseness, does not always aim to provide a comprehensive discussion of each policy context in every nation.

In relation to the central importance of OHBs to oral health outcomes, as demonstrated by this research, significant efforts have been made across the UK in recent years to improve such behaviours. Firstly, the commitment to tackling smoking is clear: restrictions on tobacco marketing and advertising have gradually increased since the 1960s (RCP 2012); anti-smoking campaigns have become increasingly prominent over a similar timeframe (Berridge and Loughlin 2005); taxation on tobacco products has increased dramatically since the 1990s (WHO & Excise Social Policy Group 2003); a complete ban on smoking in indoor public places was introduced in 2007; and stop smoking services have been made widely available over the past two decades (West et al. 2013). The UK government has also recently pledged its intention to make England smoke-free by 2030, although the current prevalence of smoking is still around fourteen percent (DHSC 2019).

Commitments to tackling sugar consumption are also evident but have been largely a more recent enterprise. Some of the most notable actions include: national campaigns, such as the ‘Change4Life’ campaign, which was introduced in 2009 and includes a focus on diet and sugar consumption (PHE 2020b); the introduction of voluntary sugar reduction targets for the food industry in 2016, albeit which have had limited success (PHE 2019b); the introduction of the Soft Drinks Industry Levy in 2018, which has resulted in very substantial reductions in the sugar content of soft drinks (Scarborough et al. 2020); and the establishment of advertising restrictions, such as the 2007 ban on the advertisement of products high in fat, sugar and salt (HFSS) around children’s programmes (Ofcom 2007).

Such initiatives are critical, given the high levels of sugar consumption in the UK (Roberts et al. 2018). However, many sources have argued that they are still insufficient (BDA 2020b; CASSH 2019). Indeed, the UK government is currently considering various additional measures, such as a total ban on the online advertising of HFSS products, curbing price and product placement promotions of HFSS products and extending the Soft Drinks Industry Levy to milk-based products (DHSC 2019; DHSC and DCMS 2020).

Furthermore, in relation to improving dental attendance and oral hygiene behaviours, key initiatives have included national and local child oral health improvement schemes, which have focused on aspects such as tooth brushing in schools and nurseries, the distribution of tooth brushing products, the provision of oral health education and the facilitation of regular dental attendance. National schemes include ‘Childsmile’ in Scotland (Childsmile 2014), ‘Designed to Smile’ in Wales (Nic Iomhair et al. 2020), ‘Happy Smiles’ in Northern Ireland (HSCB 2020) and ‘Starting Well’ in England (NHS.UK 2020a), which began in 2006, 2009, 2016 and 2017, respectively. Several local schemes also exist, such as Leicester’s ‘Happy Teeth, Happy Smiles’ programme (Leicester City Council 2020) and Greater Manchester’s ‘Smiles Matter’ scheme (Greater Manchester Health and Social Care Partnership 2019), beginning in 2014 and 2019, respectively. Other initiatives have also been targeted at adult populations, such as the Scottish oral health improvement programmes for homeless (‘Smile4Life’) and prison populations (‘Mouth Matters’), launched in 2012 and 2014, respectively (Beaton et al. 2018; University of Dundee 2021). The reach of many of the above schemes is limited, however. Specifically, most adult populations across the UK are not targeted by any schemes, whilst the children’s schemes are also not universal. For example, in England in particular, the Starting Well scheme focuses mainly on thirteen high priority local areas (NHS.UK 2020a). Challenges to the extension of such schemes likely include funding barriers, which will have been exacerbated by tight controls of NHS and public health budgets during the last decade of austerity (BMA 2016). Organisational issues also present challenges, such as the devolution of the responsibility for public health from the NHS to local authorities in England in 2012 (Health and Social Care Act 2012), which means schemes are organised at a local rather than national level. It is also important to note that the COVID-19 pandemic has halted the provision of many of these schemes since the beginning of 2020 (Childsmile 2020; Designed to Smile 2020b).

With regards to the implication of this research that socio-economic determinants of health behaviours and oral health outcomes should be addressed, substantial potential arguably remains for raising socio-economic standards in the UK. According to the recent high profile report by the United Nations Special Rapporteur on extreme poverty and human rights, Philip Alston, a fifth of the UK population live in poverty, with in-work poverty being at its highest level for twenty years (OHCHR 2018). Substantial socio-economic inequality also exists in educational attainment; for example, the recent Marmot Review on Health Equity in England highlighted that attainment of five or more GCSEs at grades A* to C has been just under 70% for fifteen to sixteen year olds from the least deprived decile in recent years, compared to just over 50% in the most deprived decile (Marmot et al. 2020). The above reports recommend a raft of remedial measures for improving socio-economic standards in England (Marmot et al. 2020) and the UK (OHCHR 2018), such as increasing the UK National Living Wage, revising the current social security system, improving local government funding and improving efforts to reduce education inequalities. However, just as the UK Government's policy of austerity was starting to ease towards the end of the 2010s (GOV.UK 2019), the COVID-19 crisis has subsequently impacted upon government finances (Harrari and Keep 2020) and may impede progress in many of the above areas. This is not to mention the uncertain economic impact of the UK's exit from the European Union (EU) (TUC 2020).

Beyond changing socio-economic standards themselves, several initiatives are also in place across the UK to target the mediating pathways between socio-economic factors and oral and wider health inequalities. To provide examples: NHS dental treatment across all four UK nations is free to those on low-incomes (Oral Health Foundation 2020a); the national and local oral health improvement schemes discussed earlier (Page 227) prioritise deprived groups (Beaton et al. 2018; Childsmile 2014; Greater Manchester Health and Social Care Partnership 2019; NHS.UK 2020a; University of Dundee 2021); and tobacco control strategies across the four nations prioritise reducing socio-economic inequalities in smoking, such as by targeting smoking cessation services towards more deprived groups (DHSSPS 2012; DoH 2017b; Scottish Government 2018b; Welsh Government 2017). Despite the existence of such initiatives, however, more can still be done to reduce socio-economic oral and general health inequalities. To provide two of many examples, the restricted coverage of many of the previously mentioned oral health improvement schemes means they do not reach many deprived populations (NHS.UK 2020a; RCPCH 2018), whilst healthy foods remain more expensive compared to unhealthy alternatives (Jones et al. 2014; Scott et al. 2018).

In relation to the implication that social environments, social relationships and the media should be utilised to improve people's health behaviours, it can, again, be suggested that such paths could be utilised to a greater extent in the UK. Many initiatives exist to target the role of parents in children's oral and general health, such as universal health visiting programmes (Black et al. 2019) and the child oral health improvement programmes discussed above, many of which include support for parents (Childsmile 2014; Designed to Smile 2020a; NHS.UK 2020a). However, there is significant variation in access to the former and latter programmes (IHV 2020), whilst the former also primarily involve parents only during the first few years of a child's life (Black et al. 2019). The strategic inclusion of family members, such as spouses, in oral and general health improvement approaches during adulthood is also limited, despite recognition of the value of such approaches (Arden-Close and McGrath 2017). For example, recent data on NHS Stop Smoking Services in England suggest that less than one percent of sessions were delivered to family groups or couples (NHS Digital 2020).

The role of schools in guiding children's oral and general health behaviours is also variable but often quite minimal. Oral and general health education has only been mandatory for schools in England, Wales and Northern Ireland since September 2020 (DfE). Notably, prior to this, a survey conducted by the FDI World Dental Federation found oral health education in UK schools to be the poorest of thirteen countries surveyed (FDI 2019). Many of the national and local oral health programmes discussed previously are also delivered via school environments (Childsmile 2014; Designed to Smile 2020a; Greater Manchester Health and Social Care Partnership 2019) but, as stated, coverage of these schemes is not universal across the UK.

Beyond schools, there are various examples of oral and general health improvement initiatives based in other social environments and peer-group settings in the UK, such as workplaces and community groups (Kent Community Health NHS Foundation Trust 2021; Peninsular Dental Social Enterprise 2020). However, these are limited and very variable across different geographic locations.

Furthermore, the widespread utilisation of media sources to promote positive oral and general health behaviours across the UK is evidenced by a variety of recent mass media campaigns, such as ‘Change4Life’, ‘Smokefree’ and ‘Stoptober’, amongst others (PHE 2020a). However, the presence of health promotion messages in the media could potentially be increased, especially those focusing on behaviours unique to oral health, such as oral hygiene and dental attendance behaviours. In relation to dental attendance, the British Society of Paediatric Dentistry recently launched their ‘Dental Check by One’ campaign (BSPD 2019), but other such media initiatives are scarce. Positive oral and general health messages are also competing with extensive negative health messaging in the media, particularly relating to the widespread prevalence of unhealthy food and drink advertising (Al-Mazyad et al. 2017; Chapman et al. 2014; Pournaghi Azar et al. 2018).

The implication of this research that psychological determinants of health behaviours must be addressed – particularly dental anxiety – faces some challenges in the UK context. A survey of General Dental Practitioners in England in 2008 suggested that the management of dental anxiety in general dental practice was often inadequate, due to factors such as a lack of confidence, a lack of competence, and time or funding constraints (Hill et al. 2008). Specifically, 68%, 47% and 58% of practitioners, respectively, felt their training in the psychological management of dental anxiety, inhalation sedation and intravenous sedation techniques was less than adequate (Hill et al. 2008). The lack of financial remuneration and time awarded by the NHS dental contract in England (which also applies to Wales) for anxiety management were also frequently reported as strong barriers to appropriate care. On the contrary, in relation to the importance of a dentist’s chairside manner in influencing patient anxiety, as highlighted by this research, a positive aspect at least is the emphasis placed on interpersonal skills in contemporary undergraduate dental training programmes, from the selection process to enter training (McAndrew and Salem-Rahemi 2013), to the assessment criteria governing the award of a dental degree (GDC 2015).

This research also suggested that dental professionals should prioritise the delivery of oral health education, due to their role in influencing patient behaviour. This is facilitated by several factors in the UK; for example, the provision of oral health education forms a key component of undergraduate dental education (GDC 2015; Holliday et al. 2018), whilst guidelines stipulate requirements for the provision of preventive education in dental practice (DoH 2017a; NICE 2015). However, there are also some barriers to this implication, the most central perhaps being time and funding constraints associated with NHS dental contracts, especially in England and Wales. The provision of preventive advice is remunerated to some extent in Scotland and Northern Ireland, which have their own individual dental remuneration systems (HSC BSO 2020; The Scottish Government 2020). However, in England and Wales, this is not the case (D'Cruz et al. 2010). Evidence suggests that, combined with the requirement to meet high activity targets, the remuneration system in England and Wales has negatively impacted upon the provision of preventive care (Chestnutt et al. 2009; Davies and Macfarlane 2010; Witton and Moles 2015). Fortunately, a dental contract reform process has been underway in England and Wales (and also Northern Ireland) now for several years, a central aim of which has been to prioritise prevention (BDA 2020a; Hill et al. 2020; Rooney 2018). Preliminary findings have been encouraging to some extent (Rooney 2018), although it is currently unknown when these reform processes will result in the actual implementation of new contracts and the final form that these contracts will take. Furthermore, the impact of the current COVID-19 pandemic on access to dental services and, hence, preventive advice must be acknowledged. UK dental practices were closed for routine care for almost three months between March and June 2020 and, since re-opening, have been working at a substantially lower capacity than pre-pandemic levels and prioritising urgent treatment (Palmer et al. 2020).

Many other pressures on the dental workforce must also be considered in light of the demonstrated importance of dental attendance and the dental profession on oral health behaviours and outcomes. Evidence showed that access to NHS dentistry was difficult in some areas of the UK even prior to the coronavirus pandemic, particularly in many areas of England (BDA 2019a) and Wales (Owen et al. 2019). Reasons for this were multifactorial, including insufficient contracting of NHS dental services to meet population need (BDA 2019c; Owen et al. 2019) and challenges in recruiting and retaining NHS dentists (BDA 2019a; Owen et al. 2019). In relation to the latter, surveys revealed that large numbers of dentists were reducing or ceasing their NHS commitments, due to dissatisfaction with the NHS dental contract (BDA 2019b; Practice Plan 2019). Furthermore, in 2020, sixteen percent of dentists working in the UK were EU nationals, who also qualified in the EU (Eaton 2020). Preliminary research has suggested that the UK's exit from the EU may affect the recruitment and retention of this section of the dental workforce (Cameron 2019).

The suggestion of this research that dental professionals should take a holistic approach to smoking and dietary behaviour change counselling, focusing upon both oral and systemic health benefits, is also interesting to consider in the current UK policy context. Many factors should facilitate this, such as the extensive teaching of general health topics across undergraduate dental training programmes (Atkin et al. 2018; GDC 2015; Mighell et al. 2011) and the strong focus on both oral and general health issues apparent in key behaviour change guidelines for dental professionals, such as the Department of Health's 'Delivering Better Oral Health' prevention toolkit (DoH 2017a). That said, however, a lack of attention to such general health issues is sometimes evident in other guidance for, or delivered by, dental teams, highlighting that this holistic approach is not completely embedded (Designed to Smile 2020c; NCSCT 2018). The converse implication that general health professionals should incorporate oral, as well as general, health benefits into their counselling may also face some challenges. In a study of recently qualified UK doctors, the majority recalled no previous training and a lack of confidence in oral health topics (Grocock et al. 2019).

Furthermore, in relation to the implication of this research that oral and general health services should work collaboratively to target common risk factors between oral and systemic diseases, it is argued that such collaboration is currently poor and that dentists predominantly work in isolation from other parts of the healthcare system (Harnagea et al. 2017; Wilson and Soni 2016). In England, however, the current strategic direction of the NHS is to improve the provision of joined-up, coordinated, integrated care, which is being facilitated by some major changes to the organisation of health care services (NHS England 2019a). Integrated Care Systems are being introduced across England to allow a shared partnership of NHS and non-NHS organisations (such as local authorities) to take collective responsibility for health in their defined area (NHS England 2019a). Furthermore, Primary Care Networks are facilitating collaboration between groups of general medical practices and other primary care providers (including dentists) within local areas (NHS England 2019a; 2019b). Such re-organisations are still in progress but could potentially help to improve collaborative working between oral and general health services.

Finally, regarding the necessity of a life course approach to target health behaviours and oral health, such an approach is generally supported by key policy makers in the UK. For example, publications from the UK's national governments (DHSC 2019; Welsh Government 2018), national public health agencies (PHE 2019a; PHW 2019) and NHS leadership bodies

(NHS England 2019a) frequently demonstrate an appreciation of supporting health from birth to end-of-life. Such an approach is also supported in national oral health plans from across the UK (PHE 2014; Scottish Government 2018a; Welsh Government 2013). For example, the Scottish Oral Health Improvement Plan, published in 2018, outlined measures targeting all stages of the life course, such as changing payments for dentists to encourage the delivery of preventive treatments in children, the introduction of a preventive care pathway for adults and the improvement of oral health support for older people in care homes and domiciliary settings (Scottish Government 2018a).

6.3.5: Implications for future research

Considering this present study alongside other evidence relating to the life course determinants of oral health, it is arguable that there is a need for further research within this field.

This thesis proposes that an understanding of the relative importance of different determinants across the life course on oral health outcomes, and their pathways of influence, is necessary to guide the development of appropriate oral health improvement interventions. Furthermore, it argues that the application of path analysis or SEM to longitudinal life course data can facilitate this (sub-section 2.12.1). However, given the complete absence of prior quantitative studies using such statistical approaches to comprehensively model the life course determinants of oral health in the UK (Section 2.13), and the effect of the limitations in the present research study on the conclusions that can be drawn (sub-section 6.2.6), it is clear that further such UK studies are needed. Furthermore, a review of the existing literature from outside of the UK (Section 2.13) also demonstrates a lack of such research in other countries – effectively limited to two studies (Broadbent et al. 2016; Curtis et al. 2018a) – highlighting the need for further research globally.

The present study highlights many methodological implications for such future research, however. Firstly, studies must consider a more comprehensive array of potential determinants than the present research, including, in particular, information on dietary behaviours but also other factors, such as fluoride exposure (see sub-section 6.2.3). Deciding upon the exact predictor information to include requires careful consideration, especially given the complexity of some determinants (e.g. the many components of oral hygiene behaviours) and the difficulties in measuring many determinants (e.g. fluoride exposure (Moore et al. 2020; Villa et al. 2010)). Secondly, samples must meet the optimal sample size requirements of SEM techniques (Bentler and Chou 1987; Kline 2016), which means particularly large samples may be required in the presence of large numbers of predictor variables. Thirdly, prospective methods of data collection should ideally be utilised, rather than retrospective methods. It is arguable that retrospective studies may be considered as a secondary option to prospective studies. However, if these are to be used, further research must be conducted into the validity of retrospective data collection methods, such as the measurement of dental attendance, oral hygiene and dental anxiety behaviours. Furthermore, unless further research can develop and validate retrospective methods for assessing sugar consumption, such measurements should be avoided. Finally, future studies may also benefit from including a range of outcome variables, such as clinical measures of caries and periodontal disease, as well as tooth loss, but also PROMS, such as OHRQoL (see sub-section 6.2.3).

Considering the above methodological recommendations, it is evident that the oral health components of existing UK prospective cohort studies require substantial improvement, if they are to contribute to this research field. As outlined in sub-section 2.11.2, no other existing prospective UK birth cohorts (other than the NTFS) have collected oral health outcome data beyond the age of 33, whilst detail regarding potential oral health determinants is lacking in all cohorts. Therefore, the expeditious addition of such components to existing cohorts still in their early years would be beneficial, in addition to prioritising oral health components in the development of new cohorts.

Outside of the UK, the existing prospective birth cohorts (see sub-section 2.11.2) are better able to meet the methodological recommendations outlined above. For example, the Dunedin, Pelotas and Iowa Fluoride birth cohort studies already include prospectively collected, detailed oral health information (although are also not without their limitations, e.g. the limited availability of dietary information in the Dunedin Study) (Levy et al. 1998; Peres et al. 2017; Peres et al. 2011a; Peres et al. 2010; Poulton et al. 2015). Therefore, future life course analyses of the determinants of oral health should continue to be based upon these cohorts. In addition, as in the UK, due consideration should be given to oral health in the planning of future waves of these existing studies and the planning of new cohorts.

This research has also highlighted that there is scope for further qualitative exploration of the life course determinants of oral health beliefs and behaviours. In particular, the present study highlighted some specific topics that would warrant further exploration, for example, the contribution of oral health motivations, compared to general health motivations, to dietary and smoking behaviours across the life course. As discussed (sub-section 6.1.4), there is limited previous research on this topic (Andersson and Johannsen 2016; Rawahi et al. 2018; Rosseel et al. 2010), but it has significant ramifications for the development of appropriate interventions. Moreover, the application of the present research to contemporary populations relied upon extrapolating findings from a cohort born in 1947. It would therefore be useful to corroborate the findings of this research in current populations, for example, by selecting individuals from across the life course and exploring differing influences in each group. In such future research studies, greater utility of the TDF framework (Cane et al. 2012) could be considered (during both interview and data analysis stages), to maximise the identification of potential determinants of behaviours.

Further implications for future research relate to the translation of the findings of the present study into the development of effective interventions. Such intervention research is a growing area of interest and studies are already addressing many relevant topics, such as: the reduction of socio-economic oral health inequalities (Bambra et al. 2015; Kidd et al. 2020; Raison and Harris 2019); school-based oral health interventions (Arora et al. 2019; Blake et al. 2015; Cooper et al. 2013; Saied-Moallemi et al. 2009); media-based interventions (Bradley et al. 2020; Croker et al. 2012; Friel et al. 2002; Gholami et al. 2017; Morley et al. 2018); couple- and peer group-based interventions (Arden-Close and McGrath 2017; Dobbie et al. 2019; Faseru et al. 2018); the effects of different contract remuneration models on dentists' preventive behaviours (Hill et al. 2017); the improvement of behaviour change counselling in dental settings, such as via motivational interviewing (Gao et al. 2014; Kopp et al. 2017); and the management of dental anxiety (James et al. 2013; Wide Boman et al. 2013).

Upon review of this evidence base, it is apparent that research around certain topics is more advanced than others and that, in some areas, there remains significant uncertainty around the effectiveness of different interventions. To provide some examples, a number of studies have evaluated interventions to improve dietary and smoking behaviours that focus upon enhancing spousal or partner support (Arden-Close and McGrath 2017; Faseru et al. 2018;

Trief et al. 2011). However, to the author's knowledge, no research has been conducted around similar interventions to improve oral hygiene or dental attendance behaviours. Potential ideas could involve couple-based behaviour change counselling or more novel ideas, such as recording partners' attendance patterns at existing patient contacts and using initiatives to improve these (e.g. sending appointment invitations). Another example where uncertainty remains is around school-based oral health interventions. The evidence around school-based smoking prevention, oral hygiene and diet interventions, plus oral health screening programmes, has been evaluated in several recent Cochrane reviews (Arora et al. 2019; Cooper et al. 2013; Thomas et al. 2013). Although Thomas et al.'s (2013) review identified 134 studies for inclusion and found strong evidence that smoking prevention programmes were effective, the other reviews identified only limited evidence for inclusion. Cooper et al. (2013) concluded that there was some evidence that school-based oral hygiene and dietary interventions improved plaque control and oral health knowledge, but that there was insufficient evidence of their effects on other outcomes. Arora et al. (2019) found some evidence that school oral health screening programmes improved children's dental attendance but concluded that this evidence was of 'low certainty'. The latter two studies both highlighted a need for substantial further research. A final example of where intervention research might be indicated, but is currently absent, relates to the focus of dietary and smoking cessation interventions in the dental setting. It would be useful to evaluate whether the effectiveness of behavioural counselling changes with a shifting focus between oral and general health benefits.

A further implication of the present study is that such future intervention research must utilise a complete life course approach. In particular, interventions must be developed and evaluated for all stages of the life course and must target the appropriate determinants acting at each stage. For example, research evaluating the effects of media interventions on oral health should consider whether effects vary across the life course, and even whether different interventions should be used to target different age groups at the outset.

The wide array of determinants identified in this research also emphasises the appropriateness of complex interventions – those which comprise several interacting components (Craig et al. 2008) – as opposed to simple interventions, to improve health behaviours and oral health outcomes. Accordingly, research into the development and evaluation of complex interventions should be prioritised, following existing examples (Brady et al. 2011; Gray-Burrows et al. 2016; Kidd et al. 2020).

A final topic worthy of further consideration is the process by which research findings relating to the determinants of health are translated into appropriate interventions. A key milestone in recent years has been the production of the 'Behaviour Change Wheel', which was designed to link each domain of the COM-B model of behaviour to specific intervention functions and policy categories (Michie et al. 2011). Once appropriate intervention targets have been identified, it is subsequently recommended that suitable behaviour change techniques can then be selected from a definitive list (Michie et al. 2014; Michie et al. 2013). Such a methodological process might be considered in future studies attempting to identify appropriate behaviour interventions, following recent examples in the oral health field (Gallagher et al. 2020; Templeton et al. 2016).

Chapter 7: Conclusions and Recommendations

The overall aim of this research was to provide further evidence regarding the life course determinants of oral health in the UK, based upon the need to thoroughly understand such determinants if appropriate and effective interventions are to be developed.

Following the identification of two major gaps in existing research – specifically the lack of qualitative exploration of the life course determinants of oral health and related behaviours, and the lack of robust and comprehensive quantitative models of the life course determinants of oral health – a mixed-methods project was devised. This was based upon a 1947 UK birth cohort – the Newcastle Thousand Families Study – and involved qualitative interviews to explore what influenced how individuals looked after their oral health across their lifetime, and a quantitative path analysis to model the life course determinants of participants' later life tooth retention.

This mixed-methods research study generated substantial new evidence regarding the life course determinants of oral health in the UK. However, it did also have several limitations. In particular, the availability and robustness of the independent variables utilised in the quantitative study restricted to some extent the conclusions that could be drawn, especially the absence of life course sugar consumption information. Furthermore, being based upon a historical 1947 birth cohort, the application of the qualitative and quantitative findings of this research to more contemporary UK populations requires careful consideration.

Taking into account the limitations of this research, and considering its findings alongside existing evidence, the overall conclusions that can be drawn are as follows:

- A broad range of factors across the life course influence later life tooth retention in the UK, likely including (but not limited to) OHBs, socio-economic determinants, dental anxiety, sex and parental encouragement to look after one's teeth.
- Regarding the particular contributions of different OHBs, this research suggests that life course smoking and dental attendance practices influence later life tooth retention. Previous research also suggests that a similar influence of life course oral hygiene and sugar consumption practices is likely, although further research is needed to confirm this.

- Due to the limitations associated with this research (and previous evidence), the relative contributions of different determinants across the life course on later life tooth retention remains relatively uncertain.
- In turn, the determinants of how and why people look after their oral health are broad, and include factors associated with the dental profession, society (e.g. school, media and peer influences), family members, and individuals themselves.
- The influencing factors of different behaviours likely overlap to a large extent, but some determinants may also differ. For example, this research suggests that enjoyment and systemic health concerns are key determinants of dietary and smoking behaviours, which are not relevant to other OHBs, whilst dental anxiety is an additional determinant unique to dental attendance.
- The influences of people's OHBs change across the life course. Parents are likely the predominant influencers in childhood, but other sources, such as dental professionals, schools and siblings may also play a role. As individuals transition to independent adulthood, the influence of childhood authorities likely persists, but other factors also begin to play a key role, such as individual-level factors and societal influences, particularly peers. Finally, this research suggests that a central role of individual-level factors, society and the dental profession likely persists in independent adulthood, but that the predominant influence of family members generally transfers from parents to spouses and children, especially the former.
- Finally, the interplay between different influences of behaviours is complex. This research supports the application of the key tenets of the PRIME theory of motivation (West 2006) and the COM-B theory of behaviour (Michie et al. 2011) to the determinants of OHBs. Respectively, these are that motivation is ultimately determined by the overall balance of positive and negative motivators, and that motivation, capability and opportunity are required for behaviours to be enacted.

In light of the above conclusions, this research has multiple wide-reaching implications for policy and practice in the UK. Such implications relate to oral health but also to the field of general health to some extent, due to the position of certain OHBs (e.g. smoking and diet) as common risk factors for many general health conditions. The key implications of this research are summarised below:

- A broad range of determinants must be targeted if oral health outcomes are to be improved in the UK. These include OHBs, but also many wider determinants of oral health outcomes and behaviours.
- The socio-economic determinants of oral health outcomes and health behaviours must be addressed, either via the levelling-up of socio-economic disparities themselves or by addressing the pathways which mediate such socio-economic inequalities.
- The impact of societal influences and social relationships on health behaviours must be utilised. This includes exploiting the influence of sources such as schools, the media, peers and family members in health behaviour improvement strategies.
- The dental profession's influence on health behaviours must be maximised, by ensuring their contribution to dental anxiety is positive and by harnessing their influence on all OHBs. To maximise the efficacy of interventions targeting smoking and dietary behaviours, dental professionals should highlight both the general and oral health benefits of behaviour change.
- Efforts to improve oral health outcomes and health behaviours must focus on the whole life course and target the appropriate determinants at each life course stage.

Currently in the UK, a number of policies and strategies are already in place, which partially facilitate the above recommendations. Nevertheless, there is substantial potential for further action. In order to facilitate this, further intervention research is now required to translate the evidence base around the life course determinants of oral health into the most effective life course oral health improvement interventions.

Alongside the above intervention research, it is also recommended that the findings of the present research be corroborated in future studies, to address the limitations of the present study and ensure any intervention research is based upon the most robust evidence. In particular:

- The quantitative life course analysis in this study should be repeated using more comprehensive, robust life course datasets. This would allow more detailed conclusions to be drawn regarding the contributions of different determinants across the life course on oral health outcomes. Notably, this has implications for the future planning of existing and new life course cohorts in the UK and elsewhere, if optimal methodological requirements are to be met.

- The contemporary applicability of the qualitative findings of the present research should also be corroborated by undertaking further qualitative research in more contemporary UK populations.

Appendix A: Ethical approval for qualitative interviews with NTFS participants (Phase 1)

Newcastle University

02/10/14
Rhiannon O'Connor
School of Dental Sciences

Faculty of Medical Sciences

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The Medical School
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FACULTY OF MEDICAL SCIENCES: ETHICS COMMITTEE

Dear Rhiannon O'Connor

Title: Predictors of poor oral health trajectories in middle age: Who is at greatest risk? Phase 2- qualitative accounts of determinants of oral health in middle age.
Application No: 00803
Start date to end date: 01/09/14 to 31/08/2016

On behalf of the Faculty of Medical Sciences Ethics Committee, I am writing to confirm that the ethical aspects of your proposal have been considered and your study has been given ethical approval.

The approval is limited to this project: **00803/2014**. If you wish for a further approval to extend this project, please submit a re-application to the FMS Ethics Committee and this will be considered.

During the course of your research project you may find it necessary to revise your protocol. Substantial changes in methodology, or changes that impact on the interface between the researcher and the participants must be considered by the FMS Ethics Committee, prior to implementation.*

At the close of your research project, please report any adverse events that have occurred and the actions that were taken to the FMS Ethics Committee.*

Best wishes,

Yours sincerely

K. Sutherland.

Kimberley Sutherland
On behalf of Faculty Ethics Committee

cc.
Professor Andy Hall, Chair of FMS Ethics Committee
Ms Lois Neal, Assistant Registrar (Research Strategy)

*Please refer to the latest guidance available on the internal Newcastle web-site.

tel: +44 (0) 191 222 6000
fax: +44 (0) 191 222 6621

www.ncl.ac.uk

Appendix B: Ethical approval for questionnaire distribution to NTFS participants and secondary data analysis of NTFS data (Phases 2 and 3)

University Ethics Form Version 2.1

Date submitted
25/05/2016 17:48:14

Applicant Details

Is this approval for a:
Student Project [A2]

What type of degree programme is being studied?
Postgraduate Research (e.g. PhD) [A3]

Name of Principal Researcher:
Rhiannon O'Connor

Please enter your email address
Rhiannon.OConnor@ncl.ac.uk

Please select your school / academic unit
School of Dental Sciences [A21]

Please enter the module code

Please enter your supervisors email:
Mark.Pearce@ncl.ac.uk

Please select your supervisor's school/unit:
Institute of Health & Society (IH&S) [A27]

Project Details

Project Title
Predictors of poor oral health trajectories in middle age: Who is at greatest risk? Phase 3-quantitative lifecourse analysis of determinants of oral health in middle age.

Project Synopsis
Aims: The aim of this research is to determine which factors across the lifecourse determine an individual's tooth retention in late middle age. Background: The loss of some or all teeth by late middle age is a problem which affects many individuals in the UK and can lead to functional but also psychological issues. Causes of tooth loss are complex and multiple factors across the lifecourse will determine tooth retention in late middle age. Methodology: The Thousand Families Study (TFS) is a long-running birth cohort study, which began in Newcastle in 1947, with 1142 babies. A vast array of data has been collected from each participant over their lifetime and remaining participants attended a dental examination at ages 50 and 62. This research will involve the distribution of questionnaires, via post or online via e-mail, to the 415 individuals who attended one or both of these dental examinations, to collect information about determinant factors of tooth loss, which have not previously been collected throughout the study (such as data on dental attendance, diet and oral hygiene practices). Subsequently, this data will be analysed alongside existing data from the study to determine the contribution of different factors across the lifecourse on tooth retention at age 50 and 62.

Project start date
01/07/2016

Project end date
23/03/2016

Is the project externally funded?
Yes - I have a MyProjects reference number [A1]

MyProjects reference
BH124032

Does your project involve collaborators outside of the University?
No [N]

Existing Ethics, Sponsorship & Responsibility

Has ethical approval to cover this proposal already been obtained?
No [N]

Will anyone be acting as sponsor under the NHS Research Governance Framework for Health and Social Care?
No [N]

Do you have a Newcastle upon Tyne Hospitals (NUTH) reference?
No [N]

Will someone other than you (the principal investigator) or your supervisor (for student projects) be responsible for the conduct, management and design of the research?
No [N]

Animals (I)

The Animals (Scientific Procedures) Act defines protected animals as: 'any living vertebrate other than man…in its foetal, larval or embryonic form……from the stage of its development when— (a)in the case of a mammal, bird or reptile, half the gestation or incubation period for the relevant species has elapsed; and (b)in any other case, it becomes capable of independent feeding'. In practice 'Protected' animals are all living vertebrates (other than man), including some immature forms, and cephalopods (e.g. octopus, squid, cuttlefish). Using this definition, does your research involve the observation, capture or manipulation of animals or their tissues?
No [N]

NHS, Health & Social Care: Facilities, Staff & Patients (I)

Will the study involve participants recruited by virtue of being NHS patients or service users, their dependents, their carers or human tissues or the use of NHS & Health/Social Care Facilities or otherwise require REC approval?
No [N]

Human Participants in a Non-Clinical Setting (I)

Does the research involve human participants e.g. use of questionnaires, focus groups, observation, surveys or lab-based studies involving human participants?
Yes [Y]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Does the study involve any of the following? [[illegible]]

Data (I)

Does the research involve the viewing, usage or transfer of Sensitive Personal Data as defined by the Data Protection Act 1998 or data governed by statute such as the Official Secrets Act 1989 / Terrorism Act 2006, commercial contract or by convention e.g. client confidentiality? (If you are unsure please tick YES and complete the sub-questions).
Yes [Y]

Will the study involve any of the following? [[illegible]]

Will the study involve any of the following? [[illegible]]

Will the study involve any of the following? [[illegible]]

Will the study involve any of the following? [[illegible]]

Will the study involve any of the following? [[illegible]]

Environment (I)

Will the study cause direct or indirect damage to the environment or emissions outside permissible levels or be conducted in an Area of Special Scientific Interest or which is of cultural significance?
No [N]

International Projects (I)

Will the research be conducted outside of the European Economic Area (EEA) or will it involve international collaborators outside the EEA?
No [N]

Next Steps

Based on your responses your project has been categorised as (ethically) low risk and no further review is required before you start work. You will receive a formal approval email on submission of this form. Should your project change you may need to apply for new ethical approval.

