Oral health status of community-dwelling older adults and its relationship with general health conditions

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Declaration

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Summary

Background

The ageing population is one of the great challenges that will confront health services in developed countries in the coming years. It is estimated that by 2050, the number of adults aged 60 years and older worldwide will increase from 901 million to 2.1 billion, and the adults called "oldest old" (80 years and over) will more than triple (125 to 434 million), as compared to 2015 (United Nations, 2015). In Ireland, in 2011 adults aged 65 years and over comprised 11.4% of the total population and this proportion is predicted to reach 22.4% in 2041. The proportion of adults aged 80 years or older is predicted to be 7.5% of the total population in 2046 (Central Statistics Office, 2013, Central Statistics Office, 2017).

The ageing population faces the challenge of different chronic diseases including physical, mental and oral health-related conditions. Oral health, directly and indirectly, mirrors the health of the entire body and mind, and poor oral health has been called a silent epidemic (Benjamin, 2010). It is impossible to be healthy without a healthy mouth because oral health has a bidirectional relationship with systemic, physical and mental health (Liljestrand et al., 2015, Petersen and Ueda, 2005, Okoro et al., 2012, Cerutti-Kopplin et al., 2016). For example, older adults may, as a result of poor oral function, eat a poor-quality diet and avoid social interaction and in this way, poor oral health may adversely affect health and wellbeing. Similarly, loss of physical and cognitive function, and increasing frailty, often result in less attention to oral health and reduced access to the care that is needed to maintain oral function.

In Ireland, it is almost eighteen years since the last national data on oral health status was collected. The Irish Longitudinal Study on Ageing (TILDA) Wave 3 provided a timely opportunity to carry out an oral health assessment of a subset of TILDA participants aged 50 years and over, and to relate these oral health findings to the socioeconomic status and systemic health conditions of the same cohort.

Aims of the study

- To evaluate the oral health status of a sample of community-dwelling adults aged 50 years and over in Ireland
- To explore the relationship between self-reported oral health status and objectively measured oral health

- To examine any relationship between systemic health conditions (diabetes, atherosclerotic cardiovascular disease, osteoporosis, and cognition) and objectively measured oral health (number of teeth and periodontal health).

Methods

An opportunistic sample of TILDA Wave 3 respondents, attending for health assessments at the TILDA health assessment centre in Trinity College Dublin, was offered an oral health examination by a dentist. To allow for international and national comparisons, WHO oral health assessment criteria and criteria used in previous oral health surveys in Ireland were used. Edentulism, mean number of teeth, functional dentition (10 or more tooth contacts), periodontal health, tooth wear, DMFT, and restorative treatment needs were recorded. The oral mucosal lesions, salivary flow, and temporomandibular disorders were not recorded.

For evaluation of the relationship between self-reported oral health and objectively measured oral health, the five self-reported questions related to oral health and access to dental care were used to relate with objectively measured oral health (Appendix 1). These oral health questions were included in the Computer Assisted Personal Interview (CAPI) component of TILDA data collection.

For the evaluation of the relationship between systemic health conditions and oral health status of community dwelling adults in Ireland, the objectively measured and self-reported data of systemic health conditions, available from TILDA data of Wave 1 and Wave 3 was used (for details see Chapter 6 methods section). Quantitative methodology was used to obtain the results.

Results

Out of the 3111, TILDA Wave 3 sample, who were offered the oral health assessment, 2539 were examined. For the purpose of analysis, the adults below 50 years of age (n=31) and adults with an incomplete oral health assessment (n=4) were omitted from the sample. The final oral health assessment (OHA) sample consisted of 2504 people, giving a response rate of 80.5%.

Objective 1: among the adults aged 50 years and over, 9.9% (249) were edentate; 11.5% (159) of females and 8% (90) of males. Of those aged 65-74 years, 11.7% (107) were edentate compared with 25.4% (94) edentate in the 75 years and older age group. Of those aged 65 years and older, 15.6% were edentate compared with 40.9% in the 2000-02 Irish national oral health survey (Whelton et al., 2007). The mean number of teeth in those aged 65 years or older was 14.9 for males and 14.2 for females. The 2000-02 figures for the same age group were 9.9 and 7.4

respectively. Approximately 56.8% of the dentate sample had 10 or more tooth contacts. Overall, the mean DMFT at the cavitation level was 18.5 and DMFT at the visual caries level was 18.6. Among the components of DMFT, the mean number of missing teeth was 10.3, mean filled teeth was 7.7 and mean decayed teeth was 0.5 per person. For adults aged 65 years and over, the mean DMFT at cavitation level decreased from 25.9 to 24.4 between 2000-02 and 2014-15.

Among dentate adults aged 50 years and over, 5.7% had deep pockets, 50.8% had shallow pockets, 31.7% had calculus, 3.5% had bleeding and just 5.8% had