Supporting Documentation

Please upload any documents (not uploaded elsewhere in the application) which you think are relevant to the consideration of your application.
Dental%20questionnaire%20v5.pdf (1570.931KB) Questionnaire - Outline%20Protocol.docx (35.698KB) Outline Protocol - Participant%20Information%20sheet%20v1.docx (52.653KB) Participant Information Sheet - Invitation%20letter%20V1.docx (40.84KB) Invitation Letter -

filecount - Please upload any documents (not uploaded elsewhere in the application) which you think are relevant to the consideration of your application.
4

Summary and Submission

Thank you for completing the University's Ethical Review Form. Based on your answers the University is satisfied that your project has met its ethical expectations and grants its ethical approval. Please be aware that if you make any significant changes to your project then you should complete this form again as further review may be required. Confirmation of this decision will be emailed to you. Please complete the declaration to submit your application. <u>Declaration</u> I certify that: [the information contained within this application is accurate.]
Yes [Y]

Thank you for completing the University's Ethical Review Form. Based on your answers the University is satisfied that your project has met its ethical expectations and grants its ethical approval. Please be aware that if you make any significant changes to your project then you should complete this form again as further review may be required. Confirmation of this decision will be emailed to you. Please complete the declaration to submit your application. <u>Declaration</u> I certify that: [the research will be undertaken in line with all appropriate, University, legal and local standards and regulations.]
Yes [Y]

Thank you for completing the University's Ethical Review Form. Based on your answers the University is satisfied that your project has met its ethical expectations and grants its ethical approval. Please be aware that if you make any significant changes to your project then you should complete this form again as further review may be required. Confirmation of this decision will be emailed to you. Please complete the declaration to submit your application. <u>Declaration</u> I certify that: [I have attempted to identify the risks that may arise in conducting this research and acknowledge my obligation to (and rights of) any participants.]
Yes [Y]

Thank you for completing the University's Ethical Review Form. Based on your answers the University is satisfied that your project has met its ethical expectations and grants its ethical approval. Please be aware that if you make any significant changes to your project then you should complete this form again as further review may be required. Confirmation of this decision will be emailed to you. Please complete the declaration to submit your application.

Declaration

I certify that:

[no work will begin until all appropriate permissions are in place.]

Yes [Y]

Appendix C: Invitation letter, participant information sheet and consent form for qualitative interviews with NTFS participants (Phase 1)

Dear

My name is Rhiannon O'Connor and I am a member of staff at Newcastle Dental School. I am working with the Newcastle Thousand Families Study team to conduct some research into the causal and influencing factors of oral and dental health.

I would like to invite you to attend an interview about your dental health. You have been specifically selected because you are one of a few members of the Newcastle Thousand Families Study cohort, who attended a dental exam both around 1997 and 2009. We would therefore really like to speak to you.

Enclosed with this letter is an information sheet, which explains what the study is about and how you would be involved if you decide to take part.

If you agree to take part, please complete and return the form below in the stamped addressed envelope provided. Upon receipt of this form, I will contact you to arrange an interview.

Thank you for your time and consideration.

Yours Faithfully,

Rhiannon O'Connor

--*(detach here)*

Study ID no: ________

I have read the enclosed participant information sheet and am willing to take part in the above study. I am happy to be contacted by Rhiannon O'Connor, who will answer any questions I may have and arrange a convenient time for the interview. I am aware that I can change my mind about taking part in the study at any time.

Signed: ______________ Name: ________________________ Date: ________

You may contact me by the methods below to arrange the interview:

E-mail ☐ at: ________________________ ☐ *preferred*

Home phone ☐ on: ________________________ ☐ *preferred*

Mobile ☐ on: ________________________ ☐ *preferred*

By post only ☐

Predictors of poor oral health trajectories in middle age: Who is at greatest risk?

Participant information

You are being invited to take part in a research study. This study will involve speaking with a research student (*Rhiannon O'Connor*) from Newcastle University about how factors across your lifetime have influenced and shaped your current dental health.

Before you decide whether you would like to take part in this project, we would like to tell you about the purpose of this study, and what taking part would involve.

Please read this leaflet carefully, talk to others if you wish, and take time to decide whether you would like to participate.

If you have any questions, you can contact Rhiannon as follows:

Rhiannon O'Connor (Research Lead)
Level 7, School of Dental Sciences
Framlington Place,
Newcastle University
Newcastle upon Tyne,
NE2 4BW.
Rhiannon.O'Connor@ncl.ac.uk
0191 208 7829

Thank you for reading this leaflet.

What is the project about?

This project is entitled *Predictors of poor oral health trajectories in middle age: Who is at greatest risk?* The purpose of this study is to find out about which factors across your lifetime have influenced and shaped your current dental health.

Why have I been asked?

You have been invited to take part in this study because you are a member of the Newcastle Thousand Families Study cohort who previously attended both dental examinations conducted as part of this study around 1997 and 2009. We now wish to interview about 30 individuals to find out more about what has influenced your dental status over your lifetime.

What is involved?

You are being invited to take part in an interview of approximately one hour. Interviews will be carried out by Rhiannon O'Connor (a member of staff at Newcastle University) at a time and location that is convenient for you. You will be asked about factors and situations across your lifetime that may have influenced your dental health. Examples of topics that may be discussed are your previous dental attendance, how you look after your teeth at home, your experiences of dental treatment in childhood etc.

The interview will be recorded using a digital audio recorder. You can stop the interview or withdraw from this study at any time.

How will data from my interview be used?

The audio recording will be typed up by Rhiannon or an authorised member of the study team and then will be analysed by Rhiannon and the study team. We are trying to find out what things over a lifetime shape someone's dental health in later life.

What are the benefits?

By sharing your experiences with us, you will be helping us to build a clearer picture of how dental health in later life is shaped across the whole lifetime. Ultimately, this will allow us to find better ways of preventing poor dental health in later life.

What are the risks?

Though all efforts will be made to avoid inconveniencing you, the interview will take up some of your time. Some of the things that influenced your dental health may also be upsetting for you to discuss. You do not have to discuss anything with Rhiannon that you do not want to.

Will people know that I took part?

All identifiable data, such as names, addresses, workplaces, etc. will be removed from the typed up interview so that all data held will be anonymous and cannot be traced back to you.

Findings from this study will most likely be published in scientific journals that are widely read by health professionals, or presented to other dental professionals at conferences. Information from your interview, including short "quotes" may be included, but will be anonymised. Therefore, no-one will know that you have taken part in the study.

There are some circumstances when the researcher may have to tell someone else information that you have given, for example, if you disclose information about harm caused to yourself or others. This is a legal obligation.

How will my data be stored and for how long?

The audio recording of your interview will be destroyed immediately after transcription. The transcribed anonymised interview will be stored securely on a password-protected computer. At the end of this research, this anonymised transcript will be returned to Dr Mark Pearce, director of the Thousand Families Study, and stored securely with the other data from the Thousand Families Study.

What do I do next?

You will be called by a member of our study team over the next 2 weeks, who will answer any questions you may have and ask if you would be happy to participate in this study. If you are happy, we will arrange an interview at a time and place convenient to you.

If you do not wish to participate, please tell the study member when they telephone you. It is completely your choice whether or not to participate.

If you wish to contact us instead of awaiting our call, please use the details on the front of this form.

I have a question.

If you would like any more information about the study, please contact the researcher using the information on the front page of this leaflet.

I have a concern and would like to speak to somebody other than the researcher.

In this case, please contact:

Dr Mark Pearce (mark.pearce@ncl.ac.uk)
Director of the Newcastle Thousand Families Study
Institute of Health & Society
Newcastle University
Sir James Spence Institute, RVI
Newcastle upon Tyne
NE1 4LP

Appendix D: Invitation letter and participant information sheet for dental questionnaire completion by NTFS participants (Phase 2)

Rhiannon O'Connor
Level 7, School of Dental Sciences
Framlington Place
Newcastle University
Newcastle upon Tyne
NE2 4BW
Rhiannon.O'Connor@ncl.ac.uk
0191 208 7829

Dear

My name is Rhiannon O'Connor and I am a member of staff at Newcastle Dental School. I am working with the Newcastle Thousand Families Study team to conduct some research investigating the influencing factors of dental health in later life.

I am writing to ask if you would be willing to complete the enclosed questionnaire. The questionnaire takes about ten minutes to complete and asks about your current dental health and factors across your life which may have influenced this, such as your toothbrushing practices, dental visiting patterns, dental anxiety, diet and relationships.

We would really like you to complete this questionnaire, so that we can link the information to the clinical data obtained at your dental examination(s) around 1997 and/or 2009.

If you agree to take part, please complete the enclosed questionnaire and return it to us in the pre-paid envelope provided.

Returning the questionnaire will be taken as your consent for us to use the information provided in our research. As with all of the information we hold, we assure you that the information provided will be treated confidentially, no one will see it apart from members of the research team and you will never be identified through any of our publications.

Thank you for your time and consideration.

Yours Sincerely,

Rhiannon O'Connor
Thousand Families Study Team

Predictors of poor oral health trajectories in middle age: Who is at greatest risk?

Phase 3-Dental Questionnaire

Participant information

As a Thousand Families Study participant, you are being invited to take part in a research project about your **dental health**. This will involve completing a short questionnaire about your current dental health and some behaviours across your life which may have influenced this.

Before you decide whether you would like to take part in this project, we would like to tell you about the purpose of this study, and what taking part would involve.

Please read this leaflet carefully, talk to others if you wish, and take time to decide whether you would like to participate.

If you have any questions, you can contact the lead researcher, Rhiannon O'connor, as follows:

Rhiannon O'Connor (Research Lead)
Level 7, School of Dental Sciences
Framlington Place,
Newcastle University
Newcastle upon Tyne,
NE2 4BW.
Rhiannon.O'Connor@ncl.ac.uk
0191 208 7829

What is the project about?

This project is entitled *Predictors of poor oral health trajectories in middle age: Who is at greatest risk? Phase 3-Dental Questionnaire.* The purpose of this study is to find out about which factors across your lifetime have influenced the number of teeth you retained in later life.

Why have I been asked?

You have been invited to take part in this study because you are a member of the Newcastle Thousand Families Study cohort who previously attended a dental examination as part of this study, around either 1997 and/or 2009. We now wish to find out a bit more information about some behaviours over your lifetime which may have influenced your dental status at the time of these examinations.

What is involved?

You are being asked to complete a short questionnaire, which should take you about **ten minutes** to complete. The questionnaire includes questions about your current dental health and about your tooth brushing habits, dental visiting patterns, diet and relationships across your lifetime.

You can complete the paper questionnaire and return it to us in the stamped addressed envelope provided, or complete an online version of the questionnaire at www.(to be completed).

How will data from the questionnaire be used?

The data you provide will be analysed, alongside relevant data you have previously provided throughout the study, by Rhiannon and other authorised members of the study team. We are trying to find out what factors over your lifetime may have influenced the number of teeth you retained in later life.

What are the benefits?

By sharing your experiences with us, you will be helping us to build a clearer picture of how dental health in later life is shaped across the whole lifetime. Ultimately, this will allow us to find better ways of preventing poor dental health in later life.

What are the risks?

Completing the questionnaire will take about ten minutes of your time but there are no other risks associated with this study.

Will people know that I took part?

No. Findings from this study will most likely be published in scientific journals that are widely read by health professionals, or presented to other dental professionals at conferences, but you will not be identifiable from any data presented.

How will my data be stored and for how long?

Data from the questionnaire will be stored electronically on a password-protected computer. Paper questionnaires will be stored securely and will only be accessible by authorised members of the study team. Electronic data and paper questionnaires will only be identifiable by your study identification number and will not be linked to any personal details, such as your name or address.

The data collected in this project will be stored as long as the Thousand Families Study continues, with all other data collected in the study.

What do I do next?

If you agree to participate, please complete the enclosed questionnaire and return it to us in the stamped addressed envelope provided, or complete the questionnaire online at www.(to be completed).

If we do not receive a completed questionnaire from you, we may contact you further by phone, e-mail or letter to check that you received the questionnaire.

If you do not wish to complete the questionnaire and do not want us to contact you further, you may let us know by using the contact details on the front of this leaflet.

I have a question or would like help completing the questionnaire.

If you would like more information about the study or help with completing the questionnaire, please contact Rhiannon using the contact details on the front page of this leaflet.

I have a concern and would like to speak to somebody other than the researcher.

In this case, please contact:

Dr Mark Pearce (mark.pearce@ncl.ac.uk)
Director of the Newcastle Thousand Families Study
Institute of Health & Society
Newcastle University
Sir James Spence Institute, RVI
Newcastle upon Tyne
NE1 4LP

Appendix E: Topic guide for qualitative interviews (initial version)

Please remember:

- I will ask you lots of questions and listen to your responses.
- Don't worry if some questions are similar and you repeat yourself when answering them.
- There are no right or wrong answers. I am purely interested in your views and experiences.
- Please feel free to be silent when thinking about your answers. I also may be silent for a few minutes whilst I think about my next question!
- If there are any questions that you'd rather not answer, you don't have to.

Introductory Questions

Can you tell me what you understand "having good teeth or good oral health" to mean?

Do you think having good dental health is important? Why/why not?

Not thinking about your dental health but thinking about dental health in general, what factors do you think influence the condition of someone's teeth and mouth?

Your dental health

Can you tell me about what your dental health (your teeth, mouth & gums) is currently like?

How happy are you with the condition of your teeth/mouth/gums?

Can you tell me about how your dental health has changed over your lifetime (ie, from when you were a child to now)?

Why teeth have been lost

We saw you for a dental exam around 1997 (when you were around 50) and around 2009 (when you were around 62). In 1997, you had ___ teeth. In 2009, you had ___ teeth.

Thinking about any adult teeth that you have ever lost or had taken out, when were these teeth lost and why (i.e, did they become loose/have decay/give you pain?)

Influencing factors of YOUR oral health

Please tell me as much as you can about why you think your dental health is as it is now. What do you think caused it to be like this?

Probing questions if needed:

- Were **certain times in your life** particularly important in shaping your dental health?
- Can you think of any **events in your life** that you think influenced your dental health?
- **How did you look after your teeth/mouth** in childhood/adolescence/adulthood?
- How has **the way you think about your mouth and teeth** changed throughout your life?
- Is there any way in which your **friends/family** have any influence on your current dental health?
- How **frequently do you visit a dentist** and has this changed over your lifetime? Why? What has your experience of visiting the dentist been like? What types of treatment have you chosen/received?

Topics to probe if not covered:

- How important do you think what people **eat & drink** is in influencing their dental health? How might your diet have affected your oral health?
- Have you ever **smoked**? If so, can you tell me about your smoking habits over your lifetime? To what extent do you think smoking may have affected your oral health?
- How important do you think mouth cleaning behaviours are? How have you cleaned your mouth and teeth over your life and what factors have influenced this?

Trajectories in middle age

I am very interested in how and why your dental health has changed over the last 20 years or so (over your 50's and 60's). Can you tell me any more about **how** your dental health has changed over these recent years? **And why?**

Most important factors

Now that you have thought in detail about what has influenced your dental health over your lifetime, which do you think have been the most important influencing factors?

Norms

How do you think your dental health compares to other people's, ie, that of your friends/family/other people? **Why** do you think that is?

Closing:

Is there anything about your experience that you feel we haven't covered?

Do you have any questions for me?

Thank you very much for taking part in this study.

Appendix F: Topic guide for qualitative interviews (final version)

NB: Changes from initial version are highlighted by shading.

Please remember:

- I will ask you lots of questions and listen to your responses.
- Don't worry if some questions are similar and you repeat yourself when answering them.
- There are no right or wrong answers. I am purely interested in your views and experiences.
- Please feel free to be silent when thinking about your answers. I also may be silent for a few minutes whilst I think about my next question!
- If there are any questions that you'd rather not answer, you don't have to.

Introductory Questions

Can you tell me what you understand 'having good teeth or good oral health' to mean?

Do you think having good dental health is important? Why/why not?

Not thinking about your dental health but thinking about dental health in general, what factors do you think influence the condition of someone's teeth and mouth?

Your dental health

Can you tell me about what your dental health (your teeth, mouth & gums) is currently like?

How happy are you with the condition of your teeth/mouth/gums?

Can you tell me about how your dental health has changed over your lifetime (i.e., from when you were a child to now)?

Why teeth have been lost

We saw you for a dental exam around 1997 (when you were around 50) and around 2009 (when you were around 62). In 1997, you had ___ teeth. In 2009, you had ___ teeth.

Thinking about any adult teeth that you have ever lost or had taken out, when were these teeth lost and why (i.e., did they become loose/have decay/give you pain?)

Influencing factors of YOUR oral health and behaviours

Please tell me as much as you can about why you think your dental health is as it is now. What do you think caused it to be like this?

Probing questions if needed:

- Were **certain times in your life** particularly important in shaping your dental health and behaviours?
- Can you think of any **events in your life** that you think influenced your dental health and behaviours?
- **How did you look after your teeth/mouth** in childhood/adolescence/adulthood and why?
- How has **the way you think about your mouth and teeth** changed throughout your life?
- Is there any way in which your **friends/family** have influenced your dental health?
- How **frequently do you visit a dentist** and has this changed over your lifetime? Why? What has your experience of visiting the dentist been like? What types of treatment have you chosen/received and why?

Topics to probe if not covered:

- How important do you think what people **eat & drink** is in influencing their dental health? How might your diet have affected your oral health and what has influenced your diet?
- Have you ever **smoked**? If so, can you tell me about your smoking habits over your lifetime and what has influenced them? To what extent do you think smoking may have affected your oral health?
- How important do you think mouth cleaning behaviours are? How have you cleaned your mouth and teeth over your life and what factors have influenced this?
- Has **money or financial issues** had any impact on your dental health at any stage of your life, in any way you can think of? (Prompt as necessary-What

about affording dental treatment/taking time off work for appointments/buying oral hygiene products?)

- Has access to dental services affected your oral health at any time across your life?

Children

Does the participant have children and how have they influenced them across their life?

Emerging Themes to Probe further

- Responsibility: Whose responsibility was it to look after your teeth across your life?/Who is responsible for the way your mouth currently is?
- Incentive: What has been the main incentive to look after your teeth across your life-history/avoidance of pain/aesthetics/function, or was it just habit/influence of others?
- Social versus personal influence-Has your social/family environment or yourself been more influential on your oral health across your life time?
- Importance of habit in oral health behaviours
- Knowledge versus action
- Expectation: How expectation of dental health influenced dental health.
- Priority with age. Have priorities changed with age and why?

Most important factors

Now that you have thought in detail about what has influenced your dental health over your lifetime, which do you think have been the most important influencing factors?

Norms

How do you think your dental health compares to other people's, i.e., that of your friends/family/other people? **Why** do you think that is?

Closing: Is there anything about your experience that you feel we haven't covered?

Thank you very much for taking part in this study.

Appendix G: Final age 69 dental questionnaire sent to NTFS participants

ID:

CONFIDENTIAL

1000 FAMILIES
from Newcastle

DENTAL QUESTIONNAIRE

Newcastle University

COMPLETING THE QUESTIONNAIRE: EXAMPLE PAGE

HOW TO FILL IN THE QUESTIONNAIRE

There are different types of questions in this booklet. Most of them can be answered by ticking a box. Please do not leave any question unanswered and try to answer all questions as accurately and honestly as possible. People and families are very different and there are no 'right' or 'wrong' answers.

For example Do you wear any false teeth or dentures?

☑ Yes ☐ No

Mistakes If you make a mistake, please cross over it and put a tick in the correct box.

☒ Yes ☑ No

If you need any help filling in the questionnaire please contact:

Rhiannon O'Connor
Level 7
School of Dental Sciences
Framlington Place
Newcastle University
Newcastle Upon Tyne
NE2 4BW

Telephone: 0191 208 7829
Email: rhiannon.o'connor@ncl.ac.uk

PLEASE TURN OVER

SECTION A: NATURAL TEETH

Q1a Do you currently have any of your own natural teeth?

☐ Yes ☐ No

Q1b If you answered "No" to Q1a, at what age did you lose your last natural tooth?

[ ] years

SECTION B: TOOTHBRUSHING HABITS

Q2 At the following ages, how often did you brush your own natural teeth, on average? (If you had no natural teeth, please tick "I had none of my own natural teeth at this age".)

Please select one option on every line.

	Twice daily or more	Once daily	Less than once per day	Never or rarely	I had none of my own natural teeth at this age
(a) Age 15	☐	☐	☐	☐	☐
(b) Age 25	☐	☐	☐	☐	☐
(c) Age 35	☐	☐	☐	☐	☐
(d) Age 50	☐	☐	☐	☐	☐
(e) Age 60	☐	☐	☐	☐	☐

SECTION C: DENTAL VISITING PATTERNS

Q3 Around the following ages, how frequently did you attend the dentist for a check-up?
Please select one option on every line.

	At least once per year	At least once every 2 years	Less frequently than every two years	I never attended for a check-up, only when I was having trouble
(a) Age 15	☐	☐	☐	☐
(b) Age 25	☐	☐	☐	☐
(c) Age 35	☐	☐	☐	☐
(d) Age 50	☐	☐	☐	☐
(e) Age 60	☐	☐	☐	☐

SECTION D: ANXIETY ABOUT VISITING THE DENTIST

PART A: CURRENT FEELINGS ABOUT VISITING THE DENTIST

This section asks about your current feelings about visiting the dentist and receiving dental treatment

Q4 If you went to the dentist for treatment tomorrow, how would you feel?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q5 If you were sitting in the waiting room (waiting for treatment), how would you feel?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q6 If you were about to have a tooth drilled, how would you feel?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q7 If you were about to have your teeth scaled and polished, how would you feel?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q8 If you were about to have a local anaesthetic injection in your gum, above an upper back tooth, how would you feel?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

PART B: PAST FEELINGS ABOUT VISITING THE DENTIST

This section asks about your past feelings about visiting the dentist and receiving dental treatment.

Q9 When you were 15 years old, how would you have felt if you needed to go to the dentist for treatment?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q10 When you were 25 years old, how would you have felt if you needed to go to the dentist for treatment?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q11 When you were 35 years old, how would you have felt if you needed to go to the dentist for treatment?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q12 When you were 50 years old, how would you have felt if you needed to go to the dentist for treatment?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

Q13 When you were 60 years old, how would you have felt if you needed to go to the dentist for treatment?

Not Anxious	Slightly Anxious	Fairly Anxious	Very Anxious	Extremely Anxious
☐	☐	☐	☐	☐

SECTION E: DIET

Questions 14a-14e (overleaf) ask about the number of times in an average day you consumed sugary food or drink at the ages of 15, 25, 35, 50 and 62 years.

The number of times per day is important. If you consumed multiple sugary foods and drinks in one go, e.g. 3 biscuits and a cup of tea with sugar added at 11am, this would count as ONE time per day.

EXAMPLE

On an average day at the age of 15, Mr Smith remembers consuming the sugary food and drink below at the following times:

8am: *Sugar added to breakfast cereal & a cup of tea with sugar added*
11am: *A sugary snack, e.g. a couple of chocolate biscuits*
1pm: *A sugary pudding, e.g. a slice of cake*
5pm: *Sweets or a bar of chocolate*
6pm: *A sugary pudding & a cup of tea with sugar added*

Therefore, he remembers consuming sugary food or drink on 5 separate occasions and would complete Question 14a as follows:

	Less than once per day	1-2 times per day	3-4 times per day	5-6 times per day	7 or more times per day
(a) Age 15	☐	☐	☐	☑	☐

Examples of sugary foods and drinks are:

Drinks

- *tea and coffee with sugar*
- *fresh fruit juice*
- *sugared milk-based drinks, e.g. hot chocolate*
- *squash/cordial (not sugar-free varieties)*
- *fizzy drinks (not diet or sugar-free varieties)*
- *some alcoholic drinks (particularly ciders, sherry, port, sweet wines and alcopops)*

Foods

- *table sugar*
- *cakes and puddings*
- *sweets*
- *biscuits*
- *chocolate*
- *jams, preserves and honey*
- *sugary breakfast cereals*
- *fruit in syrup*

Q14 At the following ages, how many times per day did you consume sugary food or drink, on average?
Please select one option on every line.

	Less than once per day	1-2 times per day	3-4 times per day	5-6 times per day	7 or more times per day
(a) Age 15	☐	☐	☐	☐	☐
(b) Age 25	☐	☐	☐	☐	☐
(c) Age 35	☐	☐	☐	☐	☐
(d) Age 50	☐	☐	☐	☐	☐
(e) Age 62	☐	☐	☐	☐	☐

SECTION F: INFLUENCE OF FAMILY MEMBERS ON YOUR DENTAL HEALTH

This section asks about the influence your parents and partner/spouse have had on your dental health

Q15 How much encouragement did you receive from your parents/guardians to look after your teeth in childhood (such as them encouraging you to brush your teeth or taking you to the dentist)?

Strong encouragement	Moderate encouragement	A little bit of encouragement	No encouragement
☐	☐	☐	☐

Q16 Overall, how much influence has your partner(s)/spouse(s) had on the way you have looked after your teeth in your adult life (such as your dental attendance or your teeth cleaning habits)?

Strong positive influence	Moderate positive influence	Small positive influence	No influence	A negative influence	Never had a partner/spouse
☐	☐	☐	☐	☐	☐

SECTION G: Relationships

This question asks about any changes to your relationships between 1996 and 2012 (the period between when you completed the age 50 Health & Lifestyle Questionnaire and attended your most recent dental examination with the Thousand Families Study team).

Q17 Please indicate below, by ticking the appropriate box(es), if any of the following happened to you **between 1996 and 2012.**
Tick as many boxes as relevant.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	N/A
(a) You got married	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
(b) You entered into a civil partnership	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
(c) You got divorced	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
(d) You legally separated from your husband/wife/ civil partner	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
(e) You were widowed	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

END - THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE
PLEASE NOW RETURN IN ENVELOPE PROVIDED

Appendix H: Initial version of the 'scenario-based' sugar intake question (not included in the final dental questionnaire)

SECTION 4: DIET

The following questions ask about the number of times per day you consumed sugary food and drink at the ages of 15, 25, 35, 50 and 62 years.

Please read the three examples below, which describe three different patterns of sugary food and drink consumption in an average day. The subsequent questions ask whether the number of times you consumed sugary food and drink in an average day, at the ages of 15, 25, 35, 50 and 62, were most similar to Example A, B or C.

Examples of sugary drinks are:

- *tea and coffee with sugar*
- *fruit juice*
- *cocoa or chocolate drinks*
- *squash/cordial (not sugar-free varieties)*
- *fizzy drinks (not diet or sugar-free varieties)*
- *some alcoholic drinks (particularly ciders, sherry, port, sweet wines and alcopops)*

Examples of sugary foods are:

- *table sugar*
- *cakes*
- *sweets*
- *biscuits*
- *puddings*
- *chocolate*
- *sugary breakfast cereals*

Example A

On an average day, I wouldn't usually consume much sugary food or drink. I would only have sugary things once or twice per day, such as a cup of tea with sugar added at breakfast and a sweet sponge pudding after my dinner, but that would be it. The rest of the time I would eat non-sugary foods and have sugar-free drinks, like water or tea without sugar.

Example B

On an average day, I would have sugary food and drink on three or four separate occasions throughout the day. For example, I would usually have some sugar at breakfast time, perhaps on my breakfast cereal and added to a cup of tea. I would then have a couple of chocolate biscuits mid-morning, perhaps with a sugary drink also. I would also always have a sweet pudding after my dinner. However, on other occasions throughout the day, I would eat and drink mainly non-sugary things.

Example C

On an average day, I would have sugary food and drink on five or more separate occasions throughout the day. I would have sugar at every mealtime; For example, I would have sugar on my cereal and added to a cup of tea at breakfast and I would have a sweet pudding and often a sugary drink at both lunch and dinner time. In between each meal, I would always have sugary food and drinks, such as cakes, sweets, biscuits, cups of tea with sugar added or drinks of fizzy pop.

Q4a At the **age of 15**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Example A, B or C? *Please select one option.*

☐ Example A ☐ Example B ☐ Example C

Q4b At the **age of 25**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Example A, B or C? *Please select one option.*

☐ Example A ☐ Example B ☐ Example C

Q4c At the **age of 35**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Example A, B or C? *Please select one option.*

☐ Example A ☐ Example B ☐ Example C

Q4d At the **age of 50**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Example A, B or C? *Please select one option.*

☐ Example A ☐ Example B ☐ Example C

Q4e At the **age of 62**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Example A, B or C? *Please select one option.*

☐ Example A ☐ Example B ☐ Example C

Appendix I: Second version of the 'scenario-based' sugar intake question (not included in the final dental questionnaire)

SECTION 4: DIET

The following questions ask about the number of times per day you consumed sugary food and drink at the ages of 15, 25, 35, 50 and 62 years.

Please read Scenarios A, B and C below, giving 3 examples of sugary food and drink consumption in an average day. The subsequent questions ask whether the number of times you consumed sugary food and drink in an average day, at the ages of 15, 25, 35, 50 and 62, was most similar to Scenario A, B or C.

If you consumed several sugary foods and drinks at the same time of day, this only counts as one episode of consumption.

Examples of sugary drinks are:

- *tea and coffee with sugar*
- *fruit juice*
- *cocoa or chocolate drinks*
- *squash/cordial (not sugar-free varieties)*
- *fizzy drinks (not diet or sugar-free varieties)*
- *some alcoholic drinks (particularly ciders, sherry, port, sweet wines and alcopops)*

Examples of sugary foods are:

- *table sugar*
- *cakes*
- *sweets*
- *biscuits*
- *puddings*
- *chocolate*
- *sugary breakfast cereals*

Scenario A

Sugary food and/or drink consumed at	*8am* *4pm*

Scenario B

Sugary food and/or drink consumed at	*8am* *11am* *3pm* *6pm*

Scenario C

Sugary food and/or drink consumed at	*8am* *11am* *1pm* *3pm* *6pm* *9pm*

Q4a	At the **age of 15**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C? *Please select one option.*

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4b	At the **age of 25**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C? *Please select one option.*

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4c	At the **age of 35**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C? *Please select one option.*

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4d	At the **age of 50**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C? *Please select one option.*

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4e	At the **age of 62**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C? *Please select one option.*

☐ Scenario A ☐ Scenario B ☐ Scenario C

Appendix J: Third version of the 'scenario-based' sugar intake question (not included in the final dental questionnaire)

SECTION 4: DIET

Questions 4a-4e (overleaf) ask about the number of times per day you consumed sugary food and drink in your past.

Please read Scenarios A, B and C below, which give 3 examples of sugary food and drink consumption in an average day. Questions 4a to 4e (overleaf) ask whether the number of times you consumed sugary food and drink in an average day, at specific ages, was most similar to Scenario A, B or C.

NB: If you consumed several sugary foods and drinks at the same time of day, this only counts as one episode of consumption.

Examples of sugary drinks are:

- *tea and coffee with sugar*
- *fresh fruit juice*
- *cocoa or chocolate drinks*
- *squash/cordial (not sugar-free varieties)*
- *fizzy drinks (not diet or sugar-free varieties)*
- *some alcoholic drinks (particularly ciders, sherry, port, sweet wines and alcopops)*

Examples of sugary foods are:

- *table sugar*
- *cakes and puddings*
- *sweets*
- *biscuits*
- *chocolate*
- *jams, preserves and honey*
- *sugary breakfast cereals*

Scenario A

8am	*A sugary drink*
6pm	*A sweet sponge pudding*

Scenario B

8am	*A sugary drink*
11am	*A couple of chocolate biscuits and a sugary drink*
3pm	*A sugary drink*
6pm	*A sweet sponge pudding*

Scenario C

8am	*A sugary drink*
11am	*A slice of cake*
1pm	*A sweet sponge pudding and a sugary drink*
3pm	*A bag of sweets*
6pm	*A sugary drink*
9pm	*A couple of chocolate biscuits*

Q4a At the **age of 15**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C?
Please select one option.

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4b At the **age of 25**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C?
Please select one option.

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4c At the **age of 35**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C?
Please select one option.

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4d At the **age of 50**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C?
Please select one option.

☐ Scenario A ☐ Scenario B ☐ Scenario C

Q4e At the **age of 62**, was the **number of times** you consumed **sugary food and drink** in an **average day** most similar to Scenario A, B or C?
Please select one option.

☐ Scenario A ☐ Scenario B ☐ Scenario C

Appendix K: Age 69 dental questionnaire responses stratified by gender (for the purpose of assessing construct validity)

	Age 15		Age 25		Age 35		Age 50		Age 60	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Tooth brushing frequency										
Twice daily or more	33.0	50.3	47.0	64.6	56.6	73.4	58.8	79.3	63.3	80.6
Once daily	45.0	40.8	45.0	31.9	36.4	25.9	35.1	19.3	30.6	18.0
Less than once daily	18.0	4.7	6.0	2.8	6.1	0.0	4.1	1.4	5.1	1.4
Never or rarely	4.0	4.1	2.0	0.7	1.0	0.7	2.1	0.0	1.0	0.0
Dental check-ups										
At least once per year	41.8	65.3	42.7	70.6	59.2	78.6	72.8	89.0	79.8	86.4
At least once every 2 yrs	11.7	8.8	22.3	11.0	16.5	9.7	4.9	4.1	4.8	0.7
Less than every 2 years	7.8	6.1	10.7	6.1	7.8	6.2	8.7	3.4	2.9	4.1
Never, only when trouble	38.8	19.7	24.2	12.3	16.5	5.5	13.6	3.4	12.5	8.8
Anxiety about treatment										
Not anxious	16.0	18.5	32.1	21.9	49.1	25.2	58.5	32.7	62.3	36.2
Slightly anxious	32.1	18.5	36.8	30.5	27.4	34.4	25.5	33.3	25.5	33.6
Fairly anxious	26.4	23.1	18.9	22.5	18.9	21.9	12.3	19.3	8.5	12.8
Very anxious	18.9	27.1	8.5	17.9	3.8	13.3	2.8	10.0	3.8	12.8
Extremely anxious	6.6	12.6	3.8	7.3	0.9	5.3	0.9	4.7	0.0	4.7
Sugar consumption frequency										
Less than once per day	3.9	2.7	2.9	2.0	8.7	7.4	13.5	11.6	20.8	17.6
1-2 times per day	18.5	20.1	22.3	25.7	29.8	22.7	36.5	36.7	41.5	38.5
3-4 times per day	44.7	47.7	45.6	46.6	34.6	45.6	30.8	38.1	25.5	32.4
5-6 times per day	20.4	27.5	20.4	25.0	22.1	17.6	16.4	11.6	9.4	8.8
7 or more times per day	12.6	2.0	8.7	0.7	4.8	1.4	2.9	2.0	2.8	2.7

	Male	**Female**
Current dental anxiety (MDAS score)	8.3	11.4
Spousal influence		
Strong positive	28.3	17.0
Moderate positive	32.1	15.7
Small positive	16.0	10.9
No influence	23.6	55.8
Negative influence	0.0	0.7

Table 32: Age 69 dental questionnaire responses stratified by gender (n=261). All values are proportions, apart from MDAS scores, which are means

Appendix L: Step-by-step model iterations, and rationale for the model building process, used to produce a path model of the life course determinants of tooth retention age 63.

Iteration number	Action	Model statistics		Explanatory notes
		Non-sig paths (p>0.05)	Modification Indices (MI)	
1.	Reduced multivariable regression analysis constructed as path model		49.6 - dental attendance 15/dental attendance 35	Theoretically sound causal path
2.	Added path: dental attendance 15 → dental attendance 35		5.2 - dental attendance 35/dental anxiety (late adulthood)	Paths between any dental attendance & dental anxiety variables not included until all dental anxiety/dental attendance variables in model (exploratory analyses demonstrated excessive number of iterations required otherwise)
			No lower MIs	
3.	Added new variable: pack-years 30-62		7.5 - pack-years 30-62/tooth count age 63	Theoretically sound causal path
4.	Added path: pack-years 30-62 → tooth count age 63		5.2 - dental attendance 35/dental anxiety (late adulthood)	Rationale as per iteration 2
			No lower MIs	
5.	Added new variable: education level		12.5 - education level/tooth count age 63	Theoretically sound causal path
6.	Added path: education level → tooth count age 63		7.4 - education level/pack-years 30-62	Theoretically sound causal path
7.	Added path: education level → pack-years 30-62		6.5 - education level/dental anxiety (late adulthood)	Theoretically sound causal path
8.	Added path: education level → dental anxiety (late adulthood)		5.5 - dental attendance 50/dental anxiety (late adulthood)	Rationale as per iteration 2

			4.9 - dental attendance 35/dental anxiety (late adulthood)	Rationale as per iteration 2
			No lower MIs	
9.	Added new variable: pack-years 10-29		110.5 - pack-years 10-29/pack-years 30-62	Theoretically sound causal path
10.	Added path: pack-years 10-29 → pack-years 30-62		5.5 - dental attendance 50/dental anxiety (late adulthood)	Rationale as per iteration 2
			4.9 - dental attendance 35/dental anxiety (late adulthood)	Rationale as per iteration 2
			No lower MIs	
11.	Added new variable: dental anxiety (early adulthood)		55.2 - dental anxiety (early adulthood)/dental anxiety (late adulthood)	Theoretically sound causal path
12.	Added path: dental anxiety (early adulthood) → dental anxiety (late adulthood)		8.3 - dental anxiety (early adulthood)/dental attendance 35	Rationale as per iteration 2
			6.1 - dental attendance 50/dental anxiety (late adulthood)	Rationale as per iteration 2
			No lower MIs	
13.	Added new variable: sugar consumption 50		As for iteration 12	Variable removed from model as no associated MIs
14.	Added new variable: illness limiting daily activity (age 50)		As for iteration 12	Variable removed from model as no associated MIs
15.	Added new variable: dental attendance 15		13.2 - dental attendance 15/dental attendance 35	Theoretically sound causal path
16.	Added path: dental attendance 15 → dental attendance 35		9.4 - dental attendance 15/dental anxiety (early adulthood)	Theoretically sound causal path (could now be added as all dental attendance/dental

					anxiety variables in model-see rationale at iteration 2)
17.	Added path: dental attendance 15 → dental anxiety (early adulthood)		9.2	- education level/dental attendance 15	No theoretical rationale (issues with temporal relationship in direction shown as education to degree level would occur after age 15/no causal rationale for reverse direction)
			7.1	- dental attendance 15/pack-years 10-29	Monitored as theoretical rationale potentially weak
			6.1	- dental attendance 50/dental anxiety (late adulthood)	Theoretically sound causal path
18.	Added path: dental attendance 50 → dental anxiety (late adulthood)	dental attendance 50 → dental anxiety (late adulthood)			
19.	Removed path: dental attendance 50 → dental anxiety (late adulthood)		9.2	- education level/dental attendance 15	Rationale as per iteration 17
			7.1	- dental attendance 15/pack-years 10-29	Rationale as per iteration 17
			6.1	- dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			5.0	- dental attendance 15/dental anxiety (late adulthood)	Theoretically sound causal path
20.	Added path: dental attendance 15 → dental anxiety (late adulthood)		9.2	- dental attendance 15/education level	Rationale as per iteration 17
			7.1	- dental attendance 15/pack-years 10-29	Rationale as per iteration 17
			6.7	- dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant

			4.7 - dental anxiety (early adulthood)/dental attendance 35	Theoretically sound causal path
21.	Added path: dental anxiety (early adulthood) → dental attendance 35		9.2 - education level/dental attendance 15	Rationale as per iteration 17.
			7.1 - dental attendance 15/pack-years 10-29	Rationale as per iteration 17
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			No lower MIs	
22.	Added new variables: tooth brushing 15, tooth brushing 35, tooth brushing 50		114.6 - tooth brushing 35/tooth brushing 50	Theoretically sound causal path
23.	Added path: tooth brushing 35 → tooth brushing 50		58.6 - tooth brushing 15/tooth brushing 35	Theoretically sound causal path
24.	Added path: tooth brushing 15 → tooth brushing 35		15.4 - education level/tooth brushing 15	No theoretical rationale (issues with temporal relationship in direction shown as education to degree level would occur after age 15/no causal rationale for reverse direction)
			9.2 - education level/dental attendance 15	Rationale as per iteration 17.
			8.1 - dental attendance 35/tooth brushing 35	Theoretically sound causal path
25.	Added path: dental attendance 35 → tooth brushing 35		15.4 - education level/tooth brushing 15	Rationale as per iteration 24
			9.2 - education level/dental attendance 15	Rationale as per iteration 17
			8.2 - dental attendance 15/tooth brushing 15	Theoretically sound causal path
26.	Added path: dental attendance 15 → tooth brushing 15		11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			9.2 - education level/dental attendance 15	Rationale as per iteration 17

			7.3 - dental attendance 50/tooth brushing 50	Theoretically sound causal path
27.	Added path: dental attendance 50 → tooth brushing 50		11.3 - education level/tooth brushing 15	Rationale as per iteration 24
			9.1 - education level/dental attendance 15	Rationale as per iteration 17
			7.0 - dental attendance 15/pack-years 10-29	Rationale as per iteration 17
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			No lower MIs	
28.	Added new variable: standardised birth weight		As for iteration 27	Variable removed from model as no associated MIs
29.	Added new variable: sex		16.8 - sex/dental attendance 15	Theoretically sound causal path
30.	Added path: sex → dental attendance 15		14.7 - education level/dental attendance 15	Rationale as per iteration 17
			11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			7.9 - sex/dental anxiety (early adulthood)	Theoretically sound causal path
31.	Added path: sex → dental anxiety (early adulthood)		14.7 - education level/dental attendance 15	Rationale as per iteration 17
			11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			6.8 - sex/pack-years 10-29	Theoretically sound causal path
32.	Added path: sex → pack-years 10-29		14.7 - education level/dental attendance 15	Rationale as per iteration 17
			11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			5.7 - sex/dental attendance 35	Theoretically sound causal path
33.			14.7 - education level/dental attendance 15	Rationale as per iteration 17

	Added path: sex → dental attendance 35		11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Rationale as per iteration 18
			No lower MIs	
34.	Added new variables: social class birth, social class 50		18.5 - social class birth/dental attendance 15	Theoretically sound causal path
35.	Added new path: social class birth → dental attendance 15		11.4 - education level/tooth brushing 15	Rationale as per iteration 24
			9.1 - education level/dental attendance 15	Rationale as per iteration 17
			8.8 - social class birth/education level	Theoretically sound causal path
36.	Added path: social class birth → education level		14.4 - education level/tooth brushing 15	Rationale as per iteration 24
			7.7 - sex/education level	Theoretically sound causal path
37.	Added path: sex → education level		19.8 - education level/tooth brushing 15	Rationale as per iteration 24
			8.6 - education level/dental attendance 15	Rationale as per iteration 17
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			6.6 - education level/social class 50	Theoretically sound causal path
38.	Added path: education level → social class 50		19.6 - education level/tooth brushing 15	Rationale as per iteration 24
			8.6 - education level/dental attendance 15	Rationale as per iteration 17
			6.7 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			6.3 - sex/social class birth	No theoretical rationale
			No lower MIs	
39.	Added new variable: parental encouragement		32.3 - parental encouragement/dental attendance 15	Theoretically sound causal path

40.	Added path: parental encouragement → dental attendance 15		19.8 - education level/tooth brushing 15	Rationale as per iteration 24
			13.5 - parental encouragement/tooth brushing 15	Theoretically sound causal path
41.	Added path: parental encouragement → tooth brushing 15	Dental attendance 15 → tooth brushing 15		
42.	Removed dental attendance 15 → tooth brushing 15		19.8 - education level/tooth brushing 15	Rationale as per iteration 24
			9.0 - education level/dental attendance 15	Rationale as per iteration 17
			6.8 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			6.3 - sex/social class birth	Rationale as per iteration 38
			5 6 - social class birth/parental encouragement	Theoretically sound causal path
43.	Added path: social class birth → parental encouragement		19.7 - education level/tooth brushing 15	Rationale as per iteration 24
			9.0 - education level/dental attendance 15	Rationale as per iteration 17
			6.8 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			6.3 - sex/social class birth	Rationale as per iteration 38
			5.2 - sex/tooth brushing 15	Theoretically sound causal path
44.	Added path: sex → tooth brushing 15		20.0 - education level/tooth brushing 15	Rationale as per iteration 24
			8.8 - education level/dental attendance 15	Rationale as per iteration 17
			6.8 - dental attendance 50/dental anxiety (late adulthood)	Tried in iteration 18 & non-significant
			6.3 - sex/social class birth	Rationale as per iteration 38
			4.0 - pack-years 10-29/dental attendance 35	No theoretical rationale
			No lower MIs	

45.	Added new variable: years married		As for iteration 44	Variable removed from model as no associated MIs No further variables to try in model so re-tried dental attendance 50 → dental anxiety (late adulthood) path as only remaining theoretically sound MI
46.	Added path: dental attendance 50 → dental anxiety (late adulthood)		20.0 - education level/tooth brushing 15	Rationale as per iteration 24
			8.8 - education level/dental attendance 15	Rationale as per iteration 17
			6.3 - sex/social class birth	Rationale as per iteration 38
			5.0 - sex/dental anxiety (late adulthood)	Theoretically sound causal path
47.	Added path: sex → dental anxiety (late adulthood)	Dental attendance 15 → dental anxiety (late adulthood)		
48.	Removed path: dental attendance 15 → dental anxiety (late adulthood)	Education level → dental anxiety (late adulthood)		
49.	Removed path: education level → dental anxiety (late adulthood)		20.0 - education level/tooth brushing 15	Rationale as per iteration 24
			8.8 - education level/dental attendance 15	Rationale as per iteration 17
			6.3 - sex/social class birth	Rationale as per iteration 38
			No lower MIs	No further variables to try in model and no theoretically justifiable MIs so re-tried all predictor variables not included in model
50.	Added variables: standardised birth weight, sugar consumption 50, illness limiting daily activity (age 50), years married		As for iteration 49	Variables removed from model as no associated MIs Next step was to remove variables with no route to outcome

51.	Removed variables: tooth brushing 15, tooth brushing 35, tooth brushing 50, social class 50			Next step was to estimate robust significance values for regression coefficients via bootstrapping
52.	Bootstrapping (based upon 50,000 samples)	Dental attendance 50 → tooth count age 63		
53.	Removed path: dental attendance 50 → tooth count age 63	Dental attendance 35 → tooth count age 63		
54.	Removed path: dental attendance 35 → tooth count age 63			MODEL COMPLETE

Table 33: Step-by-step model iterations and rationale for the model building process used to produce a path model of the life course determinants of age 63 tooth retention.
New paths were added based upon modification indices (MIs) and paths were continuously removed if their significance fell below 5% (p<0.05).
MIs indicate the expected reduction in the model chi-square statistic should a new path be added to the model between two variables or should two variables be allowed to covary. The type of path (covariance or regression) and the direction of regression paths were determined based on what was theoretically sound and justifiable. MIs are only listed in this table (in order of greatest) until an MI suggests a theoretically justifiable path to be added to the model. MIs below this are not listed for brevity. Only MIs of four or above were generated, as the addition of paths or covariances associated with MIs below this threshold do not reduce model chi-square statistics by statistically significant amounts.

Appendix M: Comparison of characteristics between 198 individuals with complete data (for all variables included in the path model building process) and 47 individuals with missing data

Variable	n=198	n=47	p-value
	Mean (SD)		
Standardised Birth Weight	-0.07 (1.08)	-0.37 (0.90)	0.075
	Median (IQR)		
Years Married	38 (34-41)	38 (35-42)	0.339
Pack-years 10-29	0 (0-5)	1.2 (0-10.5)	0.117
Pack-years 30-62	0 (0-4.5)	0 (0-8.4)	0.201
Dental Anxiety (early adulthood)	7 (5-9)	7 (4.25-10)	0.853
Dental Anxiety (late adulthood)	9 (7-12)	10 (6.5-13)	0.722
Tooth Count Age 63	25 (22-27)	25 (19-26)	0.084
	%		
Sex Ref = Male Female	 40.9 59.1	 44.7 55.3	 0.637
Parental Encouragement Ref = Little/None Strong/mod	 36.4 63.6	 50.0 50.0	 0.088
Education Level Ref = Below A-levels A-levels or above	 58.6 41.4	 72.5 27.5	 0.100
Social Class Birth Ref = Partly skilled/unskilled Skilled/managerial & technical/professional	 16.7 83.3	 27.9 72.1	 0.086
Social Class 50 Ref = Partly skilled/unskilled Skilled/managerial & technical/professional	 8.6 91.4	 18.6 81.4	 0.051
Illness Limiting Daily Activity (age 50) Ref = No Yes	 87.4 12.6	 90.9 9.1	 0.514
Sugar Consumption 50 Ref = Quantile 1 Quantile 2	 48.0 52.0	 45.5 54.6	 0.762
Dental Attendance 15 Ref = Less than once per year At least once per year	 41.9 58.1	 51.3 48.7	 0.281
Dental Attendance 35 Ref = Less than once every 2 years At least once every 2 years	 13.6 86.4	 18.4 81.6	 0.442
Dental Attendance 50 Ref = Less than once every 2 years	 10.1	 14.6	 0.396

Variable	n=198	n=47	p-value
At least once every 2 years	89.9	85.4	
Tooth Brushing 15 Ref = Once daily or less Twice daily or more	 55.6 44.4	 62.2 37.8	 0.457
Tooth Brushing 35 Ref = Once daily or less Twice daily or more	 31.8 68.2	 38.9 61.1	 0.406
Tooth Brushing 50 Ref = Once daily or less Twice daily or more	 26.8 73.2	 37.1 62.9	 0.209

Table 34: Comparison of characteristics between 198 individuals with complete data (for all variables included in the path model building process) and 47 individuals with missing data. Means, standard deviations and t-tests are presented for normally distributed continuous variables. Medians, interquartile ranges and Mann-Whitney U tests are presented for non-normally distributed continuous variables. Proportions and chi-squared tests are presented for categorical variables.

Appendix N: Comparison of characteristics between the NTFS sample eligible for path analysis (n=245) and the UK population of a similar generation.

Topic	Measurement in NTFS sample (n=245)	Value	Best available UK comparator	Value
Tooth retention	Mean number of retained teeth at age 63 (in 2010)	23.5	Mean number of retained teeth in dentate 55-64 year olds in 2009 UK ADHS (Fuller et al. 2011)	23.2
Sex	Proportion of females	58%	Proportion of females in UK's 63 year-old population in 2008 (ONS)	51%
Smoking	Proportion reporting current smoking at age 50 (in 1998)	16%	Proportion of UK adults aged 50-59 reporting current smoking in 1998 (The Health & Social Care Information Centre 2009)	27%
Dental anxiety	Mean total MDAS score at age 69 (in 2016)	10.0	Mean total MDAS score at age 65-74 in 2009 UK ADHS (Nuttall et al. 2011a)	9.2
Tooth brushing	Proportion reporting twice daily tooth brushing at age 50 (in 1998)	72%	Proportion of dentate 45-54 year olds reporting twice daily tooth brushing in the 1998 ADHS (Kelly et al. 2000)	71%
Dental attendance	Proportion reporting 'regular' attendance for dental check-ups at age 50 (in 1998)	73%	Proportion of dentate adults aged 45-54 reporting 'regular' attendance for dental check-ups in 1998 UK ADHS (Kelly et al. 2000)	64%

Table 35: Comparing characteristics of the NTFS sample eligible for path analysis (n=245) with national UK data from a similar generation.
Note: Best available comparisons are presented, so the year and age groups associated with UK comparisons may differ slightly from that of the NTFS sample (born in 1947); comparisons for socio-economic characteristics (such as social class and educational attainment) were not possible due to the incomparability of available data; the NTFS sample included only dentate participants, hence the use of dentate groups in UK comparisons of tooth retention, tooth brushing and dental attendance; the 2009 UK Adult Dental Health Survey (ADHS) excluded Scotland.

Appendix O: Table of unstandardised and standardised regression coefficients for all regression paths in the final path model of the life course determinants of age 63 tooth retention (n=198).

Regression path	Unstandardised beta	95% CI	Standardised beta	95% CI	p-value
Tooth count age 63					
Education Level Below A-levels (ref) A-levels or above	1.658	(0.463, 2.896)	0.172	(0.050, 0.293)	0.006
Pack-years 30-62	-0.072	(-0.141, -0.010)	-0.143	(-0.270, -0.020)	0.023
Dental Anxiety (late adulthood)	-0.325	(-0.517, -0.154)	-0.305	(-0.441, -0.156)	<0.001
Pack-years 30-62					
Education level Below A-levels (ref) A-levels or above	-2.241	(-3.891, -0.598)	-0.116	(-0.194, -0.032)	0.008
Pack-years 10-29	1.432	(1.165, 1.695)	0.746	(0.646, 0.835)	<0.001
Dental attendance 50 *Less than once every 2 years (ref)* *At least once every 2 years*					
Dental attendance 35 Less than once every 2 years (ref) At least once every 2 years	0.441	(0.246, 0.636)	0.500	(0.301, 0.676)	<0.001
Dental anxiety (late adulthood)					
Dental attendance 50 Less than once every 2 years (ref) At least once every 2 years	-2.971	(-4.891, -1.070)	-0.199	(-0.325, -0.070)	0.003
Sex Male (ref) Female	1.953	(0.905, 2.986)	0.214	(0.101, 0.320)	<0.001
Dental anxiety (early adulthood)	0.716	(0.535, 0.898)	0.488	(0.368, 0.599)	<0.001
Dental attendance 35 *Less than once every 2 years (ref)* *At least once every 2 years*					
Dental attendance 15 Less than once per year (ref) At least once per year	0.113	(0.002, 0.226)	0.159	(0.003, 0.308)	0.046
Sex Male (ref) Female	0.130	(0.024, 0.238)	0.187	(0.037, 0.329)	0.016
Dental anxiety (early adulthood)	-0.022	(-0.039, -0.005)	-0.196	(-0.341, -0.046)	0.011

Regression path	Unstandardised beta	95% CI	Standardised beta	95% CI	p-value
Education level *Below A-levels (ref)* *A-levels or above*					
Sex Male (ref) Female	-0.200	(-0.337, -0.063)	-0.198	(-0.330, -0.063)	0.005
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	0.326	(0.161, 0.479)	0.245	(0.119, 0.358)	<0.001
Pack-years 10-29					
Sex Male (ref) Female	-1.879	(-3.403, -0.442)	-0.185	(-0.313, -0.047)	0.010
Dental anxiety (early adulthood)					
Dental attendance 15 Less than once per year (ref) At least once per year	-1.737	(-2.521, -0.949)	-0.275	(-0.393, -0.153)	<0.001
Sex Male (ref) Female	1.329	(0.560, 2.098)	0.213	(0.092, 0.330)	0.001
Dental attendance 15 *Less than once per year (ref)* *At least once per year*					
Sex Male (ref) Female	0.201	(0.068, 0.334)	0.204	(0.068, 0.341)	0.003
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	0.284	(0.122, 0.443)	0.219	(0.092, 0.344)	0.001
Parental encouragement Little/none (ref) Strong/moderate	0.340	(0.203, 0.476)	0.338	(0.201, 0.472)	<0.001
Parental encouragement *Little/none (ref)* *Strong/moderate*					
Social class birth Partly skilled/unskilled (ref) Skilled/managerial & technical/professional	0.218	(0.030, 0.402)	0.169	(0.023, 0.310)	0.022

Table 36: Unstandardised and standardised regression coefficients for all regression paths in the final path model of the life course determinants of age 63 tooth retention (n=198).

Appendix P: Relation between the influences of OHBs identified in the qualitative study, the fourteen domains of the Theoretical Domains Framework (TDF) and the components of the COM-B model.

COM-B component		TDF domain ***(definition)***	TDF domain constructs	Examples in present study
Capability	Psychological	Knowledge *(An awareness of the existence of something)*	Knowledge (including knowledge of condition /scientific rationale) Procedural knowledge Knowledge of task environment	• Knowledge of ideal/recommended OHBs, e.g. knowledge of recommended oral hygiene regimes. • Knowledge of effects of OHBs, e.g. effects of sugar on teeth.
		Memory, attention and decision processes *(The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives)*	Memory Attention Attention control Decision making Cognitive overload / tiredness	• Limited
		Behavioural Regulation *(Anything aimed at managing or changing objectively observed or measured actions)*	Self-monitoring Breaking habit Action planning	• Relatively limited • Ability to break long-term habits, e.g. smoking habits
	Psychological and physical	Skills *(An ability or proficiency acquired through practice)*	Skills Skills development Competence Ability Interpersonal skills Practice Skill assessment	• Relatively limited • Ability to manage dental anxiety • Physical skills related to oral hygiene techniques (often taught by dentists)

Opportunity	Social	Social Influences *(Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours)*	Social pressure Social norms Group conformity Social comparisons Group norms Social support Power Intergroup conflict Alienation Group identity Modelling	• Influence of dental professionals, peers and family members, e.g. control, guidance and role modelling of OHBs/conformance to behavioural norms. • Importance of chairside manner of dentists in shaping dental anxiety and effectiveness of oral health education advice • Role modelling positive OHBs to children
	Physical	Environmental context and resources *(Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour)*	Environmental stressors Resources / material resources Organisational culture /climate Salient events / critical incidents Person x environment interaction Barriers and facilitators	• Influence of school environment, career profession, media and marketing sources, financial concerns, dental technology and techniques, time constraints and competing distractions on OHBs.

Motivation	Reflective	Beliefs about capabilities *(Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use)*	Self-confidence Perceived competence Self-efficacy Perceived behavioural control Beliefs Self-esteem Empowerment Professional confidence	• Self-efficacy beliefs influenced behaviours, e.g. beliefs about one's capability to give up smoking. • Beliefs about one's level of control over their own oral health (locus of control beliefs).
		Beliefs about consequences *(Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation)*	Beliefs Outcome expectancies Characteristics of outcome expectancies Anticipated regret Consequents	• Awareness of positive and negative consequences of OHBs was key driver of behaviours. • Beliefs were often related to own or others' past experiences of oral or general health, or advice from parents/dental professionals/media. • Denial and self-deception about oral health consequences negatively impacted behaviour.
		Intentions *(A conscious decision to perform a behaviour or a resolve to act in a certain way)*	Stability of intentions Stages of change model Transtheoretical model and stages of change	• Intentions to perform behaviours clearly drove behaviours, e.g. intentions to attend the dentist regularly or to stop smoking.
		Goals *(Mental representations of outcomes or end states that an individual wants to achieve)*	Goals (distal / proximal) Goal priority Goal / target setting Goals (autonomous / controlled) Action planning Implementation intention	• Motivation for improving behaviours was often related to certain goals, e.g. preventing the loss of further teeth or future pain, improving general health and fitness, making financial savings.

	Automatic	Reinforcement *(Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus)*	Rewards Incentives Punishment Consequents Reinforcement Contingencies Sanctions	• Motivation was often reinforced by experiences of oral or general health problems (related to self or others) and support and guidance from others (e.g. family members or dental professionals).
		Emotion *(A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event)*	Fear Anxiety Affect Stress Depression Positive / negative affect Burn-out	• Dental anxiety as barrier to dental attendance or dental treatment. • Emotional impacts of oral health problems as drivers of behaviour, e.g. related to pain, confidence, social impacts. • Experience of enjoyment associated with smoking and sugar consumption.
	Reflective and automatic	Social/professional role and identity *(A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting)*	Professional identity Professional role Social identity Identity Professional boundaries Professional confidence Group identity Leadership Organisational commitment	• Responsibility of parenthood positively influenced OHBs. • Conformance to peer behavioural norms, e.g. relating to smoking initiation. • Concerns about social acceptability of oral health to spouses and peers.
		Optimism *(The confidence that things will happen for the best or that desired goals will be attained)*	Optimism Pessimism Unrealistic optimism Identity	• Limited

Table 37: Relation between the influences of OHBs identified in the present study and the fourteen domains of the Theoretical Domains Framework (TDF) and the components of the COM-B model.
The TDF domains, definitions and constructs and their relationships to the components of the COM-B model (columns 1, 2, and 3) have been reproduced from (Cane et al. 2012).

References

Abbood HM, Hinz J, Cherukara G, Macfarlane TV. 2016. Validity of Self-Reported Periodontal Disease: A Systematic Review and Meta-Analysis. J Periodontol. 87(12):1474-1483.

Abel GA, Barclay ME, Payne RA. 2016. Adjusted indices of multiple deprivation to enable comparisons within and between constituent countries of the UK including an illustration using mortality rates. BMJ Open. 6(11):e012750.

Aboderin I, Kalache A, Ben-Shlomo Y, Lynch JW, Yajnik CS, Kuh D, Yach D. 2002. Life course perspectives on coronary heart disease, stroke and diabetes. The evidence and implications for policy and research. Geneva, Switzerland: World Health Organisation.

Acheson D. 1998. Independent inquiry into inequalities in health report. London, UK: The Stationery Office.

ADA. 2017a. Cost Barriers to Dental Care in the U.S Infographic. American Dental Association Health Policy Institute; [accessed 29th Jan 2021]. http://www.ada.org/~/media/ADA/Science%20and%20Research/HPI/Files/HPIgraphic_1117_4.pdf?la=en.

ADA. 2017b. Dental Benefits Coverage in the US Infographic. American Dental Association Health Policy Institute; [accessed 29th Jan 2021]. https://www.ada.org/~/media/ADA/Science%20and%20Research/HPI/Files/HPIgraphic_1117_3.pdf?la=en.

Adeniyi AA, Sofola OO, Kalliecharan RV. 2012. An appraisal of the oral health care system in Nigeria. Int Dent J. 62(6):292-300.

Aggarwal VR, Lunt M, Zakrzewska JM, Macfarlane GJ, Macfarlane TV. 2005. Development and validation of the Manchester orofacial pain disability scale. Community Dent Oral Epidemiol. 33(2):141-149.

Ahmed KE. 2013. The psychology of tooth wear. Spec Care Dentist. 33(1):28-34.

Ajzen I. 1991. The theory of planned behavior. Organ Behav Hum Decis Process. 50(2):179-211.

Akcali A, Akcali Z, Batool F, Petit C, Huck O. 2018. Are Sex Steroid Hormones Influencing Periodontal Conditions? A Systematic Review. Curr Oral Health Rep. 5(1):33-38.

Akcali A, Huck O, Tenenbaum H, Davideau JL, Buduneli N. 2013. Periodontal diseases and stress: a brief review. J Oral Rehabil. 40(1):60-68.

Al-Mazyad M, Flannigan N, Burnside G, Higham S, Boyland E. 2017. Food advertisements on UK television popular with children: a content analysis in relation to dental health. Br Dent J. 222(3):171-176.

Al-Moghrabi D, Tsichlaki A, Alkadi S, Fleming PS. 2019. How well are dental qualitative studies involving interviews and focus groups reported? J Dent. 84:44-48.

Al-Sudani FYH, Vehkalahti MM, Bernabe E, Knuuttila M, Suominen AL. 2017. Role of Employment in 11-Year Changes of Clinical Oral Health: A Multilevel Longitudinal Analysis. JDR Clin Trans Res. 2(4):376-385.

Albandar JM, Streckfus CF, Adesanya MR, Winn DM. 2000. Cigar, pipe, and cigarette smoking as risk factors for periodontal disease and tooth loss. J Periodontol. 71(12):1874-1881.

Albandar JM, Susin C, Hughes FJ. 2018. Manifestations of systemic diseases and conditions that affect the periodontal attachment apparatus: Case definitions and diagnostic considerations. J Periodontol. 89 Suppl 1:S183-s203.

Aleksejuniene J, Holst D, Eriksen HM, Gjermo P. 2002a. Psychosocial stress, lifestyle and periodontal health. J Clin Periodontol. 29(4):326-335.

Aleksejuniene J, Holst D, Grytten JI, Eriksen HM. 2002b. Causal patterns of dental health in populations. An empirical approach. Caries Res. 36(4):233-240.

Alikutty FK, Bernabe E. 2016. Long-term regular dental attendance and periodontal disease in the 1998 Adult Dental Health Survey. J Clin Periodontol. 43(2):114-120.

Allukian M, Carter-Pokras OD, Gooch BF, Horowitz AM, Lida H, Jacob M, Kleinman DV, Kumar J, Maas WR, Pollick H et al. 2018. Science, Politics, and Communication: The Case of Community Water Fluoridation in the US. Ann Epidemiol. 28(6):401-410.

Alm A, Wendt LK, Koch G, Birkhed D. 2008. Oral hygiene and parent-related factors during early childhood in relation to approximal caries at 15 years of age. Caries Res. 42(1):28-36.

Alves J, Perelman J, Soto-Rojas V, Richter M, Rimpelä A, Loureiro I, Federico B, Kuipers MAG, Kunst AE, Lorant V. 2016. The role of parental smoking on adolescent smoking and its social patterning: a cross-sectional survey in six European cities. J Public Health. 39(2):339-346.

Amin MS, Harrison RL. 2009. Understanding parents' oral health behaviors for their young children. Qual Health Res. 19(1):116-127.

Amos A, Bostock Y. 2008. Young people, smoking and gender - a qualitative exploration. Health Educ Res. 22:770-781.

Anand PS, Kamath KP, Nair B. 2010. Trends in extraction of permanent teeth in private dental practices in Kerala state, India. J Contemp Dent Pract. 11(3):041-048.

Anders PL, Davis EL. 2010. Oral health of patients with intellectual disabilities: a systematic review. Spec Care Dentist. 30(3):110-117.

Anderson T, Thomas C, Ryan RM, Dennes M, Fuller E. 2015. Children's Dental Health Survey 2013. Technical Report, England, Wales and Northern Ireland. Health and Social Care Information Centre.

Andersson P, Johannsen A. 2016. Dental patients' perceptions and motivation in smoking cessation activities. Acta Odontol Scand. 74(4):285-290.

Andrade FB, Antunes JLF, Souza Junior PRB, Lima-Costa MF, Oliveira C. 2018. Life course socioeconomic inequalities and oral health status in later life: ELSI-Brazil. Rev Saude Publica. 52(Suppl 2):7s.

Anwar S, Williams SA. 2008. Cultural aspects of tobacco use. Dent Update. 35(1):38-47.

Appelman Y, van Rijn BB, Ten Haaf ME, Boersma E, Peters SA. 2015. Sex differences in cardiovascular risk factors and disease prevention. Atherosclerosis. 241(1):211-218.

Arbuckle J. 2016. IBM SPSS Amos 24 User's Guide. Amos Development Corporation.

ARCPOH. 2019. Australia's Oral Health: National Study of Adult Oral Health 2017-2018. Adelaide, South Australia: Australian Research Centre for Population Oral Health, University of Adelaide.

Arden-Close E, McGrath N. 2017. Health behaviour change interventions for couples: A systematic review. Br J Health Psychol. 22(2):215-237.

Armenian SH, Armstrong GT, Aune G, Chow EJ, Ehrhardt MJ, Ky B, Moslehi J, Mulrooney DA, Nathan PC, Ryan TD et al. 2018. Cardiovascular Disease in Survivors of Childhood Cancer: Insights Into Epidemiology, Pathophysiology, and Prevention. J Clin Oncol. 36(21):2135-2144.

Armfield JM. 2010. How do we measure dental fear and what are we measuring anyway? Oral Health Prev Dent. 8(2):107-115.

Armfield JM, Slade GD, Spencer AJ. 2009. Dental fear and adult oral health in Australia. Community Dent Oral Epidemiol. 37(3):220-230.

Arora A, Khattri S, Ismail NM, Kumbargere Nagraj S, Eachempati P. 2019. School dental screening programmes for oral health. Cochrane Database Syst Rev. (8):CD012595.

Arora M, Schwarz E, Sivaneswaran S, Banks E. 2010. Cigarette smoking and tooth loss in a cohort of older Australians: the 45 and up study. J Am Dent Assoc. 141(10):1242-1249.

Artazcoz L, Cortès I, Escribà-Agüir V, Cascant L, Villegas R. 2009. Understanding the relationship of long working hours with health status and health-related behaviours. J Epidemiol Community Health. 63(7):521-527.

Asimakopoulou K, Newton JT. 2015. The contributions of behaviour change science towards dental public health practice: a new paradigm. Community Dent Oral Epidemiol. 43(1):2-8.

Astrom AN, Ekback G, Lie SA, Ordell S. 2015. Life-course social influences on tooth loss and oral attitudes among older people: evidence from a prospective cohort study. Eur J Oral Sci. 123(1):30-38.

Astrom AN, Ekback G, Ordell S, Unell L. 2011a. Social inequality in oral health-related quality-of-life, OHRQoL, at early older age: evidence from a prospective cohort study. Acta Odontol Scand. 69(6):334-342.

Astrom AN, Ekback G, Ordell S, Unell L. 2011b. Socio-behavioral predictors of changes in dentition status: a prospective analysis of the 1942 Swedish birth cohort. Community Dent Oral Epidemiol. 39(4):300-310.

Atkin PA, Thomas S, Cook RJ, Greenwood M, Bennett JH, Willis A, Donachie C, Ni Riordain R, Galvin S, Crighton A et al. 2018. Human Disease/Clinical Medical Sciences in Dentistry: Current state and future directions of undergraduate teaching in the UK and Ireland. Eur J Dent Educ. 22(3):e588-e593.

Axelsson P, Nyström B, Lindhe J. 2004. The long-term effect of a plaque control program on tooth mortality, caries and periodontal disease in adults. Results after 30 years of maintenance. J Clin Periodontol. 31(9):749-757.

Baker SR, Foster Page L, Thomson WM, Broomhead T, Bekes K, Benson PE, Aguilar-Diaz F, Do L, Hirsch C, Marshman Z et al. 2018. Structural determinants and children's oral health: A cross-national study. J Dent Res. 97(10):1129-1136.

Baker SR, Mat A, Robinson PG. 2010. What psychosocial factors influence adolescents' oral health? J Dent Res. 89(11):1230-1235.

Bala MM, Strzeszynski L, Topor-Madry R. 2017. Mass media interventions for smoking cessation in adults. Cochrane Database Syst Rev. (11):CD004704.

Bambra CL, Hillier FC, Cairns JM, Kasim A, Moore HJ, Summerbell CD. 2015. How effective are interventions at reducing socioeconomic inequalities in obesity among children and adults? Two systematic reviews. Public Health Research. 3(1).

Bandura A. 1977. Self-efficacy: Toward a unifying theory of behavioral change. Psychological Review. 84(2):191-215.

Bandura A. 1986. Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice Hall.

Banks E, Joshy G, Korda RJ, Stavreski B, Soga K, Egger S, Day C, Clarke NE, Lewington S, Lopez AD. 2019. Tobacco smoking and risk of 36 cardiovascular disease subtypes: fatal and non-fatal outcomes in a large prospective Australian study. BMC Med. 17(1):128.

Barbour LA. 2014a. Changing perspectives in pre-existing diabetes and obesity in pregnancy: maternal and infant short- and long-term outcomes. Curr Opin Endocrinol Diabetes Obes. 21(4):257-263.

Barbour R. 2014b. Introducing qualitative research: A student's guide. London, UK: SAGE Publications.

Barkan S. 2011. Sociology: Understanding and Changing the Social World. Boston, MA: FlatWorld.

Barker DJ. 1990. The fetal and infant origins of adult disease. BMJ. 301(6761):1111.

Barker DJ. 1995. Fetal origins of coronary heart disease. BMJ. 311(6998):171-174.

Barker DJ. 2001. A new model for the origins of chronic disease. Med Health Care Philos. 4(1):31-35.

Barker DJ, Osmond C, Simmonds SJ, Wield GA. 1993. The relation of small head circumference and thinness at birth to death from cardiovascular disease in adult life. BMJ. 306(6875):422-426.

Barnett I, Guell C, Ogilvie D. 2013. How do couples influence each other’s physical activity behaviours in retirement? An exploratory qualitative study. BMC Public Health. 13(1):1197.

Barr DA. 2017. The Childhood Roots of Cardiovascular Disease Disparities. Mayo Clin Proc. 92(9):1415-1421.

Bartold PM, Van Dyke TE. 2013. Periodontitis: a host-mediated disruption of microbial homeostasis. Unlearning learned concepts. Periodontol 2000. 62(1):203-217.

Bastos JL, Peres MA, Peres KG, Araujo CL, Menezes AM. 2008. Toothache prevalence and associated factors: a life course study from birth to age 12 yr. Eur J Oral Sci. 116(5):458-466.

Bates B, Lennox A, Bates C, Swan G. 2011. National Diet and Nutrition Survey. Headline results from Years 1 and 2 (combined) of the Rolling Programme (2008/2009 – 2009/10). Department of Health.

Battram DS, Piché L, Beynon C, Kurtz J, He M. 2016. Sugar-Sweetened Beverages: Children's Perceptions, Factors of Influence, and Suggestions for Reducing Intake. J Nutr Educ Behav. 48(1):27-35.

Batty GD, Alves JG, Correia J, Lawlor DA. 2007. Examining life-course influences on chronic disease: the importance of birth cohort studies from low- and middle- income countries. An overview. Braz J Med Biol Res. 40(9):1277-1286.

BDA. 2019a. 1 million new patients unable to access NHS dentistry, as recruitment and retention crisis mounts. British Dental Association; [accessed 29th Jan 2021]. https://bda.org/news-centre/press-releases/Pages/1-million-new-patients-unable-to-access-NHS-dentistry.aspx.

BDA. 2019b. 75% of NHS dental practices now struggling to fill vacancies. British Dental Association; [accessed 29th Jan 2021]. https://bda.org/news-centre/press-releases/Pages/75-per-cent-of-NHS-dental-practices-now-struggling-to-fill-vacancies.aspx.

BDA. 2019c. NHS dentistry: £12 slashed from care for every man, woman and child in England since 2010. British Dental Association; [accessed 29th Jan 2021]. https://bda.org/news-centre/press-releases/12-pound-slashed-from-dental-care-for-every-man-woman-and-child-in-england-since-2010.

BDA. 2020a. Dental contract reform across the UK. British Dental Association; [accessed 29th Jan 2021]. https://www.bda.org/about-the-bda/campaigns/pay/Pages/contract-reform.aspx.

BDA. 2020b. Stuck at the traffic lights: BDA joins voices for action on Childhood Obesity Plan to safeguard oral health. British Dental Association; [accessed 29th Jan 2021]. https://bda.org/news-centre/latest-news-articles/Pages/BDA-joins-voices-for-action-on-Childhood-Obesity-Plan-to-safeguard-oral-health.aspx.

Beaton L, Anderson I, Humphris G, Rodriguez A, Freeman R. 2018. Implementing an Oral Health Intervention for People Experiencing Homelessness in Scotland: A Participant Observation Study. Dent J (Basel). 6(4).

Behbahanirad A, Joulaei H, Jamali J, Vossoughi M, Golkari A. 2017. A model for oral health gradients in children: using structural equation modeling. Community Dent Health. 34(1):50-55.

Belsley D, Kuh E, Welsch R. 1980. Regression diagnostics: Identifying influential data and sources of collinearity. Hoboken, NJ: John Wiley & Sons.

Ben-Shlomo Y, Cooper R, Kuh D. 2016. The last two decades of life course epidemiology, and its relevance for research on ageing. Int J Epidemiol. 45(4):973-988.

Ben-Shlomo Y, Kuh D. 2002. A life course approach to chronic disease epidemiology: conceptual models, empirical challenges and interdisciplinary perspectives. Int J Epidemiol. 31(2):285-293.

Bennett AE, Doll R, Howell RW. 1970. Sugar consumption and cigarette smoking. The Lancet. 295(7655):1011-1014.

Benowitz NL. 2010. Nicotine addiction. N Engl J Med. 362(24):2295-2303.

Bentler PM, Chou C. 1987. Practical issues in structural modelling. Sociol Method Res. 16(1):78-117.

Beran TN, Violato C. 2010. Structural equation modeling in medical research: a primer. BMC Res Notes. 3:267.

Berendsen J, Bonifacio C, van Gemert-Schriks M, van Loveren C, Verrips E, Duijster D. 2018. Parents' willingness to invest in their children's oral health. J Public Health Dent. 78(1):69-77.

Berger M, Oleszek-Listopad J, Marczak M, Szymanska J. 2015. Psychological aspects of temperomandibular disorders-literature review. Curr Issues Pharm Med Sci. 28(1):55-59.

Berger R. 2015. Now I see it, now I don’t: researcher’s position and reflexivity in qualitative research. Qual Res. 15(2):219-234.

Bernaards CM, Twisk JW, Snel J, Van Mechelen W, Kemper HC. 2001. Is calculating pack-years retrospectively a valid method to estimate life-time tobacco smoking? A comparison between prospectively calculated pack-years and retrospectively calculated pack-years. Addiction. 96(11):1653-1661.

Bernabe E, Sheiham A. 2014. Tooth Loss in the United Kingdom - Trends in Social Inequalities: An Age-Period-and-Cohort Analysis. PLOS ONE. 9(8):e104808.

Bernabe E, Suominen AL, Nordblad A, Vehkalahti MM, Hausen H, Knuuttila M, Kivimaki M, Watt RG, Sheiham A, Tsakos G. 2011. Education level and oral health in Finnish adults: evidence from different lifecourse models. J Clin Periodontol. 38(1):25-32.

Bernabé E, Vehkalahti MM, Sheiham A, Lundqvist A, Suominen AL. 2016. The Shape of the Dose-Response Relationship between Sugars and Caries in Adults. J Dent Res. 95(2):167-172.

Bernabe E, Watt RG, Sheiham A, Suominen-Taipale AL, Nordblad A, Savolainen J, Kivimaki M, Tsakos G. 2009. The influence of sense of coherence on the relationship between childhood socioeconomic status and adult oral health-related behaviours. Community Dent Oral Epidemiol. 37(4):357-365.

Bernabe E, Watt RG, Sheiham A, Suominen AL, Vehkalahti MM, Nordblad A, Uutela A, Kivimaki M, Tsakos G. 2012. Childhood socioeconomic position, adult sense of coherence and tooth retention. Community Dent Oral Epidemiol. 40(1):46-52.

Berney LR, Blane DB. 1997. Collecting retrospective data: Accuracy of recall after 50 years judged against historical records. Soc Sci Med. 45(10):1519-1525.

Berridge V, Loughlin K. 2005. Smoking and the new health education in Britain 1950s-1970s. Am J Public Health. 95(6):956-964.

BFS. 2013. Executive summary – One in a Million. The British Fluoridation Society; [accessed 29th Jan 2021]. https://bfsweb.org/one-in-a-million/#1344-1344-wpfd-one-in-a-million-p2.

Biggs A. 2012. Dental reform: an overview of universal dental schemes. Parliamentary Library (Australia).

Bingham S, Luben R, Welch A, Tasevska N, Wareham N, Khaw KT. 2007. Epidemiologic assessment of sugars consumption using biomarkers: comparisons of obese and non-obese individuals in the European Prospective Investigation of Cancer Norfolk. Cancer Epidemiol Biomarkers Prev. 16(8):1651-1654.

Bingham SA, Gill C, Welch A, Cassidy A, Runswick SA, Oakes S, Lubin R, Thurnham DI, Key TJ, Roe L et al. 1997. Validation of dietary assessment methods in the UK arm of EPIC using weighed records, and 24-hour urinary nitrogen and potassium and serum vitamin C and carotenoids as biomarkers. Int J Epidemiol. 26 Suppl 1:S137-151.

Bingham SA, Welch AA, McTaggart A, Mulligan AA, Runswick SA, Luben R, Oakes S, Khaw KT, Wareham N, Day NE. 2001. Nutritional methods in the European Prospective Investigation of Cancer in Norfolk. Public Health Nutr. 4(3):847-858.

Bird CM. 2005. How I stopped dreading and learned to love transcription. Qual Inq. 11(2):226-248.

Black D. 1980. Inequalities in health: Report of a research working group. London, UK: Department of Health and Social Security.

Black M, Barnes A, Baxter S, Beynon C, Clowes M, Dallat M, Davies AR, Furber A, Goyder E, Jeffery C et al. 2019. Learning across the UK: a review of public health systems and policy approaches to early child development since political devolution. J Public Health. 42(2):224-238.

Black N. 2013. Patient reported outcome measures could help transform healthcare. BMJ. 346:f167.

Blackmore HL, Ozanne SE. 2015. Programming of cardiovascular disease across the life-course. J Mol Cell Cardiol. 83:122-130.

Blake H, Dawett B, Leighton P, Rose-Brady L, Deery C. 2015. School-Based Educational Intervention to Improve Children's Oral Health-Related Knowledge. Health Promot Pract. 16(4):571-582.

Blank MD, Breland AB, Enlow PT, Duncan C, Metzger A, Cobb CO. 2016. Measurement of smoking behavior: Comparison of self-reports, returned cigarette butts, and toxicant levels. Exp Clin Psychopharmacol. 24(5):348-355.

Block JP, Gillman MW, Linakis SK, Goldman RE. 2013. "If it tastes good, I'm drinking it": qualitative study of beverage consumption among college students. J Adolesc Health. 52(6):702-706.

Bloom I, Lawrence W, Barker M, Baird J, Dennison E, Sayer AA, Cooper C, Robinson S. 2017. What influences diet quality in older people? A qualitative study among community-dwelling older adults from the Hertfordshire Cohort Study, UK. Public Health Nutr. 20(15):2685-2693.

Blumenthal-Barby JS, Ubel PA. 2018. In Defense of "Denial": Difficulty Knowing When Beliefs Are Unrealistic and Whether Unrealistic Beliefs Are Bad. Am J Bioeth. 18(9):4-15.

BMA. 2016. Health in all policies: health, austerity and welfare reform. A briefing from the board of science. British Medical Assocation.

Bollen K, Stine R. 1992. Bootstrapping goodness of fit measures in structural equation models. Sociol Method Res. 21(2):205-229.

Bonell C, Beaumont E, Dodd M, Elbourne DR, Bevilacqua L, Mathiot A, McGowan J, Sturgess J, Warren E, Viner RM et al. 2019. Effects of school environments on student risk-behaviours: evidence from a longitudinal study of secondary schools in England. J Epidemiol Community Health. 73(6):502-508.

Boraas JC, Messer LB, Till MJ. 1988. A genetic contribution to dental caries, occlusion, and morphology as demonstrated by twins reared apart. J Dent Res. 67(9):1150-1155.

Borreani E, Jones K, Scambler S, Gallagher JE. 2010. Informing the debate on oral health care for older people: a qualitative study of older people's views on oral health and oral health care. Gerodontology. 27(1):11-18.

Bortoluzzi MC, Traebert J, Lasta R, Da Rosa TN, Capella DL, Presta AA. 2012. Tooth loss, chewing ability and quality of life. Contemp Clin Dent. 3(4):393-397.

Boudreaux ED, Bock B, O'Hea E. 2012. When an event sparks behavior change: an introduction to the sentinel event method of dynamic model building and its application to emergency medicine. Acad Emerg Med. 19(3):329-335.

Bowen KJ, Sullivan VK, Kris-Etherton PM, Petersen KS. 2018. Nutrition and Cardiovascular Disease-an Update. Curr Atheroscler Rep. 20(2):8.

Bower E, Scambler S. 2007. The contributions of qualitative research towards dental public health practice. Community Dent Oral Epidemiol. 35(3):161-169.

Bradley J, Gardner G, Rowland MK, Fay M, Mann K, Holmes R, Foster E, Exley C, Don Bosco A, Hugueniot O et al. 2020. Impact of a health marketing campaign on sugars intake by children aged 5–11 years and parental views on reducing children's consumption. BMC Public Health. 20(1):331.

Brady MC, Stott DJ, Norrie J, Chalmers C, St George B, Sweeney PM, Langhorne P. 2011. Developing and evaluating the implementation of a complex intervention: using mixed methods to inform the design of a randomised controlled trial of an oral healthcare intervention after stroke. Trials. 12:168.

Braun V, Clarke V. 2006. Using thematic analysis in psychology. Qual Res Psychol 3(2):77-101.

Brennan DS, Spencer AJ. 2005. The role of dentist, practice and patient factors in the provision of dental services. Community Dent Oral Epidemiol. 33(3):181-195.

Bretz WA, Corby PM, Hart TC, Costa S, Coelho MQ, Weyant RJ, Robinson M, Schork NJ. 2005a. Dental caries and microbial acid production in twins. Caries Res. 39(3):168-172.

Bretz WA, Corby PM, Schork NJ, Robinson MT, Coelho M, Costa S, Melo Filho MR, Weyant RJ, Hart TC. 2005b. Longitudinal analysis of heritability for dental caries traits. J Dent Res. 84(11):1047-1051.

Brigham J, Lessov-Schlaggar CN, Javitz HS, Krasnow RE, McElroy M, Swan GE. 2009. Test-retest reliability of web-based retrospective self-report of tobacco exposure and risk. J Med Internet Res. 11(3):e35.

Brigham J, Lessov-Schlaggar CN, Javitz HS, Krasnow RE, Tildesley E, Andrews J, Hops H, Cornelius MD, Day NL, McElroy M et al. 2010. Validity of recall of tobacco use in two prospective cohorts. Am J Epidemiol. 172(7):828-835.

Brigham J, Lessov-Schlaggar CN, Javitz HS, McElroy M, Krasnow R, Swan GE. 2008. Reliability of adult retrospective recall of lifetime tobacco use. Nicotine Tob Res. 10(2):287-299.

Broadbent JM, Foster Page LA, Thomson WM, Poulton R. 2013. Permanent dentition caries through the first half of life. Br Dent J. 215(7):E12.

Broadbent JM, Thomson WM, Boyens JV, Poulton R. 2011. Dental plaque and oral health during the first 32 years of life. J Am Dent Assoc. 142(4):415-426.

Broadbent JM, Thomson WM, Poulton R. 2006. Oral health beliefs in adolescence and oral health in young adulthood. J Dent Res. 85(4):339-343.

Broadbent JM, Zeng J, Foster Page LA, Baker SR, Ramrakha S, Thomson WM. 2016. Oral health-related beliefs, behaviors, and outcomes through the life course. J Dent Res. 95(7):808-813.

Broffitt B, Levy SM, Warren J, Cavanaugh JE. 2013. Factors associated with surface-level caries incidence in children aged 9 to 13: the Iowa Fluoride Study. J Public Health Dent. 73(4):304-310.

Brondani MA, Bryant SR, MacEntee MI. 2007. Elders assessment of an evolving model of oral health. Gerodontology. 24(4):189-195.

Bronfenbrenner U. 1979. The Ecology of Human Development: Experiments by Nature and Design. Cambridge, MA: Harvard University Press.

BSPD. 2019. Dental Check by One. British Society of Paediatric Dentistry; [accessed 29th Jan 2021]. https://www.bspd.co.uk/Patients/Dental-Check-by-One.

Bub KL, Ferretti LK. 2014. Cutting-edge statistical methods for a life-course approach. Adv Nutr. 5(1):46-56.

Buchwald S, Kocher T, Biffar R, Harb A, Holtfreter B, Meisel P. 2013. Tooth loss and periodontitis by socio-economic status and inflammation in a longitudinal population-based study. J Clin Periodontol. 40(3):203-211.

Burnard P, Gill P, Stewart K, Treasure E, Chadwick B. 2008. Analysing and presenting qualitative data. Br Dent J. 204(8):429-432.

Burton-Jeangros C, Cullati S, Sacker A, Blane D. 2016. A Life Course Perspective on Health Trajectories and Transitions. Cham, Switzerland: Springer.

Butani Y, Weintraub JA, Barker JC. 2008. Oral health-related cultural beliefs for four racial/ethnic groups: Assessment of the literature. BMC oral health. 8:26-26.

Cameron A. 2019. Survey of European Qualified Dental Professionals - Final Report - General Dental Council. West Yorkshire, UK: Enventure Research.

Cane J, O’Connor D, Michie S. 2012. Validation of the theoretical domains framework for use in behaviour change and implementation research. Implementation Science. 7(1):37.

Carr AB, Ebbert J. 2012. Interventions for tobacco cessation in the dental setting. Cochrane Database Syst Rev. (6):CD005084.

Cartee DL, Maker S, Dalonges D, Manski MC. 2015. Sjogren's Syndrome: Oral Manifestations and Treatment, a Dental Perspective. J Dent Hyg. 89(6):365-371.

Case A, Paxson C. 2002. Parental behavior and child health. Health Aff. 21(2):164-178.

CASP. 2018. CASP checklist: 10 questions to help you make sense of a qualitative research. . Critical Appraisal Skills Programme; [accessed 29th Jan 2021]. https://casp-uk.net/wp-content/uploads/2018/03/CASP-Qualitative-Checklist-2018_fillable_form.pdf.

CASSH. 2019. 2019 Manifesto, Health for All. Consensus Action on Salt, Sugar and Health.

Castaneda H, Carrion IV, Kline N, Tyson DM. 2010. False hope: effects of social class and health policy on oral health inequalities for migrant farmworker families. Soc Sci Med. 71(11):2028-2037.

Castilho AR, Mialhe FL, Barbosa Tde S, Puppin-Rontani RM. 2013. Influence of family environment on children's oral health: a systematic review. J Pediatr (Rio J). 89(2):116-123.

Castro Y, Cano M, Businelle MS, Correa-Fernández V, Heppner WL, Mazas CA, Wetter DW. 2014. A cross-lagged path analysis of five intrapersonal determinants of smoking cessation. Drug Alcohol Depend. 137:98-105.

Cekici A, Kantarci A, Hasturk H, Van Dyke TE. 2014. Inflammatory and immune pathways in the pathogenesis of periodontal disease. Periodontol 2000. 64(1):57-80.

Chadwick B, White D, Lader D, Pitts NB. 2011. Preventive behaviour and risks to oral health - a report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

Chadwick D, Chapman M, Davies G. 2018. Factors affecting access to daily oral and dental care among adults with intellectual disabilities. J Appl Res Intellect Disabil. 31(3):379-394.

Chankanka O, Cavanaugh JE, Levy SM, Marshall TA, Warren JJ, Broffitt B, Kolker JL. 2011. Longitudinal associations between children's dental caries and risk factors. J Public Health Dent. 71(4):289-300.

Chankanka O, Levy SM, Marshall TA, Cavanaugh JE, Warren J, Broffitt B, Kolker J. 2016. The associations between dietary intakes from 36 to 60 months of age and primary dentition non-cavitated caries and cavitated caries. J Public Health Dent. 75:265-273.

Chapman KJ, Fairchild RM, Morgan MZ. 2014. Food references in UK children's magazines - an oral health perspective. Br Dent J. 217(10):E20.

Charmaz K. 2006. Constructing Grounded Theory: A Practical Guide through Qualitative Analysis. London, UK: SAGE.

Chatrchaiwiwatana S, Ratanasiri A, Jaidee J, Soontorn S. 2012. Factors related to tooth loss due to dental caries among workers in an industrial estates in Thailand. J Med Assoc Thai. 95 Suppl 11:S1-6.

Chavarro JE, Rosner BA, Sampson L, Willey C, Tocco P, Willett WC, Chumlea WC, Michels KB. 2009. Validity of adolescent diet recall 48 years later. Am J Epidemiol. 170(12):1563-1570.

Chenery V. 2011. Adult Dental Health Survey 2009 - England key findings. Leeds, UK: The Health and Social Care Information Centre.

Chestnutt IG, Davies L, Thomas DR. 2009. Practitioners' perspectives and experiences of the new National Health Service dental contract. Br Dent J. 206(9):E18.

Cheung YB, Low L, Osmond C, Barker D, Karlberg J. 2000. Fetal growth and early postnatal growth are related to blood pressure in adults. Hypertension. 36(5):795-800.

Child Trends. 2003. Conceptualizing and measuring "Healthy Marriages" for empirical research and evaluation studies: A compendium of measures- Part II. Washington, DC: Child Trends, Inc.

Childsmile. 2014. What is Childsmile? Briefing Sheet. [accessed 29th Jan 2021]. http://www.healthscotland.com/uploads/documents/4359-What%20is%20Childsmile%20BriefingSheet%20-%20AMENDED%2025.04.14.pdf.

Childsmile. 2020. Coronavirus - Return of supervised daily toothbrushing in nursery and school settings. [accessed 29th Jan 2021]. http://www.child-smile.org.uk/professionals/Coronavirus-Return-of-supervised-daily-toothbrushing-in-nursery-and-school-settings/other-childsmile-interventions.aspx.

Ciancio SG. 2004. Medications' impact on oral health. J Am Dent Assoc. 135(10):1440-1448.

Clarke AE. 2005. Situational Analysis. Grounded Theory after the Postmodern Turn. Thousand Oaks, CA: SAGE.

Clarkson E, Mashkoor F, Abdulateef S. 2017. Oral Viral Infections: Diagnosis and Management. Dent Clin North Am. 61(2):351-363.

Cobb LK, Godino JG, Selvin E, Kucharska-Newton A, Coresh J, Koton S. 2015. Spousal Influence on Physical Activity in Middle-Aged and Older Adults: The ARIC Study. Am J Epidemiol. 183(5):444-451.

Colchero MA, Rivera-Dommarco J, Popkin BM, Ng SW. 2017. In Mexico, Evidence Of Sustained Consumer Response Two Years After Implementing A Sugar-Sweetened Beverage Tax. Health Aff. 36(3):564-571.

Commission on Social Determinants of Health. 2008. Closing the gap in a generation: health equity through action on the social determinants of health. Geneva, Switzerland: World Health Organisation.

Connelly R, Platt L. 2014. Cohort profile: UK Millennium Cohort Study (MCS). Int J Epidemiol. 43(6):1719-1725.

Connor Gorber S, Schofield-Hurwitz S, Hardt J, Levasseur G, Tremblay M. 2009. The accuracy of self-reported smoking: a systematic review of the relationship between self-reported and cotinine-assessed smoking status. Nicotine Tob Res. 11(1):12-24.

Connor J. 2017. Alcohol consumption as a cause of cancer. Addiction. 112(2):222-228.

Cooper AM, O'Malley LA, Elison SN, Armstrong R, Burnside G, Adair P, Dugdill L, Pine C. 2013. Primary school-based behavioural interventions for preventing caries. Cochrane Database Syst Rev. (5):CD009378.

Corbin J, Strauss AL. 2008. Basics of Qualitative Research. Thousand Oaks, CA: Sage.

Correa MB, Peres MA, Peres KG, Horta BL, Gigante DP, Demarco FF. 2010. Life-course determinants of need for dental prostheses at age 24. J Dent Res. 89(7):733-738.

Costa FS, Silveira ER, Pinto GS, Nascimento GG, Thomson WM, Demarco FF. 2017. Developmental defects of enamel and dental caries in the primary dentition: A systematic review and meta-analysis. J Dent. 60:1-7.

Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M. 2008. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ. 337:a1655.

Crall JJ, Forrest CB. 2018. A life course health development perspective on oral health. In: Halfon N, Forrest C, Lerner R, Faustman E, editors. Handbook of life course health development. Cham, Switzerland: Springer.

Creswell JW, Plano Clark VL. 2011. Designing and conducting mixed methods research. London, UK: Sage.

Crocombe LA, Broadbent JM, Thomson WM, Brennan DS, Poulton R. 2012. Impact of dental visiting trajectory patterns on clinical oral health and oral health-related quality of life. J Public Health Dent. 72(1):36-44.

Crocombe LA, Broadbent JM, Thomson WM, Brennan DS, Slade GD, Poulton R. 2011. Dental visiting trajectory patterns and their antecedents. J Public Health Dent. 71(1):23-31.

Croker H, Lucas R, Wardle J. 2012. Cluster-randomised trial to evaluate the 'Change for Life' mass media/ social marketing campaign in the UK. BMC Public Health. 12(1):404.

Cullati S. 2014. The influence of work-family conflict trajectories on self-rated health trajectories in Switzerland: A life course approach. Soc Sci Med. 113:23-33.

Cummings P. 2013. Missing Data and Multiple Imputation. JAMA Pediatrics. 167(7):656-661.

Curtice J, Clery E, Perry J, Phillips M, Rahim N. 2019. British Social Attitudes: the 36th Report. London, UK: The National Centre for Social Research.

Curtis AM, Cavanaugh JE, Levy SM, VanBuren J, Marshall TA, Warren JJ. 2018a. Examining caries aetiology in adolescence with structural equation modelling. Community Dent Oral Epidemiol. 46(3):258-264.

Curtis AM, VanBuren J, Cavanaugh JE, Warren JJ, Marshall TA, Levy SM. 2018b. Longitudinal associations between dental caries increment and risk factors in late childhood and adolescence. J Public Health Dent. 78(4):321-328.

D'Aiuto F, Gable D, Syed Z, Allen Y, Wanyonyi KL, White S, Gallagher JE. 2017. Evidence summary: The relationship between oral diseases and diabetes. Br Dent J. 222(12):944-948.

D'Cruz L, Rattan R, Watson M. 2010. Understanding NHS dentistry, Preparing for the Future. Cambridge, UK: Dental Publishing.

Dabawala S, Suprabha BS, Shenoy R, Rao A, Shah N. 2017. Parenting style and oral health practices in early childhood caries: a case-control study. Int J Paediatr Dent. 27(2):135-144.

Dahlander A, Soares F, Grindefjord M, Dahllöf G. 2019. Factors Associated with Dental Fear and Anxiety in Children Aged 7 to 9 Years. Dent J (Basel). 7(3):68.

Dahlgren G, Whitehead M. 1991. Policies and strategies to promote social equity in health. Background document to WHO – Strategy paper for Europe. Stockholm, Sweden: Institute for Futures Studies.

Dahly DL, Adair LS, Bollen KA. 2009. A structural equation model of the developmental origins of blood pressure. Int J Epidemiol. 38(2):538-548.

Dailey YM, Humphris GM, Lennon MA. 2001. The use of dental anxiety questionnaires: a survey of a group of UK dental practitioners. Br Dent J. 190(8):450-453.

Daly B, Clarke W, McEvoy W, Periam K, Zoitopoulos L. 2010. Child oral health concerns amongst parents and primary care givers in a Sure Start local programme. Community Dent Health. 27(3):167-171.

Daoud J. 2017. Multicollinearity and Regression Analysis. J Phys Conf Ser. 949:012009.

Darnton A. 2008. GSR Behaviour Change Knowledge Review. Reference Report: An overview of behaviour change models and their uses. Government Social Research.

Davies BJ, Macfarlane F. 2010. Clinical decision making by dentists working in the NHS General Dental Services since April 2006. Br Dent J. 209(10):E17.

Davies K, Lin YL, Callery P. 2017. Parents' and children's knowledge of oral health: a qualitative study of children with cleft palate. Int J Paediatr Dent. 27(4):264-272.

Dawber TR, Kannel WB, Revotskie N, Stokes J, 3rd, Kagan A, Gordon T. 1959. Some factors associated with the development of coronary heart disease: six years' follow-up experience in the Framingham study. Am J Public Health Nations Health. 49:1349-1356.

De Almeida Pdel V, Gregio AM, Machado MA, de Lima AA, Azevedo LR. 2008. Saliva composition and functions: a comprehensive review. J Contemp Dent Pract. 9(3):72-80.

De Castilhos ED, Horta BL, Gigante DP, Demarco FF, Peres KG, Peres MA. 2012. Association between obesity and periodontal disease in young adults: a population-based birth cohort. J Clin Periodontol. 39(8):717-724.

De Oliveira VJ, Da Costa L, Marcelo VC, Lima A. 2006. Mothers' perceptions of children's refusal to undergo dental treatment: an exploratory qualitative study. Eur J Oral Sci. 114(6):471-477.

Deary IJ, Gow AJ, Pattie A, Starr JM. 2011. Cohort Profile: The Lothian Birth Cohorts of 1921 and 1936. Int J Epi. 41(6):1576-1584.

Delaney H, MacGregor A, Amos A. 2018. "Tell them you smoke, you'll get more breaks": a qualitative study of occupational and social contexts of young adult smoking in Scotland. BMJ Open. 8(12):e023951.

Delaney M, McCarthy M. 2011. Food Choice and Health across the Life Course: A Qualitative Study Examining Food Choice in Older Irish Adults. J Food Prod Mark. 17(2-3):114-140.

Delgado-Angulo EK, Bernabe E. 2015a. Comparing lifecourse models of social class and adult oral health using the 1958 National Child Development Study. Community Dent Health. 32(1):20-25.

Delgado-Angulo EK, Bernabe E. 2015b. Intergenerational mobility and adult oral health in a British cohort. Community Dent Oral Epidemiol. 43(3):255-261.

Denscombe M. 2008. Communities of Practice: A Research Paradigm for the Mixed Methods Approach. J Mix Methods Res. 2(3):270-283.

Derblom C, Hagman-Gustafsson ML, Gabre P. 2017. Older people's description of factors that facilitate and impede regular dental care - a qualitative interview study. Int J Dent Hyg. 15(4):313-320.

Designed to Smile. 2020a. Designed to Smile. [accessed 29th Jan 2020]. https://www.designedtosmile.org/welcome-croeso/welcome/.

Designed to Smile. 2020b. Designed to Smile Programme Update June 2020. [accessed 29th Jan 2021]. https://www.designedtosmile.org/wp-content/uploads/2020/06/Designed-to-Smile-June2020.pdf.

Designed to Smile. 2020c. Healthy Eating. [accessed 29th Jan 2021]. https://www.designedtosmile.org/info/healthy-eating/.

Devaux M, Looper M. 2012. Income-Related Inequalities in Health Service Utilisation in 19 OECD Countries, 2008-2009, OECD Health Working Papers, No. 58. Paris, France: OECD Publishing.

Devine CM. 2005. A Life Course Perspective: Understanding Food Choices in Time, Social Location, and History. J Nutr Educ Behav. 37(3):121-128.

Devine CM, Connors M, Bisogni CA, Sobal J. 1998. Life-Course Influences on Fruit and Vegetable Trajectories: Qualitative Analysis of Food Choices. Journal of Nutrition Education. 30(6):361-370.

Devolution and You. 2020. Introduction to Devolution. [accessed 29th Jan 2021]. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/771525/Introduction_to_Devolution.pdf.

DfE. 2019. Relationships education, relationships and sex education (RSE) and health education. Statutory guidance for governing bodies, proprietors, head teachers, principals, senior leadership teams, teachers. Department for Education.

DHSC. 2019. Advancing our health: prevention in the 2020s – consultation document. Department of Health and Social Care; [accessed 29th Jan 2021]. https://www.gov.uk/government/consultations/advancing-our-health-prevention-in-the-2020s/advancing-our-health-prevention-in-the-2020s-consultation-document.

DHSC, DCMS. 2020. Introducing a total online advertising restriction for products high in fat, sugar and salt (HFSS). Department of Health and Social Care and Department for Digital, Culture, Media and Sport; [accessed 29th Jan 2020]. https://www.gov.uk/government/consultations/total-restriction-of-online-advertising-for-products-high-in-fat-sugar-and-salt-hfss/introducing-a-total-online-advertising-restriction-for-products-high-in-fat-sugar-and-salt-hfss.

DHSSPS. 2012. Ten-year Tobacco Control Strategy for Northern Ireland. Belfast, UK: Department of Health, Social Services and Public Safety.

Dietrich T, Sharma P, Walter C, Weston P, Beck J. 2013. The epidemiological evidence behind the association between periodontitis and incident atherosclerotic cardiovascular disease. J Periodontol. 84(4 Suppl):S70-84.

Do LG, Scott JA, Thomson WM, Stamm JW, Rugg-Gunn AJ, Levy SM, Wong C, Devenish G, Ha DH, Spencer AJ. 2014. Common risk factor approach to address socioeconomic inequality in the oral health of preschool children-a prospective cohort study. BMC Public Health. 14:429.

Do LG, Slade GD, Roberts-Thomson KF, Sanders AE. 2008. Smoking-attributable periodontal disease in the Australian adult population. J Clin Periodontol. 35(5):398-404.

Dobbie F, Purves R, McKell J, Dougall N, Campbell R, White J, Amos A, Moore L, Bauld L. 2019. Implementation of a peer-led school based smoking prevention programme: a mixed methods process evaluation. BMC Public Health. 19(1):742.

DoH. 2005. Choosing better oral health: An oral health plan for england. London, UK: Department of Health.

DoH. 2017a. Delivering better oral health: an evidence-based toolkit for prevention. London, UK: Department of Health.

DoH. 2017b. Towards a smokefree generation: a tobacco control plan for England. London, UK: Department of Health.

Dolan TA, Gilbert GH, Duncan RP, Foerster U. 2001. Risk indicators of edentulism, partial tooth loss and prosthetic status among black and white middle-aged and older adults. Community Dent Oral Epidemiol. 29(5):329-340.

Doll R, Hill AB. 1964. Mortality in relation to smoking: Ten years' observations of British doctors. Br Med J. 1(5396):1460-1467.

Donaldson AN, Everitt B, Newton T, Steele J, Sherriff M, Bower E. 2008. The effects of social class and dental attendance on oral health. J Dent Res. 87(1):60-64.

Dong Y, Peng C-YJ. 2013. Principled missing data methods for researchers. Springerplus. 2(1):222-222.

Doornik J, Hansen H. 2008. An Omnibus Test for Univariate and Multivariate Normality. Oxf Bull Econ Stat. 70:927-929.

Dorfer C, Benz C, Aida J, Campard G. 2017. The relationship of oral health with general health and NCDs: a brief review. Int Dent J. 67 Suppl 2:14-18.

Drummond M, Drummond C. 2012. Boys and their teeth: a qualitative investigation of boys' oral health in early childhood. J Child Health Care. 16(3):284-292.

Dube SR, Felitti VJ, Dong M, Giles WH, Anda RF. 2003. The impact of adverse childhood experiences on health problems: evidence from four birth cohorts dating back to 1900. Prev Med. 37(3):268-277.

Dudding T, Haworth S, Sandy J, Timpson NJ. 2018. Age 23 years + oral health questionnaire in Avon Longitudinal Study of Parents and Children. Wellcome Open Res. 3:34.

Duijster D, de Jong-Lenters M, Verrips E, van Loveren C. 2015. Establishing oral health promoting behaviours in children - parents' views on barriers, facilitators and professional support: a qualitative study. BMC Oral Health. 15:157.

Duijster D, van Loveren C, Dusseldorp E, Verrips GH. 2014. Modelling community, family, and individual determinants of childhood dental caries. Eur J Oral Sci. 122(2):125-133.

Dunbar SB, Clark PC, Quinn C, Gary RA, Kaslow NJ. 2008. Family influences on heart failure self-care and outcomes. J Cardiovasc Nurs. 23(3):258-265.

Duncan C, Jones K, Moon G. 1999. Smoking and deprivation: are there neighbourhood effects? Soc Sci Med. 48(4):497-505.

Duncan GJ, Wilkerson B, England P. 2006. Cleaning up their act: the effects of marriage and cohabitation on licit and illicit drug use. Demography. 43(4):691-710.

Dye BA. 2017. The Global Burden of Oral Disease: Research and Public Health Significance. J Dent Res. 96(4):361-363.

Dye BA, Li X, Thorton-Evans G. 2012. Oral health disparities as determined by selected healthy people 2020 oral health objectives for the United States, 2009-2010. NCHS Data Brief. (104):1-8.

Dye BA, Tan S, Smith V, Lewis BG, Barker LK, Thornton-Evans G, Eke PI, Beltrán-Aguilar ED, Horowitz AM, Li CH. 2007. Trends in oral health status: United States, 1988-1994 and 1999-2004. Vital Health Stat 11. (248):1-92.

Dye BA, Thornton-Evans G. 2010. Trends in oral health by poverty status as measured by Healthy People 2010 objectives. Public Health Rep. 125(6):817-830.

Eaton KA. 2020. Oral healthcare workforce planning in post-Brexit Britain. Br Dent J. 228(10):750-752.

Edstrom KM, Devine CM. 2001. Consistency in women's orientations to food and nutrition in midlife and older age: a 10-year qualitative follow-up. J Nutr Educ. 33(4):215-223.

Edwards MJ, Jago R, Sebire SJ, Kesten JM, Pool L, Thompson JL. 2015. The influence of friends and siblings on the physical activity and screen viewing behaviours of children aged 5–6 years: a qualitative analysis of parent interviews. BMJ Open. 5(5):e006593.

El-Sheikh AA, Abonazel MR, Gamil N. 2017. A Review of Software Packages for Structural Equation Modeling: A Comparative Study. Applied Mathematics & Physics. 5:85-94.

Elisaf M. 2001. The treatment of coronary heart disease: an update. Part 1: An overview of the risk factors for cardiovascular disease. Curr Med Res Opin. 17(1):18-26.

Elliott J, Shepherd P. 2006. Cohort profile: 1970 British Birth Cohort (BCS70). Int J Epidemiol. 35(4):836-843.

Elshatarat R, Yacoub M, Khraim F, Saleh Z, Afaneh T. 2016. Self-efficacy in treating tobacco use: A review article. Proc Singapore Healthc. 25(4):243-248.

Elwood SA, Martin DG. 2000. “Placing” Interviews: Location and Scales of Power in Qualitative Research. Prof Geogr. 52(4):649-657.

Eriksson JG, Forsen T, Tuomilehto J, Winter PD, Osmond C, Barker DJ. 1999. Catch-up growth in childhood and death from coronary heart disease: longitudinal study. BMJ. 318(7181):427-431.

Eysenbach G. 2004. Improving the quality of Web surveys: the Checklist for Reporting Results of Internet E-Surveys (CHERRIES). J Med Internet Res. 6(3):e34.

Eysteinsdottir T, Gunnarsdottir I, Thorsdottir I, Harris T, Launer LJ, Gudnason V, Steingrimsdottir L. 2011. Validity of retrospective diet history: assessing recall of midlife diet using food frequency questionnaire in later life. J Nutr Health Aging. 15(10):809-814.

Faerstein E, Chor D, Lopes C, Werneck GL. 2005. The Pro-Saude Study: general characteristics and methodological aspects. Rev Bras Epidemiol. 8:454-466.

Fägerstad A, Lundgren J, Arnrup K, Carlson E. 2019. Barriers and facilitators for adolescent girls to take on adult responsibility for dental care - a qualitative study. Int J Qual Stud Health Well-being. 14(1):1678971-1678971.

Farah CS, Lynch N, McCullough MJ. 2010. Oral fungal infections: an update for the general practitioner. Aust Dent J. 55 Suppl 1:48-54.

Faseru B, Richter KP, Scheuermann TS, Park EW. 2018. Enhancing partner support to improve smoking cessation. Cochrane Database Syst Rev. 8(8):CD002928.

FDI. 2019. UK schools rank last in providing oral health education, survey of 13 countries says. FDI World Dental Federation; [accessed 29th Jan 2021].

https://www.fdiworlddental.org/press-release/20190320/uk-schools-rank-last-in-providing-oral-health-education-survey-of-13.

Feldens CA, Giugliani ER, Vigo A, Vitolo MR. 2010. Early feeding practices and severe early childhood caries in four-year-old children from southern Brazil: a birth cohort study. Caries Res. 44(5):445-452.

Ferraro M, Vieira AR. 2010. Explaining gender differences in caries: a multifactorial approach to a multifactorial disease. Int J Dent. 2010(8):649643.

Fetters MD, Curry LA, Creswell JW. 2013. Achieving integration in mixed methods designs-principles and practices. Health Serv Res. 48(6 Pt 2):2134-2156.

Fielding JE. 1999. Public Health in the Twentieth Century: Advances and Challenges. Annu Rev Public Health. 20(1):xiii-xxx.

Fink A. 2003. The Survey Handbook. Thousand Oaks, CA: Sage.

Fish LJ, Oliver JA, Noonan D, Davis JM, Pollak KI. 2020. A qualitative study exploring cues and other motivators among a racially diverse sample of light and intermittent smokers. J Smok Cessat. 15(1):29-34.

Fisher JD, Fisher WA. 1992. Changing AIDS-risk behavior. Psychol Bull. 111(3):455-474.

Fisher MA, Gilbert GH, Shelton BJ. 2004. A cohort study found racial differences in dental insurance, utilization, and the effect of care on quality of life. J Clin Epidemiol. 57(8):853-857.

Fitzgerald R, Thomson W, Schafer C, Loose M. 2004. An exploratory qualitative study of Otago adolescents' views of oral health and oral health care. N Z Dent J. 100:62-71.

Fitzgerald RP, Thomson WM, Huakau G, Darrou M, Gilmore D, Sadler H, Bell RJ, Danse V, Broad B, Broughton JR. 2015. A qualitative study of the meaning of oral health and self-care for 40 Dunedin residents living on lower incomes. N Z Dent J. 111(2):68-75.

Fitzsimons E. 2020. Millenium Cohort Study Sixth Survey 2015-2016 User Guide (Second Edition). [accessed 29th Jan 2021]. http://doc.ukdataservice.ac.uk/doc/8156/mrdoc/pdf/mcs6_user_guide_ed2_2020-08-10.pdf.

Flora GD, Nayak MK. 2019. A Brief Review of Cardiovascular Diseases, Associated Risk Factors and Current Treatment Regimes. Curr Pharm Des. 25(38):4063-4084.

Florida Health. 2020. Community Water Fluoridation. [accessed 29th Jan 2021]. http://www.floridahealth.gov/programs-and-services/community-health/dental-health/fluoridation/index.html.

Food and Drink Federation. 2013. The facts. Science behind guideline daily amounts. [accessed 6th Sept 2019]. http://www.fdf.org.uk/publicgeneral/gdas_science_Jul09.pdf.

Forey B, Hamling J, Hamling J, Thornton A, Lee P. 2016. International smoking statistics, web edition. A collection of worldwide historical data: United Kingdom [accessed 6th Sept 2019]. http://www.pnlee.co.uk/ISS.htm.

Fowler FJ. 1995. Improving Survey Questions: Design and Evaluation. London, UK: SAGE Publications.

Fraser GE, Lindsted KD, Knutsen SF, Beeson WL, Bennett H, Shavlik DJ. 1998. Validity of dietary recall over 20 years among California Seventh-day Adventists. Am J Epidemiol. 148(8):810-818.

Freeman JV, Cole TJ, Chinn S, Jones PR, White EM, Preece MA. 1995. Cross sectional stature and weight reference curves for the UK, 1990. Arch Dis Child. 73(1):17-24.

French DP, Sutton S. 2010. Reactivity of measurement in health psychology: how much of a problem is it? What can be done about it? Br J Health Psychol. 15(3):453-468.

Friedenreich CM, Slimani N, Riboli E. 1992. Measurement of past diet: review of previous and proposed methods. Epidemiol Rev. 14:177-196.

Friel S, Hope A, Kelleher C, Comer S, Sadlier D. 2002. Impact evaluation of an oral health intervention amongst primary school children in Ireland. Health Promot Int. 17(2):119-126.

Frilander H, Solovieva S, Mutanen P, Pihlajamäki H, Heliövaara M, Viikari-Juntura E. 2015. Role of overweight and obesity in low back disorders among men: a longitudinal study with a life course approach. BMJ Open. 5(8):e007805.

Frone MR. 2012. Problem with the use of standardized coefficients. [accessed 6th Sept 2019]. https://www.researchgate.net/publication/275647774_Problem_with_the_Use_of_Standardized_Coefficients.

Fuller E, Steele J, Watt R, Nuttall N. 2011. Oral health and function - a report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

Gallagher J, Ashley P, Needleman I. 2020. Implementation of a behavioural change intervention to enhance oral health behaviours in elite athletes: a feasibility study. BMJ Open Sport Exerc Med. 6(1):e000759.

Gallagher JE, Hutchinson L. 2018. Analysis of human resources for oral health globally: inequitable distribution. Int Dent J. 68(3):183-189.

Galobardes B, Lynch JW, Smith GD. 2008. Is the association between childhood socioeconomic circumstances and cause-specific mortality established? Update of a systematic review. J Epidemiol Community Health. 62(5):387-390.

Gao X, Hamzah SH, Yiu CK, McGrath C, King NM. 2013. Dental fear and anxiety in children and adolescents: qualitative study using YouTube. J Med Internet Res. 15(2):e29.

Gao X, Lo EC, Kot SC, Chan KC. 2014. Motivational interviewing in improving oral health: a systematic review of randomized controlled trials. J Periodontol. 85(3):426-437.

Gao XL, Hsu CY, Xu YC, Loh T, Koh D, Hwarng HB. 2010. Behavioral pathways explaining oral health disparity in children. J Dent Res. 89(9):985-990.

Garbin Neumann D, Quinonez C. 2014. A comparative analysis of oral health care systems in the United States, United Kingdom, France, Canada, and Brazil. NCOHR Working Paper Series. Network for Canadian Oral Health Research.

Garson GD. 2014. Path Analysis. NC, USA: Statistical Associates Publishing.

Garson GD. 2015. Structural equation modelling. NC, USA: Statistical Associates Publishing.

GDC. 2015. Preparing for practice. Dental team learning outcomes for registration (2015 revised edition). General Dental Council.

Genco RJ, Borgnakke WS. 2013. Risk factors for periodontal disease. Periodontol 2000. 62(1):59-94.

George A, Grace R, Elcombe E, Villarosa AR, Mack HA, Kemp L, Ajwani S, Wright DC, Anderson C, Bucknall N et al. 2018. The oral health behaviours and fluid consumption practices of young urban Aboriginal preschool children in south-western Sydney, New South Wales, Australia. Health Promot J Austr. 29(1):23-30.

Gerritsen AE, Allen PF, Witter DJ, Bronkhorst EM, Creugers NHJ. 2010. Tooth loss and oral health-related quality of life: a systematic review and meta-analysis. Health Qual Life Outcomes. 8(1):126.

Ghaffari M, Rakhshanderou S, Ramezankhani A, Noroozi M, Armoon B. 2018. Exploration of brushing behavior among university students in Iran: a qualitative research. Int J Adolesc Med Health. 32(2):[Preprint]. https://doi.org/10.1515/ijamh-2017-0115.

Gholami M, Pakdaman A, Montazeri A, Virtanen JI. 2017. Evaluation of the Impact of a Mass Media Campaign on Periodontal Knowledge among Iranian Adults: A Three-Month Follow-Up. PLoS ONE. 12(1):e0169668.

Giannopoulou C, Kamma JJ, Mombelli A. 2003. Effect of inflammation, smoking and stress on gingival crevicular fluid cytokine level. J Clin Periodontol. 30(2):145-153.

Gibbons RJ, van Houte J. 1975. Dental caries. Annu Rev Med. 26:121-136.

Gibson BJ, Kettle JE, Robinson PG, Walls A, Warren L. 2019. Oral care as a life course project: A qualitative grounded theory study. Gerodontology. 36(1):8-17.

Gil GS, Morikava FS, Santin GC, Pintarelli TP, Fraiz FC, Ferreira FM. 2015. Reliability of self-reported toothbrushing frequency as an indicator for the assessment of oral hygiene in epidemiological research on caries in adolescents: a cross-sectional study. BMC Med Res Methodol. 15:14-14.

Gilbert GH, Duncan RP, Shelton BJ. 2003. Social determinants of tooth loss. Health Serv Res. 38(6 Pt 2):1843-1862.

Gilbert GH, Foerster U, Dolan TA, Duncan RP, Ringelberg ML. 2000. Twenty-four month coronal caries incidence: the role of dental care and race. Caries Res. 34(5):367-379.

Gilbert GH, Rose JS, Shelton BJ. 2002. A prospective study of the validity of data on self-reported dental visits. Community Dent Oral Epidemiol. 30(5):352-362.

Gill P, Stewart K, Chetcuti D, Chestnutt IG. 2011. Children's understanding of and motivations for toothbrushing: a qualitative study. Int J Dent Hyg. 9(1):79-86.

Glaser BG. 1992. Basics of Grounded Theory Analysis. Emergence vs Forcing. Mill Valley, CA: Sociology Press.

Glaser BG, Strauss AL. 1967. The discovery of grounded theory: Strategies for qualitative research. Chicago, IL: Aldine.

Glenn N. 2005. Cohort Analysis (Second edition). Thousand Oaks, CA: Sage.

Glick M, Williams DM, Kleinman DV, Vujicic M, Watt RG, Weyant RJ. 2016. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. J Am Dent Assoc. 147(12):915-917.

Godin G, Sheeran P, Conner M, Germain M. 2008. Asking questions changes behavior: mere measurement effects on frequency of blood donation. Health Psychol. 27(2):179-184.

Goettems ML, Nascimento GG, Peres MA, Santos IS, Matijasevich A, Barros AJD, Peres KG, Demarco FF. 2018. Influence of maternal characteristics and caregiving behaviours on children's caries experience: An intergenerational approach. Community Dent Oral Epidemiol. 46(5):435-441.

Goldthorpe J, Ali N, Calam R. 2018. Providing healthy diets for young children: the experience of parents in a UK inner city. Int J Qual Stud Health Well-being. 13(1):1490623.

Gomaa N, Glogauer M, Tenenbaum H, Siddiqi A, Quinonez C. 2016. Social-biological interactions in oral disease: A 'cells to society' view. PLoS One. 11(1):e0146218.

GOV.UK. 2019. Spending Round 2019: Chancellor Sajid Javid's speech. [accessed 29th Jan 2021]. https://www.gov.uk/government/speeches/spending-round-2019-sajid-javids-speech.

Graham JE, Mayan M, McCargar LJ, Bell RC. 2013. Making compromises: a qualitative study of sugar consumption behaviors during pregnancy. J Nutr Educ Behav. 45(6):578-585.

Grassi MC, Alessandri G, Pasquariello S, Milioni M, Enea D, Ceccanti M, Nencini P, Caprara GV. 2014. Association between positivity and smoking cessation. Biomed Res Int. 2014:780146.

Gray-Burrows KA, Day PF, Marshman Z, Aliakbari E, Prady SL, McEachan RRC. 2016. Using intervention mapping to develop a home-based parental-supervised toothbrushing intervention for young children. Implement Sci. 11(1):61.

Gray PG, Todd JE, Slack GL, Bulman JS. 1970. Adult Dental Health in England and Wales in 1968. London, UK: HMSO.

Greater Manchester Health and Social Care Partnership. 2019. Stopping the rot: Greater Manchester under 5s to benefit from programme tackling tooth decay. [accessed 29th Jan 2021]. http://www.gmhsc.org.uk/oral-health-programme-launch/.

Green J, Thorogood N. 2018. Qualitative methods for health research. London, UK: SAGE.

Greene JC, Caracelli VJ. 1997. Advances in mixed-method evaluation: the challenges and benefits of integrating diverse paradigms. San Francisco, CA: Jossey-Bass Publishers.

Greenhalgh E, Jenkins S, Stillman S, Ford C. 2016. 7.7 Factors that predict success or failure in quit attempts. In: Greenhalgh EM, Scollo MM and Winstanley MH, editors. Tobacco in Australia: Facts and issues. Melbourne, Australia: Cancer Council Victoria [accessed 29th Jan 2020]. http://www.tobaccoinaustralia.org.au/7-7-personal-factors-associated-with-quitting

Greenland, S., Maclure M, Schlesselmen J, Poole C, Morgenstern H. 1991. Standardized Regression Coefficients: A Further Critique and Review of Some Alternatives. Epidemiology. 2(5):387-392.

Gregory J, Gibson B, Robinson PG. 2007. The relevance of oral health for attenders and non-attenders: a qualitative study. Br Dent J. 202(7):E18.

Gregory J, Thomson WM, Broughton JR, Cullinan MP, Seymour GJ, Kieser JA, Donaghy MA, Shearer DM. 2012. Experiences and perceptions of oral health and oral health care among a sample of older New Zealanders. Gerodontology. 29(1):54-63.

Groarke JM, Richmond J, Kelly MG, McSharry J, Groarke A, Kerr T, Singaroyan N, Harney O, Haughey C, Glynn L et al. 2019. Examining the Impact of a Personalized Self-Management Lifestyle Program Using Mobile Technology on the Health and Well-Being of Cancer Survivors: Protocol and Rationale for a Randomized Controlled Trial (The Moving On Study). JMIR Res Protoc. 8(8):e13214-e13214.

Grocock R. 2018. The relevance of alcohol to dental practice. Br Dent J. 223(12):895-899.

Grocock R, Holden B, Robertson C. 2019. The missing piece of the body? Oral health knowledge and confidence of doctors. Br Dent J. 226(6):427-431.

Gromshaw J. 2014. SURGE (The SUrvey Reporting GuidelinE). In: D. M, Altman DG, Schulz KF, Simera I, Wager E, editors. Guidelines for Reporting Health Research: A User's Manual. New Jersey, US.: Wiley-Blackwell. p. 206-213.

Grundy EM, Tomassini C. 2010. Marital history, health and mortality among older men and women in England and Wales. BMC Public Health. 10:554.

Grunfelder J, Rispling L, Norlén G, (eds). 2018. State of the Nordic Region 2018. Theme 3: Economy. Copenhagen, DK: Nordic Council of Ministers.

Guarnizo-Herreno CC, Watt RG, Pikhart H, Sheiham A, Tsakos G. 2014. Inequalities in oral impacts and welfare regimes: analysis of 21 European countries. Community Dent Oral Epidemiol. 42(6):517-525.

Gülcan F, Ekbäck G, Ordell S, Lie SA, Åstrøm AN. 2015. Inequality in oral health related to early and later life social conditions: a study of elderly in Norway and Sweden. BMC oral health. 15:20-20.

Gururatana O, Baker SR, Robinson PG. 2014. Determinants of children's oral-health-related quality of life over time. Community Dent Oral Epidemiol. 42(3):206-215.

Gwaltney CJ, Metrik J, Kahler CW, Shiffman S. 2009. Self-efficacy and smoking cessation: a meta-analysis. Psychol Addict Behav. 23(1):56-66.

Ha DH, Do LG. 2018. Early life professional and layperson support reduce poor oral hygiene habits in toddlers-a prospective birth cohort study. Dent J. 6(4):56.

Halfon N, Forrest C, Lerner R, Faustman E. 2018. Handbook of life course health development. Cham, Switzerland: Springer.

Hall-Scullin E, Goldthorpe J, Milsom K, Tickle M. 2015. A qualitative study of the views of adolescents on their caries risk and prevention behaviours. BMC Oral Health. 15:141.

Hamasha AA, Warren JJ, Levy SM, Broffitt B, Kanellis MJ. 2006. Oral health behaviors of children in low and high socioeconomic status families. Pediatr Dent. 28(4):310-315.

Hara AT, Zero DT. 2014. The potential of saliva in protecting against dental erosion. Monogr Oral Sci. 25:197-205.

Hardeman W, Johnston M, Johnston D, Bonetti D, Wareham N, Kinmonth AL. 2002. Application of the Theory of Planned Behaviour in Behaviour Change Interventions: A Systematic Review. Psychology & Health. 17(2):123-158.

Hardy R, Lawlor DA, Kuh D. 2015. A life course approach to cardiovascular aging. Future Cardiol. 11(1):101-113.

Harmon G, Lefante J, Krousel-Wood M. 2006. Overcoming barriers: the role of providers in improving patient adherence to antihypertensive medications. Curr Opin Cardiol. 21(4):310-315.

Harnagea H, Couturier Y, Shrivastava R, Girard F, Lamothe L, Bedos CP, Emami E. 2017. Barriers and facilitators in the integration of oral health into primary care: a scoping review. BMJ Open. 7(9):e016078.

Harrari D, Keep M. 2020. Coronavirus: Ecomonic Impact. House of Commons Library Briefing Paper, Number 8866. House of Commons Library.

Harrison SL, Mann KD, Pearce MS. 2013. Early life influences kidney function at age 63-64 years, but so does adult body size: results from the Newcastle Thousand Families Birth Cohort. PLoS One. 8(6):e66660.

Health and Social Care Act. 2012. c.7. [accessed 29th Jan 2020]. https://www.legislation.gov.uk/ukpga/2012/7/contents/enacted.

Health and Social Care Information Centre. 2013. Children's Dental Health Survey 2013. Executive summary: England, Wales and Northern Ireland. Leeds, UK: Health and Social Care Information Centre.

Healthdirect. 2020. Cost of Dental Care. [accessed 29th Jan 2021]. https://www.healthdirect.gov.au/cost-of-dental-care.

Heidari E, Andiappan M, Banerjee A, Newton JT. 2017. The oral health of individuals with dental phobia: a multivariate analysis of the Adult Dental Health Survey, 2009. BDJ. 222(8):595-604.

Heilmann A, Tsakos G, Watt RG. 2015. Oral health over the lifecourse. In: Burton-Jeangros C, Cullati S, Sacker A, Blane D, editors. A life course perspective on health trajectories and transitions. Cham, Switzerland: Springer.

HESA. 2019. Who's studying in higher education. Higher Education Statistics Agency; [accessed 29th Jan 2021]. https://www.hesa.ac.uk/data-and-analysis/students/whos-in-he.

Hettmann A, Demcsak A, Decsi G, Bach A, Palinko D, Rovo L, Nagy K, Takacs M, Minarovits J. 2016. Infectious agents associated with head and neck carcinomas. In: Donelli G, editor. Advances in experimental medicine and biology. Cham, Switzerland: Springer.

HHS.Gov. 2017. Where can i find low cost dental care. U.S. Department of Health and Human Services; [accessed 29th Jan 2021]. https://www.hhs.gov/answers/health-care/where-can-i-find-low-cost-dental-care/index.html.

Hill H, Birch S, Tickle M, McDonald R, Donaldson M, O'Carolan D, Brocklehurst P. 2017. Does capitation affect the delivery of oral healthcare and access to services? Evidence from a pilot contact in Northern Ireland. BMC Health Serv Res. 17(1):175.

Hill H, Howarth E, Walsh T, Tickle M, Birch S, Brocklehurst P. 2020. The impact of changing provider remuneration on clinical activity and quality of care: Evaluation of a pilot NHS contract in Northern Ireland. Comm Dent Oral Epi. 48(5):395-401.

Hill KB, Hainsworth JM, Burke FJ, Fairbrother KJ. 2008. Evaluation of dentists' perceived needs regarding treatment of the anxious patient. Br Dent J. 204(8):E13.

Hill KB, White DA, Morris AJ, Hall AC, Goodwin N, Burke FJ. 2003. National evaluation of personal dental services: a qualitative investigation into patients' perceptions of dental services. Br Dent J. 195(11):654-656.

Hillsdon M, Foster C, Thorogood M. 2005. Interventions for promoting physical activity. Cochrane Database Syst Rev. (1):CD003180.

Hilton IV, Stephen S, Barker JC, Weintraub JA. 2007. Cultural factors and children's oral health care: a qualitative study of carers of young children. Community Dent Oral Epidemiol. 35(6):429-438.

Hirschfeld L, Wasserman B. 1978. A long-term survey of tooth loss in 600 treated periodontal patients. J Periodontol. 49(5):225-237.

Hitsman B, Papandonatos GD, McChargue DE, DeMott A, Herrera MJ, Spring B, Borrelli B, Niaura R. 2013. Past major depression and smoking cessation outcome: a systematic review and meta-analysis update. Addiction. 108(2):294-306.

Ho MH, Rita Chang HC, Lin YK, Traynor V, Tsai HH, Buckwalter K, Liu MF, Chang CC. 2019. Application of the Integrated Behavioral Model to oral self-care behavior of community-dwelling middle-aged and older people in Taiwan. Public Health Nurs. 36(5):726-734.

Hobdell M, Petersen PE, Clarkson J, Johnson N. 2003. Global goals for oral health 2020. Int Dent J. 53(5):285-288.

Hoffman BR, Monge PR, Chou CP, Valente TW. 2007. Perceived peer influence and peer selection on adolescent smoking. Addict Behav. 32(8):1546-1554.

Holliday R, Amin K, Lawrence V, Preshaw PM. 2018. Tobacco education in UK dental schools: A survey of current practice. Eur J Dent Educ. 22(2):e248-e252.

Hollister MC, Anema MG. 2004. Health behavior models and oral health: a review. J Dent Hyg. 78(3):6.

Holmes J, Meng Y, Meier PS, Brennan A, Angus C, Campbell-Burton A, Guo Y, Hill-McManus D, Purshouse RC. 2014. Effects of minimum unit pricing for alcohol on different income and socioeconomic groups: a modelling study. Lancet. 383(9929):1655-1664.

Holst D, Schuller AA. 2012. Oral health in a life-course: birth-cohorts from 1929 to 2006 in Norway. Community Dent Health. 29(2):134-143.

Hooley M, Skouteris H, Boganin C, Satur J, Kilpatrick N. 2012. Parental influence and the development of dental caries in children aged 0-6 years: a systematic review of the literature. J Dent. 40(11):873-885.

Hooper D, Coughlan J, Mullen MR. 2008. Structural equation modelling: Guidelines for determining model fit. Electron J Bus Res Methods. 6(1):53-60.

Hosseinpoor AR, Itani L, Petersen PE. 2012. Socio-economic inequality in oral healthcare coverage: results from the World Health Survey. J Dent Res. 91(3):275-281.

Host A, Mcmahon A-T, Walton K, Charlton K. 2016. 'While we can, we will': Exploring food choice and dietary behaviour amongst independent older Australians. Nutr Diet. 73(5):463-473.

HSC BSO. 2020. NORTHERN IRELAND STATEMENT OF DENTAL REMUNERATION 2020 (Number 2). Belfast, UK: Health and Social Care Northern Ireland Business Services Organisation.

HSCB. 2020. Happy Smiles Pre-School Oral Health Programme. Health and Social Care Board; [accessed 29th Jan 2021]. http://www.hscboard.hscni.net/our-work/integrated-care/dental-services/happy-smiles/.

Hull PS, Worthington HV, Clerehugh V, Tsirba R, Davies RM, Clarkson JE. 1997. The reasons for tooth extractions in adults and their validation. J Dent. 25(3-4):233-237.

Humphris GM, Dyer TA, Robinson PG. 2009. The modified dental anxiety scale: UK general public population norms in 2008 with further psychometrics and effects of age. BMC Oral Health. 9:20-20.

Humphris GM, Freeman R, Campbell J, Tuutti H, D'Souza V. 2000. Further evidence for the reliability and validity of the Modified Dental Anxiety Scale. Int Dent J. 50(6):367-370.

Humphris GM, Morrison T, Lindsay SJ. 1995. The Modified Dental Anxiety Scale: Validation and United Kingdom norms. Community Dent Health. 12(3):143-150.

Huxley R, Neil A, Collins R. 2002. Unravelling the fetal origins hypothesis: is there really an inverse association between birthweight and subsequent blood pressure? Lancet. 360(9334):659-665.

Huxley R, Owen CG, Whincup PH, Cook DG, Rich-Edwards J, Smith GD, Collins R. 2007. Is birth weight a risk factor for ischemic heart disease in later life? Am J Clin Nutr. 85(5):1244-1250.

Iheozor-Ejiofor Z, Worthington HV, Walsh T, O'Malley L, Clarkson JE, Macey R, Alam R, Tugwell P, Welch V, Glenny AM. 2015. Water fluoridation for the prevention of dental caries. Cochrane Database Syst Rev. (6):CD010856.

IHV. 2020. Health Visiting in England: State of Health Visiting in England. Results from a survey of 1040 practising health visitors. Institute of Health Visiting.

Institute of Medicine. 2003. Chapter 7: Media. In: The Future of the Public's Health in the 21st Century. Washington, US: National Academies Press.

Ioannidou E. 2017. The Sex and Gender Intersection in Chronic Periodontitis. Front Public Health. 5:189-189.

Islam MA, Hossain M, Sarwar S, Kawsar L, Smrity L, Ashraf-Ul-Alam M, Hossain M, Bhuia MR. 2016. Structural Equation Modeling to Assess the Impact of Socio-Demographic Variables on Fertility of Ethnic Manipuri Women. Biom Biostat Int J. 5:00078.

Ismail AI, Burt BA, Brunelle JA. 1987. Prevalence of total tooth loss, dental caries, and periodontal disease in Mexican-American adults: results from the southwestern HHANES. J Dent Res. 66(6):1183-1188.

Jacobsen PE, Haubek D, Henriksen TB, Ostergaard JR, Poulsen S. 2014. Developmental enamel defects in children born preterm: a systematic review. Eur J Oral Sci. 122(1):7-14.

Jafarian M, Etebarian A. 2013. Reasons for extraction of permanent teeth in general dental practices in Tehran, Iran. Med Princ Pract. 22(3):239-244.

James AC, James G, Cowdrey FA, Soler A, Choke A. 2013. Cognitive behavioural therapy for anxiety disorders in children and adolescents. Cochrane Database Syst Rev. (6):CD004690.

Jamieson LM, Armfield JM, Roberts-Thomson KF, Sayers SM. 2010a. A retrospective longitudinal study of caries development in an Australian Aboriginal birth cohort. Caries Res. 44(4):415-420.

Jamieson LM, Roberts-Thomson KF, Sayers SM. 2010b. Dental caries risk indicators among Australian Aboriginal young adults. Community Dent Oral Epidemiol. 38(3):213-221.

Jamieson LM, Roberts-Thomson KF, Sayers SM. 2010c. Risk indicators for severe impaired oral health among indigenous Australian young adults. BMC Oral Health. 10:1.

Jansson C, Nordenstedt H, Johansson S, Wallander M-A, Johnsen R, Hveem K, Lagergren J. 2007. Relation Between Gastroesophageal Reflux Symptoms and Socioeconomic Factors: A Population-Based Study (the HUNT Study). Clin Gastroenterol Hepatol. 5(9):1029-1034.

Jarvis MJ. 1996. The association between having children, family size and smoking cessation in adults. Addiction. 91(3):427-434.

Jensen O, Gabre P, Skold UM, Birkhed D. 2011. Fluoride toothpaste and toothbrushing; knowledge, attitudes and behaviour among Swedish adolescents and adults. Swed Dent J. 35(4):203-213.

Jepsen S, Caton JG, Albandar JM, Bissada NF, Bouchard P, Cortellini P, Demirel K, de Sanctis M, Ercoli C, Fan J et al. 2018. Periodontal manifestations of systemic diseases and developmental and acquired conditions: Consensus report of workgroup 3 of the 2017

World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Clin Periodontol. 45 Suppl 20:S219-S229.

Jepson RG, Harris FM, Platt S, Tannahill C. 2010. The effectiveness of interventions to change six health behaviours: a review of reviews. BMC Public Health. 10(1):538.

Johannsen A, Rydmark I, Soder B, Asberg M. 2007. Gingival inflammation, increased periodontal pocket depth and elevated interleukin-6 in gingival crevicular fluid of depressed women on long-term sick leave. J Periodontal Res. 42(6):546-552.

John MT, Miglioretti DL, LeResche L, Koepsell TD, Hujoel P, Micheelis W. 2006. German short forms of the Oral Health Impact Profile. Community Dent Oral Epidemiol. 34(4):277-288.

Johnson S, Carpenter L, Amezdroz E, Dashper S, Gussy M, Calache H, de Silva AM, Waters E. 2017. Cohort Profile: The VicGeneration (VicGen) study: An Australian oral health birth cohort. Int J Epidemiol. 46(1):29-30.

Jones NR, Conklin AI, Suhrcke M, Monsivais P. 2014. The growing price gap between more and less healthy foods: analysis of a novel longitudinal UK dataset. PLoS One. 9(10):e109343.

Jones S, Burt BA, Petersen PE, Lennon MA. 2005. The effective use of fluorides in public health. Bull World Health Organ. 83(9):670-676.

Joossens L. 2004. Effective tobacco control policies in 28 European countries. Brussels: European Network for Smoking Prevention.

Kalsi JS, Hemmings K. 2013. The influence of patients' decisions on treatment planning in restorative dentistry. Dent Update. 40(9):698.

Kandelman D, Arpin S, Baez RJ, Baehni PC, Petersen PE. 2012. Oral health care systems in developing and developed countries. Periodontol 2000. 60(1):98-109.

Kang J, Wu B, Bunce D, Ide M, Pavitt S, Wu J. 2019. Cognitive function and oral health among ageing adults. Community Dent Oral Epidemiol. 47(3):259-266.

Kapur KK, Glass RL, Loftus ER, Alman JE, Feller RP. 1972. The Veterans Administration Longitudinal Study of Oral Health and Disease: Methodology and Preliminary Findings. Int J Aging Hum Dev. 3(1):125-137.

Karaman S, Ürek D, Bilgin Demir I, Ugurluoglu O, Işik O. 2020. The Impact of Healthcare Spending on Health Outcomes: New Evidence from OECD Countries. Erciyes Med J. 42(2):218-222.

Kassebaum NJ, Smith AGC, Bernabe E, Fleming TD, Reynolds AE, Vos T, Murray CJL, Marcenes W. 2017. Global, regional, and national prevalence, incidence, and disability-adjusted life years for oral conditions for 195 countries, 1990-2015: A systematic analysis for the global burden of diseases, injuries, and risk factors. J Dent Res. 96(4):380-387.

Katikireddi SV, Beeston C, Millard A, Forsyth R, Deluca P, Drummond C, Eadie D, Graham L, Hilton S, Ludbrook A et al. 2019. Evaluating possible intended and unintended consequences of the implementation of alcohol minimum unit pricing (MUP) in Scotland: a natural experiment protocol. BMJ Open. 9(6):e028482.

Kay EJ, Blinkhorn AS. 1996. A qualitative investigation of factors governing dentists' treatment philosophies. Br Dent J. 180(5):171-176.

Kay EJ, Northstone K, Ness A, Duncan K, Crean SJ. 2010. Is there a relationship between birthweight and subsequent growth on the development of dental caries at 5 years of age? A cohort study. Community Dent Oral Epidemiol. 38(5):408-414.

Keller A, Rohde JF, Raymond K, Heitmann BL. 2015. Association between periodontal disease and overweight and obesity: a systematic review. J Periodontol. 86(6):766-776.

Kelly M, Steele J, Nuttall N, Bradnock G, Morris J, Nunn J, Pine C, Pitts N, Treasure E, White D. 2000. Adult Dental Health Survey: Oral Health in the United Kingdom 1998. London, UK: The Stationery Office.

Kelly MP, Barker M. 2016. Why is changing health-related behaviour so difficult? Public Health. 136:109-116.

Kent Community Health NHS Foundation Trust. 2021. Oral Health Promotion Service. [accessed 29th Jan 2021]. https://www.kentcht.nhs.uk/service/dental-services/oral-health-promotion/.

Kerr S, Watson H, Tolson D, Lough M, Brown M. 2006. Smoking after the age of 65 years: A qualitative exploration of older current and former smokers' views on smoking, stopping smoking, and smoking cessation resources and services. Health Soc Care Community. 14(6):572-582.

Kettle JE, Warren L, Glenn Robinson P, Walls A, Gibson BJ. 2019. 'I didn't want to pass that on to my child, being afraid to go to the dentist': making sense of oral health through narratives of connectedness over the life course. Sociol Health Illn. 41(4):658-672.

Kidd JB, McMahon AD, Sherriff A, Gnich W, Mahmoud A, Macpherson LM, Conway DI. 2020. Evaluation of a national complex oral health improvement programme: a population data linkage cohort study in Scotland. BMJ Open. 10(11):e038116.

Kiecolt-Glaser JK, Newton TL. 2001. Marriage and health: his and hers. Psychol Bull. 127(4):472-503.

Kim S, Park S, Lin M. 2017. Permanent tooth loss and sugar-sweetened beverage intake in U.S. young adults. J Public Health Dent. 77(2):148-154.

King K, Humphris GM. 2010. Evidence to confirm the cut-off for screening dental phobia using the Modified Dental Anxiety Scale. SSD Open. 1:21-28.

Kisely S, Baghaie H, Lalloo R, Siskind D, Johnson NW. 2015. A systematic review and meta-analysis of the association between poor oral health and severe mental illness. Psychosom Med. 77(1):83-92.

Kisely S, Sawyer E, Siskind D, Lalloo R. 2016. The oral health of people with anxiety and depressive disorders - a systematic review and meta-analysis. J Affect Disord. 200:119-132.

Kline RB. 2016. Principles and practice of structural equation modelling. NY, USA: The Guilford Press.

Kneckt MC, Syrjala AM, Knuuttila ML. 1999. Locus of control beliefs predicting oral and diabetes health behavior and health status. Acta Odontol Scand. 57(3):127-131.

Knop MR, Geng TT, Gorny AW, Ding R, Li C, Ley SH, Huang T. 2018. Birth Weight and Risk of Type 2 Diabetes Mellitus, Cardiovascular Disease, and Hypertension in Adults: A Meta-Analysis of 7 646 267 Participants From 135 Studies. J Am Heart Assoc. 7(23):e008870.

Kocher T, Konig J, Borgnakke WS, Pink C, Meisel P. 2018. Periodontal complications of hyperglycemia/diabetes mellitus: Epidemiologic complexity and clinical challenge. Periodontol 2000. 78(1):59-97.

Kojima A, Ekuni D, Mizutani S, Furuta M, Irie K, Azuma T, Tomofuji T, Iwasaki Y, Morita M. 2013. Relationships between self-rated oral health, subjective symptoms, oral health behavior and clinical conditions in Japanese university students: a cross-sectional survey at Okayama University. BMC Oral Health. 13:62.

Kopp SL, Ramseier CA, Ratka-Krüger P, Woelber JP. 2017. Motivational Interviewing As an Adjunct to Periodontal Therapy-A Systematic Review. Front Psychol. 8:279.

Kowal P, Dowd JE. 2001. Definition of an older person. Proposed working definition of an older person in Africa for the MDS Project. Geneva, Switzerland: World Health Organisation.

Krall EA, Dietrich T, Nunn ME, Garcia RI. 2006. Risk of tooth loss after cigarette smoking cessation. Prev Chronic Dis. 3(4):A115.

Kreatsoulas C, Anand SS. 2010. The impact of social determinants on cardiovascular disease. Can J Cardiol. 26(Suppl C):8C-13C.

Krieger N, Okamoto A, Selby JV. 1998. Adult Female Twins' Recall of Childhood Social Class and Father's Education: A Validation Study for Public Health Research. Am J Epidemiol. 147(7):704-708.

Kruger E, Thomson WM, Poulton R, Davies S, Brown RH, Silva PA. 1998. Dental caries and changes in dental anxiety in late adolescence. Community Dent Oral Epidemiol. 26(5):355-359.

Krukowski C, Conley K, Sterling M, Rainville A. 2016. A Qualitative Study of Adolescent Views of Sugar-Sweetened Beverage Taxes, Michigan, 2014. Prev Chronic Dis. 13:E60.

Kuh D, Ben-Shlomo Y. 2004. A Lifecourse Approach to Chronic Disease Epidemiology. Second ed. Oxford: Oxford University Press.

Kumar S, Tadakamadla J, Zimmer-Gembeck MJ, Kroon J, Lalloo R, Johnson NW. 2017. Parenting practices and children's dental caries experience: A structural equation modelling approach. Community Dent Oral Epidemiol. 45(6):552-558.

Kuroshima S, Sasaki M, Sawase T. 2019. Medication-related osteonecrosis of the jaw: A literature review. J Oral Biosci. 61(2):99-104.

Kwan SY, Holmes MA. 1999. An exploration of oral health beliefs and attitudes of Chinese in West Yorkshire: a qualitative investigation. Health Educ Res. 14(4):453-460.

Laine ML, Crielaard W, Loos BG. 2012. Genetic susceptibility to periodontitis. Periodontol 2000. 58(1):37-68.

Lamont D, Parker L, White M, Unwin N, Bennett SM, Cohen M, Richardson D, Dickinson HO, Adamson A, Alberti KG et al. 2000. Risk of cardiovascular disease measured by carotid intima-media thickness at age 49-51: lifecourse study. BMJ. 320(7230):273-278.

Laranjo L, Arguel A, Neves AL, Gallagher A, Kaplan R, Mortimer N, Mendes G, Lau A. 2014. The influence of social networking sites on health behavior change: A systematic review and meta-analysis. J Am Med Inform Assoc. 22(1):243-256.

Larsson P, List T, Lundström I, Marcusson A, Ohrbach R. 2004. Reliability and validity of a Swedish version of the Oral Health Impact Profile (OHIP-S). Acta Odontol Scand. 62(3):147-152.

Lebold KM, Jacoby DB, Drake MG. 2020. Inflammatory mechanisms linking maternal and childhood asthma. J Leukoc Biol. 108(1):113-121.

Lefcourt HM. 1992. Durability and impact of the locus of control construct. Psychol Bull. 112(3):411-414.

Leffondré K, Abrahamowicz M, Siemiatycki J, Rachet B. 2002. Modeling Smoking History: A Comparison of Different Approaches. Am J Epidemiol. 156(9):813-823.

Lei PW, Wu Q. 2007. Introduction to structural equation modelling: Issues and practical considerations. Educ Meas. 26(3):33-43.

Leicester City Council. 2020. Healthy Teeth, Happy Smiles. [accessed 29th Jan 2021]. https://www.leicester.gov.uk/health-and-social-care/public-health/get-oral-health-advice/healthy-teeth-happy-smiles/#:~:text=Healthy%20Teeth%2C%20Happy%20Smiles%20aims%20to%20provide%3A,toothpaste%20and%20oral%20health%20information.

Lennon LT, Ramsay SE, Papacosta O, Shaper AG, Wannamethee SG, Whincup PH. 2015. Cohort Profile Update: The British Regional Heart Study 1978-2014: 35 years follow-up of cardiovascular disease and ageing. Int J Epidemiol. 44(3):826-826g.

Levy SM, Kiritsy MC, Slager SL, Warren JJ. 1998. Patterns of dietary fluoride supplement use during infancy. J Public Health Dent. 58(3):228-233.

Levy SM, Warren JJ, Broffitt B, Hillis SL, Kanellis MJ. 2003. Fluoride, beverages and dental caries in the primary dentition. Caries Res. 37(3):157-165.

Lewis MA, Butterfield RM. 2007. Social control in marital relationships: Effect of one's partner on health behaviors. J Appl Soc Psychol. 37(2):298-319.

Lewis MA, Butterfield RM, Darbes LA, Johnston-Brooks C. 2004. The conceptualization and assessment of health-related social control. J Soc Pers Relat. 21(5):669-687.

Liinavuori A, Tolvanen M, Pohjola V, Lahti S. 2019. Longitudinal interrelationships between dental fear and dental attendance among adult Finns in 2000-2011. Community Dent Oral Epidemiol. 47:309-315.

Lin YL, Davies K, Callery P. 2017. Experience of maintaining tooth brushing for children born with a cleft lip and/or palate. BMC Oral Health. 17(1):120.

Linden GJ, Lyons A, Scannapieco FA. 2013. Periodontal systemic associations: review of the evidence. J Clin Perio. 40(Suppl 14):S8-S19.

Listl S, Broadbent JM, Thomson WM, Stock C, Shen J, Steele J, Wildman J, Heilmann A, Watt RG, Tsakos G et al. 2018. Childhood socioeconomic conditions and teeth in older adulthood: Evidence from SHARE wave 5. Community Dent Oral Epidemiol. 46(1):78-87.

Listl S, Galloway J, Mossey PA, Marcenes W. 2015. Global economic impact of dental diseases. J Dent Res. 94(10):1355-1361.

Listl S, Watt R, Tsakos G. 2014. Early life conditions, adverse life events, and chewing ability at middle and later adulthood. Am J Public Health. 104(5):e55-e61.

Lithell HO, McKeigue PM, Berglund L, Mohsen R, Lithell UB, Leon DA. 1996. Relation of size at birth to non-insulin dependent diabetes and insulin concentrations in men aged 50-60 years. BMJ. 312(7028):406-410.

Liu H, Deng H, Cao CF, Ono H. 1998. Genetic analysis of dental traits in 82 pairs of female-female twins. Chin J Dent Res. 1(3):12-16.

Loberg EM, Jorgensen HA, Green MF, Rund BR, Lund A, Diseth A, Oie M, Hugdahl K. 2006. Positive symptoms and duration of illness predict functional laterality and attention modulation in schizophrenia. Acta Psychiatr Scand. 113(4):322-331.

Loos BG, Chin D. 2017. What is the extent of the role played by genetic factors in the aetiology of periodontitis? European Federation of Periodontology Perio Insight. Issue 4:2-5.

Lopez R, Smith PC, Gostemeyer G, Schwendicke F. 2017. Ageing, dental caries and periodontal diseases. J Clin Periodontol. 44 Suppl 18:S145-S152.

Lopez Silva CP, Singh A, Calache H, Derbi HA, Borromeo GL. 2021. Association between disability status and dental attendance in Australia—A population-based study. Comm Dent Oral Epi. 49(1):33-39.

Lu HX, Wong MC, Lo EC, McGrath C. 2011. Trends in oral health from childhood to early adulthood: a life course approach. Community Dent Oral Epidemiol. 39(4):352-360.

Lu MC, Halfon N. 2003. Racial and ethnic disparities in birth outcomes: a life-course perspective. Matern Child Health J. 7(1):13-30.

Lucenteforte E, Garavello W, Bosetti C, La Vecchia C. 2009. Dietary factors and oral and pharyngeal cancer risk. Oral Oncol. 45(6):461-467.

Lukacs JR. 2011. Gender differences in oral health in South Asia: metadata imply multifactorial biological and cultural causes. Am J Hum Biol. 23(3):398-411.

Lung ZH, Kelleher MG, Porter RW, Gonzalez J, Lung RF. 2005. Poor patient awareness of the relationship between smoking and periodontal diseases. Br Dent J. 199(11):731-737.

MacEntee MI, Wong ST, Chi I, Lo ECM, Minichiello V, Soheilipour S, Marino R. 2019. Developmental regulation of lifelong dental experiences and beliefs in Guangzhou and Hong Kong. Gerodontology. 36(1):18-29.

Mago A, MacEntee MI, Brondani M, Frankish J. 2018. Anxiety and anger of homeless people coping with dental care. Community Dent Oral Epidemiol. 46(3):225-230.

Mann K. 2017. Whole grain intake, diet quality and cardio-metabolic health in two UK cohorts (Doctoral Thesis). Newcastle upon Tyne, UK: Newcastle University.

Mann KD, Hayes L, Basterfield L, Parker L, Pearce MS. 2013. Differing lifecourse associations with sport-, occupational- and household-based physical activity at age 49-51 years: the Newcastle Thousand Families Study. Int J Public Health. 58(1):79-88.

Mann KD, Tennant PW, Parker L, Unwin NC, Pearce MS. 2011. The relatively small contribution of birth weight to blood pressure at age 49-51 years in the Newcastle Thousand Families Study. J Hypertens. 29(6):1077-1084.

Marcenes W, Kassebaum NJ, Bernabe E, Flaxman A, Naghavi M, Lopez A, Murray CJ. 2013. Global burden of oral conditions in 1990-2010: a systematic analysis. J Dent Res. 92(7):592-597.

Marcus SE, Drury TF, Brown LJ, Zion GR. 1996. Tooth Retention and Tooth Loss in the Permanent Dentition of Adults: United States, 1988–1991. J Dent Res. 75(Suppl 2):684-695.

Marinho VC, Higgins JP, Sheiham A, Logan S. 2003a. Fluoride toothpastes for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. (1):CD002278.

Marinho VC, Worthington HV, Walsh T, Clarkson JE. 2013. Fluoride varnishes for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. (7):CD002279.

Marinho VCC, Higgins JPT, Logan S, Sheiham A. 2003b. Topical fluoride (toothpastes, mouthrinses, gels or varnishes) for preventing dental caries in children and adolescents. Cochrane Database Syst Rev. (4):CD002782.

Markey CN, Gomel JN, Markey PM. 2008. Romantic relationships and eating regulation: an investigation of partners' attempts to control each others' eating behaviors. J Health Psychol. 13(3):422-432.

Marmot M. 2010. Fair society, healthy lives. The Marmot Review. Strategic review of health inequalities in England post-2010. London, UK: The Stationery Office.

Marmot M, Allen J, Boyce T, Goldblatt P, Morrison J. 2020. Health equity in England: The Marmot Review 10 years on. London, UK: Institute of Health Equity.

Marmot M, Bell R. 2011. Social determinants and dental health. Adv Dent Res. 23(2):201-206.

Marshman Z, Ahern SM, McEachan RRC, Rogers HJ, Gray-Burrows KA, Day PF. 2016. Parents' experiences of toothbrushing with children: A qualitative study. JDR Clin Trans Res. 1(2):122-130.

Martin LT, Fitzmaurice GM, Kindlon DJ, Buka SL. 2004. Cognitive performance in childhood and early adult illness: a prospective cohort study. J Epidemiol Community Health. 58(8):674-679.

Martin M, Rosales G, Sandoval A, Lee H, Pugach O, Avenetti D, Alvarez G, Diaz A. 2019. What really happens in the home: a comparison of parent-reported and observed tooth brushing behaviors for young children. BMC Oral Health. 19(1):35.

Martinez-Herrera M, Silvestre-Rangil J, Silvestre FJ. 2017. Association between obesity and periodontal disease. A systematic review of epidemiological studies and controlled clinical trials. Med Oral Patol Oral Cir Bucal. 22(6):e708-e715.

Martyn CN, Barker DJ, Jespersen S, Greenwald S, Osmond C, Berry C. 1995. Growth in utero, adult blood pressure, and arterial compliance. Br Heart J. 73(2):116-121.

Mason J, Pearce MS, Walls AW, Parker L, Steele JG. 2006. How do factors at different stages of the lifecourse contribute to oral-health-related quality of life in middle age for men and women? J Dent Res. 85(3):257-261.

Mathews SA, Kurien BT, Scofield RH. 2008. Oral manifestations of Sjogren's syndrome. J Dent Res. 87(4):308-318.

Maurer WC. 2005. Fluoridation in Iowa. Iowa Heritage Illustrated: 89-90. [accessed 29th Jan 2021]. https://ir.uiowa.edu/cgi/viewcontent.cgi?article=1189&context=ihi.

Mays N, Pope C. 1995. Rigour and qualitative research. BMJ. 311(6997):109-112.

Mays N, Pope C. 2000. Qualitative research in health care. Assessing quality in qualitative research. BMJ. 320(7226):50-52.

McAndrew R, Salem-Rahemi M. 2013. Advice and guidance on the admissions process to UK dental schools. Dent Update. 40(2):129-142.

McCaul KD, Hockemeyer JR, Johnson RJ, Zetocha K, Quinlan K, Glasgow RE. 2006. Motivation to quit using cigarettes: a review. Addict Behav. 31(1):42-56.

McCaul LK, Jenkins WM, Kay EJ. 2001. The reasons for extraction of permanent teeth in Scotland: a 15-year follow-up study. Br Dent J. 190(12):658-662.

McColl E, Jacoby A, Thomas L, Soutter J, Bamford C, Steen N, Thomas R, Harvey E, Garratt A, Bond J. 2001. Design and use of questionnaires: a review of best practice applicable to surveys of health service staff and patients. Health Technol Assess. 5(31):1-256.

McColl E, Thomas R. 2000. Master classes in primary care research, No. 2: The use and design of questionnaires. London, UK: The Royal College of General Practioners.

McEachan RRC, Conner M, Taylor NJ, Lawton RJ. 2011. Prospective prediction of health-related behaviours with the Theory of Planned Behaviour: a meta-analysis. Health Psychol Rev. 5(2):97-144.

McGee CE, Trigwell J, Fairclough SJ, Murphy RC, Porcellato L, Ussher M, Foweather L. 2015. Influence of family and friend smoking on intentions to smoke and smoking-related attitudes and refusal self-efficacy among 9–10 year old children from deprived neighbourhoods: a cross-sectional study. BMC Public Health. 15(1):225.

McGrath C. 2019. Behavioral Sciences in the Promotion of Oral Health. J Dent Res. 98(13):1418-1424.

McKeown NM, Day NE, Welch AA, Runswick SA, Luben RN, Mulligan AA, McTaggart A, Bingham SA. 2001. Use of biological markers to validate self-reported dietary intake in a random sample of the European Prospective Investigation into Cancer United Kingdom Norfolk cohort. Am J Clin Nutr. 74(2):188-196.

McKernan SC, Reynolds JC, Ingleshwar A, Pooley M, Kuthy RA, Damiano PC. 2017. Transportation Barriers and Use of Dental Services among Medicaid-Insured Adults. JDR Clin Trans Res. 3(1):101-108.

McLeod DE, Lainson PA, Spivey JD. 1997. The effectiveness of periodontal treatment as measured by tooth loss. J Am Dent Assoc. 128(3):316-324.

Mehanna H, Beech T, Nicholson T, El-Hariry I, McConkey C, Paleri V, Roberts S. 2013. Prevalence of human papillomavirus in oropharyngeal and nonoropharyngeal head and neck cancer-systematic review and meta-analysis of trends by time and region. Head Neck. 35(5):747-755.

Melis M, Di Giosia M. 2016. The role of genetic factors in the etiology of temporomandibular disorders: a review. Cranio. 34(1):43-51.

Meng H, Ren X, Tian Y, Feng X, Xu L, Zhang L, Lu R, Shi D, Chen Z. 2011. Genetic study of families affected with aggressive periodontitis. Periodontol 2000. 56(1):87-101.

Michie S, Atkins L, West R. 2014. The behaviour change wheel: a guide to designing interventions. Great Britain: Silverback Publishing.

Michie S, Johnston M, Abraham C, Lawton R, Parker D, Walker A. 2005. Making psychological theory useful for implementing evidence based practice: a consensus approach. BMJ Qual Saf. 14(1):26-33.

Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, Eccles MP, Cane J, Wood CE. 2013. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med. 46(1):81-95.

Michie S, van Stralen MM, West R. 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 6:42.

Miettunen J, Haapea M, Bjornholm L, Huhtaniska S, Juola T, Kinnunen L, Lehtiniemi H, Lieslehto J, Rautio N, Nordstrom T. 2019. Psychiatric research in the Northern Finland Birth Cohort 1986 - a systematic review. Int J Circumpolar Health. 78(1):1571382.

Mighell A, Atkin P, Webster K, Thomas S, McCreary C, Healy C, Gibson J, Crighton A, Dawson L, Smalley J et al. 2011. Clinical medical sciences for undergraduate dental students in the United Kingdom and Ireland – a curriculum. Eur J Dent Educ. 15:179-188.

Miller FJW, Court SDM, Knox EG, Brandon S. 1974. The school years in Newcastle upon Tyne. London, UK: Oxford University Press.

Miller FJW, Court SDM, Walton WS, Knox EG. 1960. Growing up in Newcastle Upon Tyne: A continuing study of health and illness in young children within their families. London, UK: Oxford University Press.

Milner JJ, Beck MA. 2012. The impact of obesity on the immune response to infection. Proc Nutr Soc. 71(2):298-306.

Ministry of Health. 2010. Methodology Report for the 2009 New Zealand Oral Health Survey. Wellington, NZ: Minsitry of Health.

Mitchell C. 2010. Are Divorce Studies Trustworthy? The Effects of Survey Nonresponse and Response Errors. J Marriage Fam. 72(4):893-905.

Mittal H, John MT, Sekulić S, Theis-Mahon N, Rener-Sitar K. 2019. Patient-Reported Outcome Measures for Adult Dental Patients: A Systematic Review. J Evid Based Dent Pract. 19(1):53-70.

Monna B, Gauthier AH. 2008. A Review of the Literature on the Social and Economic Determinants of Parental Time. J Fam Econ Issues. 29(4):634-653.

Monsarrat P, Blaizot A, Kemoun P, Ravaud P, Nabet C, Sixou M, Vergnes JN. 2016. Clinical research activity in periodontal medicine: a systematic mapping of trial registers. J Clin Periodontol. 43(5):390-400.

Moore D, Goodwin M, Pretty IA. 2020. Long-term variability in artificially and naturally fluoridated water supplies in England. Community Dent Oral Epidemiol. 48(1):49-55.

Moore D, Poynton M, Broadbent JM, Thomson WM. 2017. The costs and benefits of water fluoridation in NZ. BMC Oral Health. 17(1):134.

Mori M, Hara M, Wada I, Hara T, Yamamoto K, Honda M, Naramoto J. 2000. Prospective Study of Hepatitis B and C Viral Infections, Cigarette Smoking, Alcohol Consumption, and Other Factors Associated with Hepatocellular Carcinoma Risk in Japan. Am J Epidemiol. 151(2):131-139.

Morita I, Okamoto Y, Yoshii S, Nakagaki H, Mizuno K, Sheiham A, Sabbah W. 2011. Five-year incidence of periodontal disease is related to body mass index. J Dent Res. 90(2):199-202.

Morley BC, Niven PH, Dixon HG, Swanson MG, McAleese AB, Wakefield MA. 2018. Controlled cohort evaluation of the LiveLighter mass media campaign's impact on adults' reported consumption of sugar-sweetened beverages. BMJ Open. 8(4):e019574.

Morris AJ, Chenery V, Douglas GV, Treasure E. 2011. Service considerations-a report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

Morse JQ. 2003. Principles of mixed methods and multimethod research design. In: Tashakkori A, Teddlie C, editors. Handbook of mixed methods in social & behavioral research. Thousand Oaks, CA: Sage.

Moynihan P, Abbasi-tabrizi S, Foster E. 2018. Relationship Between Amount and Frequency of Sugars Intake by Children. Oral presentation at; 96th General Session & Exhibition of the International Association of Dental Research. London, England. https://iadr2018.zerista.com/event/member/491275.

Moynihan PJ, Kelly SA. 2014. Effect on caries of restricting sugars intake: systematic review to inform WHO guidelines. J Dent Res. 93(1):8-18.

MRC. 2021. Cohort Directory. Medical Research Council; [accessed 29th Jan 2021]. https://mrc.ukri.org/research/facilities-and-resources-for-researchers/cohort-directory/.

Muirhead V, Subramanian SK, Wright D, Wong FSL. 2017. How do foster carers manage the oral health of children in foster care? A qualitative study. Community Dent Oral Epidemiol. 45(6):529-537.

Mullan K, Chauhan R, Gardee R, Macpherson L. 2006. Exploring issues related to oral health and attitudes to diet among second-generation ethnic groups. Divers Equal Health Care. 3:131-139.

Mullen J. 2005. History of Water Fluoridation. Br Dent J. 199(7):1-4.

Mulligan AA, Luben RN, Bhaniani A, Parry-Smith DJ, O'Connor L, Khawaja AP, Forouhi NG, Khaw KT. 2014. A new tool for converting food frequency questionnaire data into nutrient and food group values: FETA research methods and availability. BMJ Open. 4(3):e004503.

Murray H, Clarke M, Locker D, Kay EJ. 1997. Reasons for tooth extractions in dental practices in Ontario, Canada according to tooth type. Int Dent J. 47(1):3-8.

Naidu R, Nunn J, Forde M. 2012. Oral healthcare of preschool children in Trinidad: a qualitative study of parents and caregivers. BMC Oral Health. 12:27.

Nascimento AC, Moyses ST, Werneck RI, Moyses SJ. 2013. Oral health in the context of primary care in Brazil. Int Dent J. 63(5):237-243.

Nascimento GG, Gastal MT, Leite FRM, Quevedo LA, Peres KG, Peres MA, Horta BL, Barros FC, Demarco FF. 2019. Is there an association between depression and periodontitis? A birth cohort study. J Clin Periodontol. 46(1):31-39.

Nascimento GG, Leite FRM, Vestergaard P, Scheutz F, Lopez R. 2018. Does diabetes increase the risk of periodontitis? A systematic review and meta-regression analysis of longitudinal prospective studies. Acta Diabetol. 55(7):653-667.

Nascimento GG, Peres MA, Mittinty MN, Peres KG, Do LG, Horta BL, Gigante DP, Correa MB, Demarco FF. 2017. Diet-induced overweight and obesity and periodontitis risk: An application of the parametric g-formula in the 1982 pelotas birth cohort. Am J Epidemiol. 185(6):442-451.

Nascimento LFC, Marcitelli R, Agostinho FS, Gimenes CS. 2004. Hierarchical approach to determining risk factors for pneumonia in children. J Bras Pneumol. 30:445-451.

NCSCT. 2018. Very Brief Advice on Smoking for Dental Patients. National Centre for Smoking Cessation and Training; [accessed 29th Jan 2021]. https://www.ncsct.co.uk/usr/pub/NCSCT%20dental%20VBA.pdf.

Neidell M, Herzog K, Glied S. 2010. The association between community water fluoridation and adult tooth loss. Am J Public Health. 100(10):1980-1985.

New Zealand Government. 2020. Dental Care. [accessed 29th Jan 2021]. https://www.govt.nz/browse/health/gps-and-prescriptions/dental-care/.

Newton JT. 2001. Qualitative research and evidence-based dentistry: linking evidence to practice. Evid Based Dent. 2:104-106.

Newton JT, Bower EJ. 2005. The social determinants of oral health: new approaches to conceptualizing and researching complex causal networks. Community Dent Oral Epidemiol. 33(1):25-34.

Newton JT, Edwards JC. 2005. Psychometric properties of the modified dental anxiety scale: an independent replication. Community Dent Health. 22(1):40-42.

Newton JT, Thorogood N, Bhavnani V, Pitt J, Gibbons DE, Gelbier S. 2001. Barriers to the use of dental services by individuals from minority ethnic communities living in the United Kingdom: findings from focus groups. Prim Dent Care. 8(4):157-161.

NHS Digital. 2020. Statistics on NHS Stop Smoking Services, England, April 2020 to June 2021 [accessed 29th Jan 2021]. https://digital.nhs.uk/data-and-information/publications/statistical/statistics-on-nhs-stop-smoking-services-in-england/april-2020-to-june-2020.

NHS England. 2014. Improving dental care and oral health-a call to action. [accessed 29th Jan 2021]. https://www.england.nhs.uk/wp-content/uploads/2014/02/imp-dent-care.pdf.

NHS England. 2015. Introductory Guide for Commissioning Dental Specialties. London, UK: NHS England.

NHS England. 2019a. The NHS Long Term Plan. NHS England.

NHS England. 2019b. Primary Care Networks: Frequently Asked Questions. [accessed 29th Jan 2020]. https://www.england.nhs.uk/wp-content/uploads/2019/04/pcn-faqs-000429.pdf.

NHS.UK. 2017. Who is entitled to free NHS dental treatment in England. [accessed 29th Jan 2021]. https://www.nhs.uk/common-health-questions/dental-health/who-is-entitled-to-free-nhs-dental-treatment-in-england/.

NHS.UK. 2020a. Starting Well 13. [accessed 29th Jan 2021]. https://www.england.nhs.uk/primary-care/dentistry/smile4life/starting-well-13/.

NHS.UK. 2020b. Understanding NHS dental charges. [accessed 29th Jan 2021]. https://www.nhs.uk/using-the-nhs/nhs-services/dentists/understanding-nhs-dental-charges/.

Nic Iomhair A, Wilson M, Morgan M. 2020. Ten years of Designed to Smile in Wales. BDJ Team. 7(4):12-15.

NICE. 2004. Dental checks: intervals between oral health reviews (Clinical Guideline 19). London, UK: National Institute for Health and Care Excellence.

NICE. 2014. Behaviour change: individual approaches (Public Health Guideline 49). London, UK: National Institute for Health and Care Excellence.

NICE. 2015. Oral health promotion: general dental practice (NICE guideline 30). London, UK: National Institute for Health and Care Excellence.

Nicolau B, Marcenes W, Bartley M, Sheiham A. 2003a. A life course approach to assessing causes of dental caries experience: the relationship between biological, behavioural, socio-economic and psychological conditions and caries in adolescents. Caries Res. 37(5):319-326.

Nicolau B, Marcenes W, Hardy R, Sheiham A. 2003b. A life-course approach to assess the relationship between social and psychological circumstances and gingival status in adolescents. J Clin Periodontol. 30(12):1038-1045.

Nicolau B, Netuveli G, Kim JW, Sheiham A, Marcenes W. 2007a. A life-course approach to assess psychosocial factors and periodontal disease. J Clin Periodontol. 34(10):844-850.

Nicolau B, Thomson WM, Steele JG, Allison PJ. 2007b. Life-course epidemiology: concepts and theoretical models and its relevance to chronic oral conditions. Community Dent Oral Epidemiol. 35(4):241-249.

NIH OBSS. 2018. Best practices for mixed methods research in the health sciences (2nd edition). Bethesda, MA: National Institutes of Health Office of Behavioral and Social Sciences.

Niiranen T, Widström E, Niskanen T. 2008. Oral Health Care Reform in Finland - aiming to reduce inequity in care provision. BMC Oral Health. 8:3-3.

Nonterah EA, Debpuur C, Agongo G, Amenga-Etego L, Crowther NJ, Ramsay M, Rexford Oduro A. 2018. Socio-demographic and behavioural determinants of body mass index among an adult population in rural Northern Ghana: the AWI-Gen study. Glob Health Action. 11(Suppl 2):1467588.

Norcross W, Ramirez C, Palinkas L. 1996. The influence of women on the health care-seeking behavior of men. J Fam Pract. 43:475-480.

Nurses' Health Study. 2020. About Nurses' Health Study. [accessed 29th Jan 2021]. https://www.nurseshealthstudy.org/about-nhs.

Nuttall N, Freeman R, Beavan-Seymour C, Hill K. 2011a. Access and barriers to care-A report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

Nuttall N, Tsakos G, Lader D, Hill K. 2011b. Outcome and impact-A report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

O'Donnell A, Anderson P, Jane-Llopis E, Manthey J, Kaner E, Rehm J. 2019. Immediate impact of minimum unit pricing on alcohol purchases in Scotland: controlled interrupted time series analysis for 2015-18. BMJ. 366:l5274.

O'Dowd LK, Durham J, McCracken GI, Preshaw PM. 2010. Patients' experiences of the impact of periodontal disease. J Clin Periodontol. 37(4):334-339.

O'Hora AP, Wilkinson J. 2006. Child dental health in the North East of England, 2003/2004. North East Public Health Observatory.

O'Sullivan I, Lader D, Beavan-Seymour C, Chenery V, Fuller E, Sadler K. 2011. Foundation Report: Adult Dental Health Survey 2009 (Technical information). London, UK: The NHS Information Centre for Health and Social Care.

OECD. 2021. OECD Data. Organisation for Economic Co-operation and Development; [accessed 29th Jan 2021]. https://data.oecd.org/.

Ofcom. 2007. Television Advertising of Food and Drink Products to Children. Final Statement. Office of Communications.

OHCHR. 2018. Statement on visit to the United Kingdom, by Professor Philip Alston, United Nations Special Rapporteur on extreme poverty and human rights. Office of the High Commissioner for Human Rights; [accessed 29th Jan 2021]. https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=23881&LangID=E.

Okoro CA, Strine TW, Eke PI, Dhingra SS, Balluz LS. 2012. The association between depression and anxiety and use of oral health services and tooth loss. Community Dent Oral Epidemiol. 40(2):134-144.

Oláh LS, Kotowska IE, Richter R. 2018. The New Roles of Men and Women and Implications for Families and Societies. In: Doblhammer G, Gumà J, editors. A Demographic Perspective on Gender, Family and Health in Europe. Cham, Switzerland: Springer International Publishing.

Olivari MG, Tagliabue S, Confalonieri E. 2013. Parenting Style and Dimensions Questionnaire: A Review of Reliability and Validity. Marriage Fam Rev. 49(6):465-490.

Oliveira M, Vale M, Bendo C, Paiva S, Serra-Negra J. 2017. Influence of negative dental experiences in childhood on the development of dental fear in adulthood: A case-control study. J Oral Rehabil. 44(6):434-441.

Oltmann S. 2016. Qualitative Interviews: A Methodological Discussion of the Interviewer and Respondent Contexts. Forum Qual Soc Res. 17(2):15.

ONS. 2016. Historic economic data for regions of the UK (1966 to 1996). Office for National Statistics; [accessed 29th Jan 2021]. https://www.ons.gov.uk/economy/regionalaccounts/grossdisposablehouseholdincome/adhocs/006226historiceconomicdataforregionsoftheuk1966to1996.

ONS. 2020a. Adult smoking habits in the UK: 2019. [accessed 31st Jan 2021]. https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/healthandlifeexpectancies/bulletins/adultsmokinghabitsingreatbritain/2019#:~:text=In%20the%20UK%2C%20in%202019,2018%20to%2014.1%25%20in%202019.

ONS. 2020b. Dataset: Parents living with dependent children by economic activity by single year of age of youngest dependent child. Office for National Statistics; [accessed 29th Jan 2021]. https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/parentslivingwithdependentchildrenbyeconomicactivitybysingleyearofageofyoungestdependentchildtablet.

ONS. 2021. UK population pyramid interactive. Office for National Statistics; [accessed 29th Jan 2021]. https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/articles/ukpopulationpyramidinteractive/2020-01-08.

Opal S, Garg S, Jain J, Walia I. 2015. Genetic factors affecting dental caries risk. Aust Dent J. 60(1):2-11.

OPCS. 1990. Standard Occupational Classification Volumes 1, 2 and 3. London, UK: Office of Population Censuses and Surveys, HMSO.

Opdenakker R. 2006. Advantages and Disadvantages of Four Interview Techniques in Qualitative Research. Forum Qual Soc Res. 7(4):11.

Oral Health Foundation. 2019. Health not cost is the number one reason why Brits quit smoking. [accessed 29th Jan 2021]. https://www.dentalhealth.org/news/health-not-cost-is-the-number-one-reason-why-brits-quit-smoking.

Oral Health Foundation. 2020a. Paying for Dental Treatment in the UK. [accessed 29th Jan 2021]. https://www.dentalhealth.org/paying-for-dental-treatment-in-the-united-kingdom.

Oral Health Foundation. 2020b. State of Mouth Cancer: UK Report 2020/2021. Oral Health Foundation.

Ortiz-Ospina E. 2019. The rise of social media. Our World in Data; [accessed 29th Jan 2021]. https://ourworldindata.org/rise-of-social-media.

Osmond C, Barker DJ, Winter PD, Fall CH, Simmonds SJ. 1993. Early growth and death from cardiovascular disease in women. BMJ. 307(6918):1519-1524.

Östberg AL. 2005. Adolescents' views of oral health education. A qualitative study. Acta Odontol Scand. 63(5):300-307.

Ostberg AL, Jarkman K, Lindblad U, Halling A. 2002. Adolescents' perceptions of oral health and influencing factors: a qualitative study. Acta Odontol Scand. 60(3):167-173.

Owen C, Seddon C, Clarke K, Bysouth T. 2019. NHS general dentistry in Wales: evaluation of patient access and budget expenditure. Br Dent J. 226(12):967-978.

Pace F, Pallotta S, Tonini M, Vakil N, Bianchi Porro G. 2008. Systematic review: gastro-oesophageal reflux disease and dental lesions. Aliment Pharmacol Ther. 27(12):1179-1186.

Painter RC, de Rooij SR, Bossuyt PM, Phillips DI, Osmond C, Barker DJ, Bleker OP, Roseboom TJ. 2006. Blood pressure response to psychological stressors in adults after prenatal exposure to the Dutch famine. J Hypertens. 24(9):1771-1778.

Palmer H, Campbell-Jack D, Lillis J, Elsby A. 2020. The Impact of COVID-19 on Dental Professionals, A report for the General Dental Council. Birmingham, UK: Ecorys UK.

Palvarinne R, Widstrom E, Forsberg BC, Eaton KA, Birkhed D. 2018. The healthcare system and the provision of oral healthcare in European Union member states. Part 9: Sweden. Br Dent J. 224(8):647-651.

Pampel FC, Krueger PM, Denney JT. 2010. Socioeconomic Disparities in Health Behaviors. Annu Rev Sociol. 36:349-370.

Pan B, Jin X, Jun L, Qiu S, Zheng Q, Pan M. 2019. The relationship between smoking and stroke: A meta-analysis. Medicine. 98(12):e14872.

Panday S, Reddy SP, Bergström E. 2003. A qualitative study on the determinants of smoking behaviour among adolescents in South Africa. Scand J Public Health. 31(3):204-210.

Park MH, Falconer C, Viner RM, Kinra S. 2012. The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review. Obes Rev. 13(11):985-1000.

Parke R, Tinsley B. 1987. Family interaction in infancy. In: Osofsky J, editor. Handbook of Infant Development. Second ed. NY, USA: John Wiley & Sons.

Parker G, Tupling H, Brown LB. 1979. A parental bonding instrument. British Journal of Medical Psychology. 52(1):1-10.

Parker L, Lamont DW, Unwin N, Pearce MS, Bennett SM, Dickinson HO, White M, Mathers JC, Alberti KG, Craft AW. 2003. A lifecourse study of risk for hyperinsulinaemia, dyslipidaemia and obesity (the central metabolic syndrome) at age 49-51 years. Diabet Med. 20(5):406-415.

Patton MQ. 2015. Qualitative research and evaluation methods. CA, USA: SAGE.

Pearce MS, Ahmed A, Tennant PW, Parker L, Unwin NC. 2012. Lifecourse predictors of adult fibrinogen levels: the Newcastle Thousand Families Study. Int J Cardiol. 155(2):206-211.

Pearce MS, Steele JG, Mason J, Walls AW, Parker L. 2004. Do circumstances in early life contribute to tooth retention in middle age? J Dent Res. 83(7):562-566.

Pearce MS, Thomson WM, Walls AW, Steele JG. 2009a. Lifecourse socio-economic mobility and oral health in middle age. J Dent Res. 88(10):938-941.

Pearce MS, Unwin NC, Parker L, Alberti KG. 2006. Life course determinants of insulin secretion and sensitivity at age 50 years: the Newcastle thousand families study. Diabetes Metab Res Rev. 22(2):118-125.

Pearce MS, Unwin NC, Parker L, Craft AW. 2009b. Cohort profile: the Newcastle Thousand Families 1947 birth cohort. Int J Epidemiol. 38(4):932-937.

Pearce MS, Unwin NC, Relton CL, Alberti KG, Parker L. 2005. Lifecourse determinants of fasting and post-challenge glucose at age 50 years: the Newcastle Thousand Families Study. Eur J Epidemiol. 20(11):915-923.

Peker K, Bermek G. 2011. Oral health: locus of control, health behavior, self-rated oral health and socio-demographic factors in Istanbul adults. Acta Odontol Scand. 69(1):54-64.

Peninsular Dental Social Enterprise. 2020. In the community. [accessed 29th Jan 2021]. http://peninsuladental.org.uk/in-the-community/.

Peres KG, Nascimento GG, Peres MA, Mittinty MN, Demarco FF, Santos IS, Matijasevich A, Barros AJD. 2017. Impact of prolonged breastfeeding on dental caries: A population-based birth cohort study. Pediatrics. 140(1):e20162943.

Peres KG, Peres MA, Demarco FF, Tarquinio SB, Horta BL, Gigante DP. 2011a. Oral health studies in the 1982 Pelotas (Brazil) birth cohort: methodology and principal results at 15 and 24 years of age. Cad Saude Publica. 27(8):1569-1580.

Peres MA, Barros AJ, Peres KG, Araujo CL, Menezes AM. 2009. Life course dental caries determinants and predictors in children aged 12 years: a population-based birth cohort. Community Dent Oral Epidemiol. 37(2):123-133.

Peres MA, Barros AJ, Peres KG, Araujo CL, Menezes AM, Hallal PC, Victora CG. 2010. Oral health follow-up studies in the 1993 Pelotas (Brazil) birth cohort study: methodology and principal results. Cad Saude Publica. 26(10):1990-1999.

Peres MA, de Oliveira Latorre Mdo R, Sheiham A, Peres KG, Barros FC, Hernandez PG, Maas AM, Romano AR, Victora CG. 2005. Social and biological early life influences on severity of dental caries in children aged 6 years. Community Dent Oral Epidemiol. 33(1):53-63.

Peres MA, Liu P, Demarco FF, Silva AER, Wehrmeister FC, Menezes AM, Peres KG. 2018a. Income trajectories affect treatment of dental caries from childhood to young adulthood: a birth cohort study. Braz Oral Res. 32:e36.

Peres MA, Nascimento GG, Peres KG, Demarco FF, Menezes AB. 2018b. Oral health-related behaviours do not mediate the effect of maternal education on adolescents' gingival bleeding: A birth cohort study. Community Dent Oral Epidemiol. 46(2):169-177.

Peres MA, Peres KG, de Barros AJ, Victora CG. 2007. The relation between family socioeconomic trajectories from childhood to adolescence and dental caries and associated oral behaviours. J Epidemiol Community Health. 61(2):141-145.

Peres MA, Peres KG, Thomson WM, Broadbent JM, Gigante DP, Horta BL. 2011b. The influence of family income trajectories from birth to adulthood on adult oral health: findings from the 1982 Pelotas birth cohort. Am J Public Health. 101(4):730-736.

Peres MA, Sheiham A, Liu P, Demarco FF, Silva AE, Assuncao MC, Menezes AM, Barros FC, Peres KG. 2016. Sugar consumption and changes in dental caries from childhood to adolescence. J Dent Res. 95(4):388-394.

Peres MA, Thomson WM, Peres KG, Gigante DP, Horta BL, Broadbent JM, Poulton R. 2011c. Challenges in comparing the methods and findings of cohort studies of oral health: the Dunedin (New Zealand) and Pelotas (Brazil) studies. Aust N Z J Public Health. 35(6):549-556.

Peters R, Ee N, Peters J, Beckett N, Booth A, Rockwood K, Anstey KJ. 2019. Common risk factors for major noncommunicable disease, a systematic overview of reviews and commentary: the implied potential for targeted risk reduction. Ther Adv Chronic Dis. 10:2040622319880392.

Petersen PE. 2014. Strengthening of oral health systems: oral health through primary health care. Med Princ Pract. 23(Suppl 1):3-9.

Peterson SN, Snesrud E, Schork NJ, Bretz WA. 2011. Dental caries pathogenicity: a genomic and metagenomic perspective. Int Dent J. 61 Suppl 1:11-22.

PHE. 2014. Local authorities improving oral health: commissioning better oral health for children and young people. An evidence-informed toolkit for local authorities London, UK: Public Health England.

PHE. 2015a. Sugar reduction: The evidence for action. London, UK: Public Health England.

PHE. 2015b. Sugar Reduction: The evidence for action. Annexe 2: A mixed method review of behaviour changes resulting from experimental studies that examine the effect of fiscal measures targeted at high sugar food and non-alcoholic drink. London, UK: Public Health England.

PHE. 2019a. Health matters: Prevention-a life course approach.: Public Health England; [accessed 29th Jan 2021]. https://www.gov.uk/government/publications/health-matters-life-course-approach-to-prevention/health-matters-prevention-a-life-course-approach.

PHE. 2019b. Sugar reduction: Report on progress between 2015 and 2018. London, UK: Public Health England.

PHE. 2020a. Campaign Resource Centre. Public Health England; [accessed 29th Jan 2021]. https://campaignresources.phe.gov.uk/resources/campaigns.

PHE. 2020b. Change4Life. Public Health England; [accessed 29th Jan 2021]. https://campaignresources.phe.gov.uk/resources/campaigns/17-change4life.

PHE. 2020c. Local Authority Health Profiles. Public Health England; [accessed 29th Jan 2020]. https://fingertips.phe.org.uk/profile/health-profiles/data#page/1/gid/1938132701/pat/15/par/E92000001/ati/6/are/E12000009/iid/90323/age/201/sex/4.

PHW. 2019. Our Strategic Plan 2019-2022. Public Health Wales.

Piano MR. 2017. Alcohol's Effects on the Cardiovascular System. Alcohol Res. 38(2):219-241.

Picos A, Badea ME, Dumitrascu DL. 2018. Dental erosion in gastro-esophageal reflux disease. A systematic review. Clujul Med. 91(4):387-390.

Pohjola V, Lahti S, Vehkalahti MM, Tolvanen M, Hausen H. 2007. Association between dental fear and dental attendance among adults in Finland. Acta Odontol Scand. 65(4):224-230.

Polk DE, Geng M, Levy S, Koerber A, Flay BR. 2014. Frequency of daily tooth brushing: predictors of change in 9- to 11-year old US children. Community Dent Health. 31(3):136-140.

Polk DE, Weyant RJ, Manz MC. 2010. Socioeconomic factors in adolescents' oral health: are they mediated by oral hygiene behaviors or preventive interventions? Community Dent Oral Epidemiol. 38(1):1-9.

Pope C, Mays N. 2006. Qualitative methods in health research. 3rd ed. Oxford, UK: Blackwell Publishing.

Poulton R, Caspi A, Milne B, Thomson WM, Taylor A, Sears M, Moffitt T. 2002. Association between children's experience of socioeconomic disadvantage and adult health: a life-course study. Lancet. 360(9346):1640-1645.

Poulton R, Moffitt T, Silva P. 2015. The Dunedin Multidisciplinary Health and Development Study: overview of the first 40 years, with an eye to the future. Soc Psychiatry Psychiatr Epidemiol. 50(5):679-693.

Poulton R, Waldie KE, Thomson WM, Locker D. 2001. Determinants of early- vs late-onset dental fear in a longitudinal-epidemiological study. Behav Res Ther. 39(7):777-785.

Pournaghi Azar F, Mamizadeh M, Nikniaz Z, Ghojazadeh M, Hajebrahimi S, Salehnia F, Mashhadi Abdolahi H. 2018. Content analysis of advertisements related to oral health in children: a systematic review and meta-analysis. Public Health. 156:109-116.

Pourtau L, Martin E, Menvielle G, El Khoury-Lesueur F, Melchior M. 2019. To smoke or not to smoke? A qualitative study among young adults. Prev Med Rep. 15:100927.

Power C, Elliott J. 2006. Cohort profile: 1958 British birth cohort (National Child Development Study). Int J Epidemiol. 35(1):34-41.

Practice Plan. 2019. 2019 Dentistry Confidence Monitor Survey, Results Report. Practice Plan Ltd; [accessed 29th Jan 2021]. https://www.nhsdentistryinsights.co.uk/.

Pratt BA, Frost LJ. 2016. The Life Course Approach to Health: A Rapid Review of the Literature (focusing on conceptual and operational considerations). Global Health Insights. [accessed 29th Jan 2021]. https://www.who.int/life-course/publications/life-course-approach-literature-review.pdf?ua=1.

Preshaw PM, Bissett SM. 2019. Periodontitis and diabetes. Br Dent J. 227(7):577-584.

Preshaw PM, Henne K, Taylor JJ, Valentine RA, Conrads G. 2017. Age-related changes in immune function (immune senescence) in caries and periodontal diseases: a systematic review. J Clin Periodontol. 44 Suppl 18:S153-S177.

Puri S, Vasthare R, Munoli R. 2019. The Impact of Sibling Behavior on Oral Health: A Narrative Review. J Int Soc Prev Community Dent. 9(2):106-111.

Ragelienė T, Grønhøj A. 2020. The influence of peers' and siblings' on children's and adolescents' healthy eating behavior. A systematic literature review. Appetite. 148:104592.

Raison H, Harris RV. 2019. Interventions to reduce socio-economic inequalities in dental service utilisation - a systematic review. Community Dent Health. 36(1):39-45.

Ramsay SE, Papachristou E, Watt RG, Lennon LT, Papacosta AO, Whincup PH, Wannamethee SG. 2018. Socioeconomic disadvantage across the life-course and oral health in older age: findings from a longitudinal study of older British men. J Public Health. 40(4):e423-e430.

Ramsay SE, Whincup PH, Watt RG, Tsakos G, Papacosta AO, Lennon LT, Wannamethee SG. 2015. Burden of poor oral health in older age: findings from a population-based study of older British men. BMJ Open. 5(12):e009476.

Ramseier CA, Anerud A, Dulac M, Lulic M, Cullinan MP, Seymour GJ, Faddy MJ, Bürgin W, Schätzle M, Lang NP. 2017. Natural history of periodontitis: Disease progression and tooth loss over 40 years. J Clin Periodontol. 44(12):1182-1191.

Rantakallio P. 1988. The longitudinal study of the northern Finland birth cohort of 1966. Paediatr Perinat Epidemiol. 2(1):59-88.

Rawahi SHA, Asimakopoulou K, Newton JT. 2018. Factors related to reducing free sugar intake among white ethnic adults in the UK: a qualitative study. BDJ Open. 4:17024.

RCP. 2012. Fifty years since smoking and health. Progress, lessons and priorities for a smoke-free UK. Report of conference proceedings. London, UK: Royal College of Physicians.

RCPCH. 2018. Abolish postcode lottery to good dental health, say children's doctors. Royal College of Paediatrics and Child Health; [accessed 29th Jan 2021]. https://www.rcpch.ac.uk/news-events/news/abolish-postcode-lottery-good-dental-health-say-childrens-doctors.

Reading R, Langford IH, Haynes R, Lovett A. 1999. Accidents to preschool children: comparing family and neighbourhood risk factors. Soc Sci Med. 48(3):321-330.

Reissmann DR. 2019. Dental Patient-Reported Outcome Measures Are Essential for Evidence-Based Prosthetic Dentistry. J Evid Based Dent Pract. 19(1):1-6.

Rendall MS, Weden MM, Favreault MM, Waldron H. 2011. The protective effect of marriage for survival: a review and update. Demography. 48(2):481-506.

Reynolds J, Houlston C, Coleman L. 2014. Understanding relationship quality. London, UK: OnePlusOne.

Reynolds RM, Allan KM, Raja EA, Bhattacharya S, McNeill G, Hannaford PC, Sarwar N, Lee AJ, Bhattacharya S, Norman JE. 2013. Maternal obesity during pregnancy and premature mortality from cardiovascular event in adult offspring: follow-up of 1 323 275 person years. BMJ. 347:f4539.

Richards H, Emslie C. 2000. The ‘doctor’ or the ‘girl from the University’? Considering the influence of professional roles on qualitative interviewing. Family Practice. 17(1):71-75.

Richards W, Ameen J, Coll AM, Higgs G. 2005. Reasons for tooth extraction in four general dental practices in South Wales. Br Dent J. 198(5):275-278.

Richter L, Norris S, Pettifor J, Yach D, Cameron N. 2007. Cohort Profile: Mandela's children: the 1990 Birth to Twenty study in South Africa. Int J Epi. 36(3):504-511.

Rigotti NA, McKool KM, Shiffman S. 1994. Predictors of smoking cessation after coronary artery bypass graft surgery. Results of a randomized trial with 5-year follow-up. Ann Intern Med. 120(4):287-293.

Riley JL, Gilbert GH. 2005. Childhood dental history and adult dental attitudes and beliefs. Int Dent J. 55(3):142-150.

Ritchie J, Lewis J. 2014. Qualitative research practice: a guide for social science students and researchers. Second Edition. London, UK: Sage.

Ritchie J, Lewis J, Elam G, Tennant R, Rahim N. 2014. Designing and selecting samples. In: Ritchie J, Lewis J, McNaughton Nicholls C, Ormston R, editors. Qualitative research practice: A guide for social science students and researchers. London, UK: SAGE Publications.

Ritchie J, Spencer L. 1994. Qualitative data analysis for applied policy research. In: Bryman A, Burgess RG, editors. Analysing Qualitative Data. London, UK: Routledge.

Roberts C, Steer T, Maplethorpe N, Cox L, Meadows S, Nicholson S, Page P, Swan G. 2018. National Diet and Nutrition Survey: Results from Years 7 and 8 (combined) of the Rolling Programme (2014/2015 to 2015/2016). London, UK: Public Health England.

Rolland-Cachera MF, Deheeger M, Maillot M, Bellisle F. 2006. Early adiposity rebound: causes and consequences for obesity in children and adults. Int J Obes. 30(Suppl 4):S11-17.

Rooney E. 2018. Dental Contract Reform. Evaluation of the first year of prototyping 2016-2017. Department of Health and Social Care.

Rosenstock IM. 1974. Historical Origins of the Health Belief Model. Health Educ Monogr. 2(4):328-335.

Roser M, Ritchie H, Ortiz-Ospina E. 2015. Internet. Our World in Data; [accessed 29th Jan 2021]. https://ourworldindata.org/internet.

Rosseel JP, Hilberink SR, Jacobs JE, Maassen IM, Plasschaert AJ, Grol RP. 2010. Are oral health complaints related to smoking cessation intentions? Community Dent Oral Epidemiol. 38(5):470-478.

Roter DL. 1983. Physician/patient communication: transmission of information and patient effects. Md State Med J. 32(4):260-265.

Rotter JB. 1966. Generalized expectancies for internal versus external control of reinforcement. Psychol Monogr. 80(1):1-28.

Rousseau N, Steele J, May C, Exley C. 2014. 'Your whole life is lived through your teeth': biographical disruption and experiences of tooth loss and replacement. Sociol Health Illn. 36(3):462-476.

Rouxel P, Tsakos G, Demakakos P, Zaninotto P, Chandola T, Watt RG. 2015a. Is social capital a determinant of oral health among older adults? Findings from the English Longitudinal Study of Ageing. PLoS One. 10(5):e0125557.

Rouxel PL, Heilmann A, Aida J, Tsakos G, Watt RG. 2015b. Social capital: theory, evidence, and implications for oral health. Community Dent Oral Epidemiol. 43(2):97-105.

Rugg-Gunn AJ, Do L. 2012. Effectiveness of water fluoridation in caries prevention. Community Dent Oral Epidemiol. 40 Suppl 2:55-64.

Rugg-Gunn AJ, Spencer AJ, Whelton HP, Jones C, Beal JF, Castle P, Cooney PV, Johnson J, Kelly MP, Lennon MA et al. 2016. Critique of the review of 'Water fluoridation for the prevention of dental caries' published by the Cochrane Collaboration in 2015. Br Dent J. 220(7):335-340.

Russell SL, Gordon S, Lukacs JR, Kaste LM. 2013. Sex/Gender differences in tooth loss and edentulism: historical perspectives, biological factors, and sociologic reasons. Dent Clin North Am. 57(2):317-337.

SA Health. 2020. Fluoride in Water. South Australia Health; [accessed 29th Jan 2021]. https://www.sahealth.sa.gov.au/wps/wcm/connect/public+content/sa+health+internet/public+health/water+quality/fluoride+in+water/fluoride+in+water.

Sabbah W, Suominen AL, Vehkalahti MM, Aromaa A, Bernabé E. 2015. The Role of Behaviour in Inequality in Increments of Dental Caries among Finnish Adults. Caries Res. 49(1):34-40.

Sabbah W, Tsakos G, Sheiham A, Watt RG. 2009. The role of health-related behaviors in the socioeconomic disparities in oral health. Soc Sci Med. 68(2):298-303.

Sadri G, Mahjub H. 2007. Tobacco smoking and oral cancer: a meta-analysis. J Res Health Sci. 7(1):18-23.

Saekel R. 2018. Evaluation of different oral care systems: Results for Germany and selected highly developed countries. An update of a former study. Dent Oral Craniofacial Res. 4:1-8.

Saied-Moallemi Z, Virtanen JI, Vehkalahti MM, Tehranchi A, Murtomaa H. 2009. School-based intervention to promote preadolescents' gingival health: a community trial. Community Dent Oral Epidemiol. 37(6):518-526.

Salanitri S, Seow WK. 2013. Developmental enamel defects in the primary dentition: aetiology and clinical management. Aust Dent J. 58(2):133-140.

Salas MM, Nascimento GG, Vargas-Ferreira F, Tarquinio SB, Huysmans MC, Demarco FF. 2015. Diet influenced tooth erosion prevalence in children and adolescents: Results of a meta-analysis and meta-regression. J Dent. 43(8):865-875.

Salvy SJ, de la Haye K, Bowker JC, Hermans RCJ. 2012. Influence of peers and friends on children's and adolescents' eating and activity behaviors. Physiol Behav. 106(3):369-378.

Sanders AE, Spencer AJ, Stewart JF. 2005. Clustering of risk behaviours for oral and general health. Community Dent Health. 22(3):133-140.

Santos IS, Barros AJ, Matijasevich A, Domingues MR, Barros FC, Victora CG. 2011. Cohort profile: the 2004 Pelotas (Brazil) birth cohort study. Int J Epidemiol. 40(6):1461-1468.

Saraiva MC, Chiga S, Bettiol H, Silva AA, Barbieri MA. 2007. Is low birthweight associated with dental caries in permanent dentition? Paediatr Perinat Epidemiol. 21(1):49-56.

Sayers SM, Mackerras D, Singh GR. 2017. Cohort Profile: The Australian Aboriginal Birth Cohort (ABC) study. Int J Epidemiol. 46(5):1383-1383f.

Sbaraini A, Carter SM, Evans RW, Blinkhorn A. 2011. How to do a grounded theory study: a worked example of a study of dental practices. BMC Med Res Methodol. 11(1):128.

Scalici F, Schulz PJ. 2014. Influence of Perceived Parent and Peer Endorsement on Adolescent Smoking Intentions: Parents Have More Say, But Their Influence Wanes as Kids Get Older. PLOS ONE. 9(7):e101275.

Scambler S, Klass C, Wright D, Gallagher JE. 2010. Insights into the oral health beliefs and practices of mothers from a north London Orthodox Jewish community. BMC Oral Health. 10:14.

Scarborough P, Adhikari V, Harrington RA, Elhussein A, Briggs A, Rayner M, Adams J, Cummins S, Penney T, White M. 2020. Impact of the announcement and implementation of the UK Soft Drinks Industry Levy on sugar content, price, product size and number of available soft drinks in the UK, 2015-19: A controlled interrupted time series analysis. PLOS Medicine. 17(2):e1003025.

Schaefer ES. 1965. Children's Reports of Parental Behavior: An Inventory. Child Development. 36(2):413-424.

Schneider H, Palmer N. 2002. Getting to the truth? Researching user views of primary health care. Health Policy Plan. 17(1):32-41.

Schooling M, Kuh D. 2002. Chapter 13: A life course perspective on women's health behaviours. In: Kuh D, Hardy R, editors. A life course approach to women's health. Oxford, UK: Oxford University Press.

Schuch HS, Peres KG, Demarco FF, Horta BL, Gigante DP, Peres MA, Do LG. 2018. Effect of life-course family income trajectories on periodontitis: Birth cohort study. J Clin Periodontol. 45(4):394-403.

Schuller AA, Holst D. 1998. Changes in the oral health of adults from Trondelag, Norway, 1973-1983-1994. Community Dent Oral Epidemiol. 26(3):201-208.

Schuller AA, Willumsen T, Holst D. 2003. Are there differences in oral health and oral health behavior between individuals with high and low dental fear? Community Dent Oral Epidemiol. 31(2):116-121.

Schwarzer R, Lippke S, Luszczynska A. 2011. Mechanisms of Health Behavior Change in Persons With Chronic Illness or Disability: The Health Action Process Approach (HAPA). Rehabil Psychol. 56:161-170.

Scott C, Sutherland JS, Taylor A. 2018. Affordability of the UK's Eatwell Guide. The Food Foundation; [accessed 29th Jan 2021]. https://foodfoundation.org.uk/wp-content/uploads/2018/10/Affordability-of-the-Eatwell-Guide_Final_Web-Version.pdf.

Scottish Dental. 2021. Treatment Charges. [accessed 29th Jan 2021]. https://www.scottishdental.org/public/treatment-charges/.

Scottish Government. 2018a. Oral Health Improvement Plan. Edinburgh, UK: Scottish Government.

Scottish Government. 2018b. Raising Scotland's tobacco-free generation – our tobacco-control action plan 2018. Edinburgh, UK: Scottish Government.

Seale C. 2003. Media and health. London, UK: SAGE.

Selwitz RH, Ismail AI, Pitts NB. 2007. Dental caries. Lancet. 369(9555):51-59.

Seo JH, Kim H, Shin YJ. 2010. Analysis for the impact of adulthood and childhood socioeconomic positions and intergenerational social mobility on adulthood health. J Prev Med Public Health. 43(2):138-150.

Sfreddo CS, Moreira CHC, Celeste RK, Nicolau B, Ardenghi TM. 2019. Pathways of socioeconomic inequalities in gingival bleeding among adolescents. Community Dentistry & Oral Epidemiology. 47(2):177-184.

Sgan-Cohen HD, Evans RW, Whelton H, Villena RS, MacDougall M, Williams DM, Steering I-G, Task G. 2013. IADR Global Oral Health Inequalities Research Agenda (IADR-GOHIRA): a call to action. J Dent Res. 92(3):209-211.

Shaffer JR, Wang X, McNeil DW, Weyant RJ, Crout R, Marazita ML. 2015. Genetic Susceptibility to Dental Caries Differs between the Sexes: A Family-Based Study. Caries Res. 49(2):133-140.

Shaw L, Glenwright HD. 1989. The role of medications in dental caries formation: need for sugar-free medication for children. Pediatrician. 16(3-4):153-155.

Shearer DM, Thomson WM, Broadbent JM, Poulton R. 2011. Maternal oral health predicts their children's caries experience in adulthood. J Dent Res. 90(5):672-677.

Sheiham A, Nicolau B. 2005. Evaluation of social and psychological factors in periodontal disease. Periodontol 2000. 39:118-131.

Shepherd J, Harden A, Rees R, Brunton G, Garcia J, Oliver S, Oakley A. 2006. Young people and healthy eating: a systematic review of research on barriers and facilitators. Health Educ Res. 21(2):239-257.

Sheppard P, Pearce MS, Sear R. 2016. How does childhood socioeconomic hardship affect reproductive strategy? Pathways of development. Am J Hum Biol. 28(3):356-363.

Shipley B. 2016. Cause and correlation in biology: A user's guide to path analysis, structural equations and causal inference with R. Cambridge, UK: Cambridge University Press.

Shivakumar S, Srivastava A, G.C. S. 2018. Body Mass Index and Dental Caries: A Systematic Review. Int J Clin Pediatr Dent. 11(3):228-232.

Shook-Sa BE, Chen D-G, Zhou H. 2017. Using Structural Equation Modeling to Assess the Links between Tobacco Smoke Exposure, Volatile Organic Compounds, and Respiratory Function for Adolescents Aged 6 to 18 in the United States. Int J Environ Res Public Health. 14(10):1112.

Shuler CF. 2001. Inherited risks for susceptibility to dental caries. J Dent Educ. 65(10):1038-1045.

Sigel I, Dreyer A, McGillicuddy-DeLisi A. 1984. Psychological perspectives of the family. In: Parke R, editor. Review of child development research. Chicago: The University of Chicago Press.

Silva MP, Vettore MV, Rebelo MAB, Rebelo Vieira JM, Herkrath A, Queiroz AC, Herkrath FJ, Pereira JV. 2020. Clinical Consequences of Untreated Dental Caries, Individual Characteristics, and Environmental Factors on Self-Reported Oral Health Measures in Adolescents: A Follow-Up Prevalence Study. Caries Res. 54(2):176-184.

Simila T, Virtanen JI. 2015. Association between smoking intensity and duration and tooth loss among Finnish middle-aged adults: The Northern Finland Birth Cohort 1966 Project. BMC Public Health. 15:1141.

Simons-Morton BG, Farhat T. 2010. Recent findings on peer group influences on adolescent smoking. The journal of primary prevention. 31(4):191-208.

Simpson TC, Weldon JC, Worthington HV, Needleman I, Wild SH, Moles DR, Stevenson B, Furness S, Iheozor-Ejiofor Z. 2015. Treatment of periodontal disease for glycaemic control in people with diabetes mellitus. Cochrane Database Syst Rev. (11):CD004714.

Sinclair E, Eaton KA, Widstrom E. 2019. The healthcare systems and provision of oral healthcare in European Union member states. Part 10: comparison of systems and with the United Kingdom. Br Dent J. 227(4):305-310.

Singh A, Rouxel P, Watt RG, Tsakos G. 2013. Social inequalities in clustering of oral health related behaviors in a national sample of British adults. Prev Med. 57(2):102-106.

Sinha DN, Agarwal N, Gupta P. 2015. Prevalence of smokeless tobacco use and number of users in 121 countries. Br J Med Med Res. 9(6):1-155.

Sischo L, Broder HL. 2011. Oral health-related quality of life: what, why, how, and future implications. J Dent Res. 90(11):1264-1270.

Skafida V, Chambers S. 2018. Positive association between sugar consumption and dental decay prevalence independent of oral hygiene in pre-school children: a longitudinal prospective study. J Public Health. 40(3):e275-e283.

Slade GD. 1997. Derivation and validation of a short-form oral health impact profile. Community Dent Oral Epidemiol. 25(4):284-290.

Slade GD, Spencer AJ. 1994. Development and evaluation of the Oral Health Impact Profile. Community Dent Health. 11(1):3-11.

Smith A, MacEntee MI, Beattie BL, Brondani M, Bryant R, Graf P, Hornby K, Kobayashi K, Wong ST. 2013. The influence of culture on the oral health-related beliefs and behaviours of elderly chinese immigrants: a meta-synthesis of the literature. J Cross Cult Gerontol. 28(1):27-47.

Smith CEL, Poulter JA, Antanaviciute A, Kirkham J, Brookes SJ, Inglehearn CF, Mighell AJ. 2017. Amelogenesis Imperfecta; genes, proteins, and pathways. Front Physiol. 8:435.

Sohn W, Ismail AI. 2005. Regular dental visits and dental anxiety in an adult dentate population. J Am Dent Assoc. 136(1):58-66.

Spence J, Walton WS, Miller FJW, Court SDM. 1954. A Thousand Families in Newcastle upon Tyne: An approach to the study of health and illness in children. London, UK: Oxford University Press.

Sreebny LM. 1982. Sugar availability, sugar consumption and dental caries. Community Dent Oral Epidemiol. 10(1):1-7.

Sreeramulu B, Shyam ND, Ajay P, Suman P. 2015. Papillon-Lefevre syndrome: clinical presentation and management options. Clin Cosmet Investig Dent. 7:75-81.

Stead M, McDermott L, Mackintosh AM, Adamson A. 2011. Why healthy eating is bad for young people's health: identity, belonging and food. Soc Sci Med. 72(7):1131-1139.

Steele J, Pitts NB, Fuller E, Treasure E. 2011. Urgent conditions-A report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

Steele J, Shen J, Tsakos G, Fuller E, Morris S, Watt R, Guarnizo-Herreno C, Wildman J. 2014. The interplay between socioeconomic inequalities and clinical oral health. J Dent Res. 94(1):19-26.

Steele JG, Rooney E, Clarke J, Wilson T. 2009. NHS Dental Services in England. An independent review led by Professor Jimmy Steele. London, UK: Department of Health.

Steele JG, Treasure ET, O'Sullivan I, Morris J, Murray JJ. 2012. Adult Dental Health Survey 2009: transformations in British oral health 1968-2009. Br Dent J. 213(10):523-527.

Steptoe A, Breeze E, Banks J, Nazroo J. 2013. Cohort profile: the English longitudinal study of ageing. Int J Epidemiol. 42(6):1640-1648.

Stimson G, Webb B. 1975. Going to see the doctor: The consultation process in General Practice. London, UK: Routledge and Kegan Paul PLC.

Stokes E, Ashcroft A, Platt MJ. 2006. Determining Liverpool adolescents' beliefs and attitudes in relation to oral health. Health Educ Res. 21(2):192-205.

Stormon N, Ford PJ, Lalloo R. 2019. Oral health in the Longitudinal Study of Australian Children: An age, period, and cohort analysis. Int J Paediatr Dent. 29(4):404-412.

Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K. 2008. Creating healthy food and eating environments: policy and environmental approaches. Annu Rev Public Health. 29:253-272.

Streiner DL. 2005. Finding our way: an introduction to path analysis. Can J Psychiatry. 50(2):115-122.

Sturges JE, Hanrahan KJ. 2004. Comparing Telephone and Face-to-Face Qualitative Interviewing: a Research Note. Qual Res. 4(1):107-118.

Sudlow C, Gallacher J, Allen N, Beral V, Burton P, Danesh J, Downey P, Elliott P, Green J, Landray M et al. 2015. UK biobank: an open access resource for identifying the causes of a wide range of complex diseases of middle and old age. PLoS medicine. 12(3):e1001779-e1001779.

Suresh R, Jones KC, Newton JT, Asimakopoulou K. 2012. An exploratory study into whether self-monitoring improves adherence to daily flossing among dental patients. J Public Health Dent. 72(1):1-7.

Susser M, Susser E. 1996. Choosing a future for epidemiology: I. Eras and paradigms. Am J Public Health. 86(5):668-673.

Sussex PV, Thomson WM, Fitzgerald RP. 2010. Understanding the 'epidemic' of complete tooth loss among older New Zealanders. Gerodontology. 27(2):85-95.

Syrjala AM, Knuuttila ML, Syrjala LK. 2001. Self-efficacy perceptions in oral health behavior. Acta Odontol Scand. 59(1):1-6.

Takahashi N, Nyvad B. 2011. The role of bacteria in the caries process: ecological perspectives. J Dent Res. 90(3):294-303.

Takeuchi K, Aida J, Kondo K, Osaka K. 2013. Social participation and dental health status among older Japanese adults: a population-based cross-sectional study. PLoS One. 8(4):e61741.

Tanaka K, Miyake Y. 2014. Low birth weight, preterm birth or small-for-gestational-age are not associated with dental caries in young Japanese children. BMC Oral Health. 14:38.

Tariq S, Woodman J. 2010. Using mixed methods in health research. JRSM Short Rep. 4(6):2042533313479197.

Tashakkori A, Teddlie C. 2010. SAGE Handbook of Mixed Methods in Social & Behavioral Research. Second edition. Thousand Oaks, CA: SAGE.

Tatangelo G, McCabe M, Campbell S, Szoeke C. 2017. Gender, marital status and longevity. Maturitas. 100:64-69.

Taylor R. 2019. Calorie restriction for long-term remission of type 2 diabetes. Clin Med. 19(1):37-42.

Teddlie C, Tashakkori A. 2009. Foundations of mixed methods research. Integrating quantitative and qualitative approaches in social and behavioural sciences. Thousand Oaks, CA: SAGE.

Teicher MH, Samson JA, Anderson CM, Ohashi K. 2016. The effects of childhood maltreatment on brain structure, function and connectivity. Nat Rev Neurosci. 17(10):652-666.

Templeton AR, Young L, Bish A, Gnich W, Cassie H, Treweek S, Bonetti D, Stirling D, Macpherson L, McCann S et al. 2016. Patient-, organization-, and system-level barriers and facilitators to preventive oral health care: a convergent mixed-methods study in primary dental care. Implement Sci. 11:5.

Tennant PW, Gibson GJ, Pearce MS. 2008. Lifecourse predictors of adult respiratory function: results from the Newcastle Thousand Families Study. Thorax. 63(9):823-830.

Terrades M, Coulter WA, Clarke H, Mullally BH, Stevenson M. 2009. Patients' knowledge and views about the effects of smoking on their mouths and the involvement of their dentists in smoking cessation activities. Br Dent J. 207(11):E22.

The Health & Social Care Information Centre. 2009. Statistics on Smoking: England, 2009. Leeds, UK: The Health & Social Care Information Centre.

The Scottish Government. 2020. Statement of Dental Remuneration, Amendment No 148. [accessed 29th Jan 2021]. https://www.scottishdental.org/wp-content/uploads/2020/11/Amendment-No-148-FINAL-03nov2020.pdf.

Thomas RE, McLellan J, Perera R. 2013. School-based programmes for preventing smoking. Cochrane Database Syst Rev. (4):CD001293.

Thomeer M, Hernandez E, Umberson D, Thomas P. 2019. Influence of Social Connections on Smoking Behavior across the Life Course. Adv Life Course Res. 42:100294.

Thompson R. 2019. Education, Inequality and Social Class: Expansion and Stratification in Educational Opportunity. Oxford, UK: Routledge.

Thomson WM. 2012. Social inequality in oral health. Community Dent Oral Epidemiol. 40 Suppl 2:28-32.

Thomson WM, Broadbent JM, Locker D, Poulton R. 2009. Trajectories of dental anxiety in a birth cohort. Community Dent Oral Epidemiol. 37(3):209-219.

Thomson WM, Broadbent JM, Welch D, Beck JD, Poulton R. 2007. Cigarette smoking and periodontal disease among 32-year-olds: a prospective study of a representative birth cohort. J Clin Periodontol. 34(10):828-834.

Thomson WM, Caspi A, Poulton R, Moffitt TE, Broadbent JM. 2011. Personality and oral health. Eur J Oral Sci. 119(5):366-372.

Thomson WM, Poulton R, Kruger E, Boyd D. 2000. Socio-economic and behavioural risk factors for tooth loss from age 18 to 26 among participants in the Dunedin Multidisciplinary Health and Development Study. Caries Res. 34(5):361-366.

Thomson WM, Poulton R, Milne BJ, Caspi A, Broughton JR, Ayers KM. 2004. Socioeconomic inequalities in oral health in childhood and adulthood in a birth cohort. Community Dent Oral Epidemiol. 32(5):345-353.

Thomson WM, Williams SM, Broadbent JM, Poulton R, Locker D. 2010. Long-term dental visiting patterns and adult oral health. J Dent Res. 89(3):307-311.

Thorstensson H, Johansson B. 2010. Why do some people lose teeth across their lifespan whereas others retain a functional dentition into very old age? Gerodontology. 27(1):19-25.

Tiwari T, Scarbro S, Bryant LL, Puma J. 2016. Factors Associated with Tooth Loss in Older Adults in Rural Colorado. J Community Health. 41(3):476-481.

Todd JE, Lader D. 1991. Adult Dental Health 1988: United Kingdom. London, UK: The Stationery Office.

Todd JE, Walker AM. 1980. Adult Dental health, Volume 1, England and Wales 1968-78. London, UK: HMSO.

Todd JE, Walker AM, Dodd P. 1982. Adult Dental Health, Volume 2, United Kingdom 1978. London, UK.

Tolvanen M, Lahti S, Miettunen J, Hausen H. 2012. Relationship between oral health-related knowledge, attitudes and behavior among 15-16-year-old adolescents: a structural equation modeling approach. Acta Odontol Scand. 70(2):169-176.

Tomar SL, Asma S. 2000. Smoking-attributable periodontitis in the United States: findings from NHANES III. J Periodontol. 71(5):743-751.

Tombor I, Vangeli E, West R, Shahab L. 2017. Progression towards smoking cessation: Qualitative analysis of successful, unsuccessful, and never quitters. J Subst Use. 23(2):214-222.

Tonetti MS, Van Dyke TE. 2013. Periodontitis and atherosclerotic cardiovascular disease: consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. J Clin Periodontol. 40 Suppl 14:S24-29.

Torres de Heens GL, Loos BG, van der Velden U. 2010. Monozygotic twins are discordant for chronic periodontitis: clinical and bacteriological findings. J Clin Periodontol. 37(2):120-128.

Torriani DD, Ferro RL, Bonow ML, Santos IS, Matijasevich A, Barros AJ, Demarco FF, Peres KG. 2014. Dental caries is associated with dental fear in childhood: findings from a birth cohort study. Caries Res. 48(4):263-270.

Touliatos J, Perlmutter BF, Straus MA. 2001. Handbook of Family Measurement Techniques. Thousand Oaks, CA: SAGE.

Tourangeau R, Rips LJ, Rasinski K. 2000. The Psychology of Survey Response. Cambridge, UK: Cambridge University Press.

Townend E, Dimigen G, Fung D. 2000. A clinical study of child dental anxiety. Behav Res Ther. 38(1):31-46.

Tramacere I, Negri E, Bagnardi V, Garavello W, Rota M, Scotti L, Islami F, Corrao G, Boffetta P, La Vecchia C. 2010. A meta-analysis of alcohol drinking and oral and pharyngeal cancers. Part 1: overall results and dose-risk relation. Oral Oncol. 46(7):497-503.

Treasure E, Kelly M, Nuttall N, Nunn J, Bradnock G, White D. 2001. Factors associated with oral health: a multivariate analysis of results from the 1998 Adult Dental Health survey. Br Dent J. 190(2):60-68.

Trichia E, Imamura F, Brage S, De Lucia Rolfe E, Griffin SJ, Wareham NJ, Forouhi NG. 2019. Associations of types of dairy consumption with adiposity: cross-sectional findings from over 12 000 adults in the Fenland Study, UK. Br J Nutr. 122(8):928-935.

Trief P, Sandberg JG, Ploutz-Snyder R, Brittain R, Cibula D, Scales K, Weinstock RS. 2011. Promoting couples collaboration in type 2 diabetes: the diabetes support project pilot data. Fam Syst Health. 29(3):253-261.

Trost S, Loprinzi P. 2011. Parental Influences on Physical Activity Behavior in Children and Adolescents: A Brief Review. Am J Lifestyle Med. 5:171-181.

Tsakos G, Demakakos P, Breeze E, Watt RG. 2011. Social gradients in oral health in older adults: findings from the English Longitudinal Survey of Aging. Am J Public Health. 101(10):1892-1899.

Tsakos G, Hill K, Chadwick B, Anderson T. 2015. Children’s Dental Health Survey 2013. Report 1: Attitudes, behaviours and children’s dental health: England, Wales and Northern Ireland 2013. Leeds, UK: Health and Social Care Information Centre.

Tsao CW, Vasan RS. 2015. Cohort Profile: The Framingham Heart Study (FHS): overview of milestones in cardiovascular epidemiology. Int J Epidemiol. 44(6):1800-1813.

Tu YK. 2009. Commentary: Is structural equation modelling a step forward for epidemiologists? Int J Epidemiol. 38(2):549-551.

TUC. 2020. Impact of Covid-19 and Brexit for the UK economy. Review of forecasts published between July-November 2020. Trades Union Congress.

Turani D, Bissett SM, Preshaw PM. 2013. Techniques for effective management of periodontitis. Dent Update. 40(3):181.

Umberson D. 1992. Gender, marital status and the social control of health behavior. Soc Sci Med. 34(8):907-917.

Umberson D, Crosnoe R, Reczek C. 2010. Social Relationships and Health Behavior Across Life Course. Annu Rev Sociol. 36:139-157.

Umberson D, Donnelly R, Pollitt AM. 2018. Marriage, Social Control, and Health Behavior: A Dyadic Analysis of Same-sex and Different-sex Couples. J Health Soc Behav. 59(3):429-446.

University of Dundee. 2021. Scottish Oral Health Improvement Prison Programme (SOHIPP). [accessed 29th Jan 2021]. https://www.dundee.ac.uk/projects/sohipp.

University of Florida Health. 2020. Florida Dental Care Study. [accessed 29th Jan 2021]. https://hsrmp.phhp.ufl.edu/projectscenters/florida-dental-care-study/.

Uppal N, Shahab L, Britton J, Ratschen E. 2013. The forgotten smoker: a qualitative study of attitudes towards smoking, quitting, and tobacco control policies among continuing smokers. BMC Public Health. 13(1):432.

Üstün TB, Kostanjsek N, Chatterji S, Rehm J. 2010. Measuring Health and Disability: Manual for WHO Disability Assessment Schedule, WHODAS 2.0. Malta: World Health Organisation.

Vainionpää R, Pesonen P, Laitala ML, Pohjola V, Anttonen V. 2019. Dental Fear and Dental Health and Attendance among Finnish Male Prisoners. J Oral Maxillofac Res. 10(4):e4.

Van't Spijker A, Rodriguez JM, Kreulen CM, Bronkhorst EM, Bartlett DW, Creugers NH. 2009. Prevalence of tooth wear in adults. Int J Prosthodont. 22(1):35-42.

Van Hout MC, Hearne E. 2014. Oral health behaviours amongst homeless people attending rehabilitation services in Ireland. J Ir Dent Assoc. 60(3):144-149.

Van Loveren C. 2019. Sugar restriction for caries prevention: Amount and frequency. Which is more important? Caries Res. 53(2):168-175.

Vargesson N. 2019. The teratogenic effects of thalidomide on limbs. J Hand Surg Eur Vol. 44(1):88-95.

Vendrame E, Goulart MA, Hilgert JB, Hugo FN, Celeste RK. 2018. Decomposing early and adult life social position effects on oral health and chronic diseases in a cross-sectional study of Southern Brazil. Community Dent Oral Epidemiol. 46(6):601-607.

Vettore MV, Faerstein E, Baker SR. 2016. Social position, social ties and adult's oral health: 13 year cohort study. J Dent. 44:50-56.

Victora CG, Barros FC. 2006. Cohort profile: the 1982 Pelotas (Brazil) birth cohort study. Int J Epidemiol. 35(2):237-242.

Victora CG, Hallal PC, Araujo CL, Menezes AM, Wells JC, Barros FC. 2008. Cohort profile: the 1993 Pelotas (Brazil) birth cohort study. Int J Epidemiol. 37(4):704-709.

Victora CG, Huttly SR, Fuchs SC, Olinto MT. 1997. The role of conceptual frameworks in epidemiological analysis: a hierarchical approach. Int J Epidemiol. 26(1):224-227.

Villa A, Anabalon M, Zohouri V, Maguire A, Franco AM, Rugg-Gunn A. 2010. Relationships between fluoride intake, urinary fluoride excretion and fluoride retention in children and adults: an analysis of available data. Caries Res. 44(1):60-68.

Vlassoff C. 2007. Gender differences in determinants and consequences of health and illness. J Health Popul Nutr. 25(1):47-61.

Wadsworth M, Kuh D, Richards M, Hardy R. 2006. Cohort Profile: The 1946 National Birth Cohort (MRC National Survey of Health and Development). Int J Epidemiol. 35(1):49-54.

Waite L, J., Gallagher M. 2000. The case for marriage: Why married people are happier, healthier, and better off financially. NY, USA: Doubleday.

Wakefield M, Loken B, Hornik R. 2010. Use of Mass Media Campaigns to Change Health Behaviour. Lancet. 376:1261-1271.

Walker DA, Smith TJ. 2017. Computing robust, bootstrap-adjusted fit indices for use with non-normal data. Meas Eval Couns Dev. 50(1-2):131-137.

Walsh T, Worthington HV, Glenny AM, Marinho VC, Jeroncic A. 2019. Fluoride toothpastes of different concentrations for preventing dental caries. Cochrane Database Syst Rev. (3):CD007868.

Wang NJ, Gropen AM, Ogaard B. 1997. Risk factors associated with fluorosis in a non-fluoridated population in Norway. Community Dent Oral Epidemiol. 25(6):396-401.

Wang X, Willing MC, Marazita ML, Wendell S, Warren JJ, Broffitt B, Smith B, Busch T, Lidral AC, Levy SM. 2012. Genetic and environmental factors associated with dental caries in children: the Iowa Fluoride Study. Caries Res. 46(3):177-184.

Warnakulasuriya S, Dietrich T, Bornstein MM, Casals Peidro E, Preshaw PM, Walter C, Wennstrom JL, Bergstrom J. 2010. Oral health risks of tobacco use and effects of cessation. Int Dent J. 60(1):7-30.

Warren JJ, Levy SM, Broffitt B, Kanellis MJ. 2006. Longitudinal study of non-cavitated carious lesion progression in the primary dentition. J Public Health Dent. 66(2):83-87.

Watt R, Listl S, Peres MA, Heilmann A. 2015. Social inequalities in oral health: from evidence to action. London, UK: International Centre for Oral Health Inequalities and Policy.

Watt R, Sheiham A. 1999. Inequalities in oral health: a review of the evidence and recommendations for action. Br Dent J. 187(1):6-12.

Watt RG. 2002. Emerging theories into the social determinants of health: implications for oral health promotion. Community Dent Oral Epidemiol. 30(4):241-247.

Watt RG. 2007. From victim blaming to upstream action: tackling the social determinants of oral health inequalities. Community Dent Oral Epidemiol. 35(1):1-11.

Watt RG. 2012. Social determinants of oral health inequalities: implications for action. Community Dent Oral Epidemiol. 40 Suppl 2:44-48.

Watt RG, Venturelli R, Daly B. 2019. Understanding and tackling oral health inequalities in vulnerable adult populations: from the margins to the mainstream. Br Dent J. 227(1):49-54.

Weitkunat R, Wildner M. 2002. Exploratory causal modeling in epidemiology: are all factors created equal? J Clin Epidemiol. 55(5):436-444.

Welsh Government. 2013. Together for Health: A National Oral Health Plan for Wales 2013-18. Welsh Government.

Welsh Government. 2017. Tobacco Control Delivery Plan for Wales 2017-2020. Welsh Government.

Welsh Government. 2018. A Healthier Wales: Our Plan for Health and Social Care. Welsh Government.

Wendt LK, Hallonsten AL, Koch G, Birkhed D. 1994. Oral hygiene in relation to caries development and immigrant status in infants and toddlers. Scand J Dent Res. 102(5):269-273.

Werneck RI, Mira MT, Trevilatto PC. 2010. A critical review: an overview of genetic influence on dental caries. Oral Dis. 16(7):613-623.

West P, Sweeting H, Leyland A. 2004. School effects on pupils' health behaviours: evidence in support of the health promoting school. Res Pap Educ. 19(3):261-291.

West R. 2006. Theory of Addiction. Oxford, UK: Blackwells.

West R, May S, West M, Croghan E, McEwen A. 2013. Performance of English stop smoking services in first 10 years: analysis of service monitoring data. BMJ. 347:f4921.

Wham C, Bowden J. 2011. Eating for health: Perspectives of older men who live alone. Nutr Diet. 68:221-226.

White D, Pitts N, Steele J, Sadler K, Chadwick B. 2011. Disease and related disorders-A report from the Adult Dental Health Survey 2009. Leeds, UK: The Health and Social Care Information Centre.

White DA, Tsakos G, Pitts NB, Fuller E, Douglas GV, Murray JJ, Steele JG. 2012. Adult Dental Health Survey 2009: common oral health conditions and their impact on the population. Br Dent J. 213(11):567-572.

Whitelock E, Ensaff H. 2018. On Your Own: Older Adults' Food Choice and Dietary Habits. Nutrients. 10(4):413.

WHO. 1978. Declaration of alma-ata. International conference on primary health care. Alma-ata, USSR. World Health Organisation. https://www.who.int/publications/almaata_declaration_en.pdf.

WHO. 2000. The implications for training of embracing a life course approach to health. Geneva, Switzerland: World Health Organisation.

WHO. 2003. The World Oral Health Report 2003. Geneva, Switzerland: World Health Organisation.

WHO. 2019. WHO Report on the Global Tobacco Epidemic, 2019. Geneva, Switzerland: World Health Organisation.

WHO. 2020a. Factsheet: Oral Health. [accessed 29th Jan 2021]. https://www.who.int/news-room/fact-sheets/detail/oral-health.

WHO. 2020b. Global Health Observatory data repository. Prevalence of current tobacco use, data by country. World Health Organisation; [accessed 29th Jan 2021]. https://apps.who.int/gho/data/view.main.GSWCAH20v.

WHO & Excise Social Policy Group. 2003. Report on Tobacco Taxation in the United Kingdom. UCSF: Center for Tobacco Control Research and Education.

Wichi RB, Souza SB, Casarini DE, Morris M, Barreto-Chaves ML, Irigoyen MC. 2005. Increased blood pressure in the offspring of diabetic mothers. Am J Physiol Regul Integr Comp Physiol. 288(5):R1129-1133.

Wide Boman U, Carlsson V, Westin M, Hakeberg M. 2013. Psychological treatment of dental anxiety among adults: a systematic review. Eur J Oral Sci. 121(3 Pt 2):225-234.

Widstrom E, Ekman A, Aandahl LS, Pedersen MM, Agustsdottir H, Eaton KA. 2005. Developments in oral health policy in the Nordic countries since 1990. Oral Health Prev Dent. 3(4):225-235.

Widström E, Tiira H, Tillberg A. 2019. Public Dental Service personnel facing a major health care reform in Finland. BDJ Open. 5(1):5.

Williams CL, Heikes EJ. 1993. The Importance of Researcher's Gender in the In-Depth Interview: Evidence from Two Case Studies of Male Nurses. Gend Soc. 7(2):280-291.

Wilson N, Soni A. 2016. Interprofessional working: a spearhead opportunity for dentistry and pharmacy. Br Dent J. 221(10):607-608.

Wilson NJ, Lin Z, Villarosa A, Lewis P, Philip P, Sumar B, George A. 2019. Countering the poor oral health of people with intellectual and developmental disability: a scoping literature review. BMC Public Health. 19(1):1530.

Witton RV, Moles DR. 2015. Identifying dentists' attitudes towards prevention guidance using Q-sort methodology. Community Dent Health. 32(2):72-76.

Woelber JP, Bienas H, Fabry G, Silbernagel W, Giesler M, Tennert C, Stampf S, Ratka-Krüger P, Hellwig E. 2015. Oral hygiene-related self-efficacy as a predictor of oral hygiene behaviour: a prospective cohort study. J Clin Periodontol. 42(2):142-149.

Wong HM, Zhang YY, Perfecto A, McGrath CPJ. 2020. Dental fear association between mothers and adolescents-a longitudinal study. PeerJ. 8:e9154.

Wood L, Greenhalgh E, Vittiglia A, Hanley-Jones S. 2019. 5.2 Factors influencing uptake by young people: overview. In: Scollo MM and Winstanley MH, editors. Tobacco in Australia: Facts and issues. Melbourne, Australia: Cancer Council Victoria [accessed 29th Jan 2021]. https://www.tobaccoinaustralia.org.au/chapter-5-uptake/5-2-factors-influencing-uptake-by-young-people-ove.

World Cancer Research Fund International. 2018. Building momentum: lessons on implementing a robust sugar sweetened beverage tax. World Cancer Research Fund International.

Wriedt S, Martin M, Al-Nawas B, Wehrbein H. 2010. Long-term effects of traumatic injuries to incisors and periodontal tissues during childhood: a retrospective study. J Orofac Orthop. 71(5):318-329.

Wright FAC, Law GG, Milledge KL, Chu SK, Hsu B, Valdez E, Naganathan V, Hirani V, Blyth FM, LeCouteur DG et al. 2018. Chewing function, general health and the dentition of older Australian men: The Concord Health and Ageing in Men Project. Comm Dent Oral Epi. 47(2):134-141.

Wright JT, Hart TC. 2002. The genome projects: implications for dental practice and education. J Dent Educ. 66(5):659-671.

Xie H, Li C, He Y, Griffin R, Ye Q, Li L. 2015. Chronic stress promotes oral cancer growth and angiogenesis with increased circulating catecholamine and glucocorticoid levels in a mouse model. Oral Oncol. 51(11):991-997.

Yanagisawa T, Marugame T, Ohara S, Inoue M, Tsugane S, Kawaguchi Y. 2009. Relationship of smoking and smoking cessation with number of teeth present: JPHC Oral Health Study. Oral Dis. 15(1):69-75.

Ylostalo P, Sakki T, Laitinen J, Jarvelin MR, Knuuttila M. 2004. The relation of tobacco smoking to tooth loss among young adults. Eur J Oral Sci. 112(2):121-126.

Yule PL, Barclay SC. 2015. Worn Down by Toothwear? Aetiology, Diagnosis and Management Revisited. Dent Update. 42(6):525-532.

Zeng J, Williams SM, Fletcher DJ, Cameron CM, Broadbent JM, Shearer DM, Thomson WM. 2014. Reexamining the association between smoking and periodontitis in the Dunedin study with an enhanced analytical approach. J Periodontol. 85(10):1390-1397.

Zhang W. 2008. Oral health service needs and barriers for Chinese migrants in the Wellington area. N Z Dent J. 104(3):78-83.

Zhang Y, Wong MC, Lo EC. 2016. Pathways of oral health knowledge, attitudes, practices, and status in married couples. Community Dent Oral Epidemiol. 44(4):400-407.

Zhu L, Petersen PE, Wang HY, Bian JY, Zhang BX. 2005. Oral health knowledge, attitudes and behaviour of adults in China. Int Dent J. 55(4):231-241.

Zinke A, Hannig C, Berth H. 2018. Comparing oral health in patients with different levels of dental anxiety. Head Face Med. 14(1):25.

Zvolensky MJ, Vujanovic AA, Miller MOB, Bernstein A, Yartz AR, Gregor KL, McLeish AC, Marshall EC, Gibson LE. 2007. Incremental Validity of Anxiety Sensitivity in Terms of Motivation to Quit, Reasons for Quitting, and Barriers to Quitting Among Community-Recruited Daily Smokers. Nicotine Tob Res. 9(9):965-975.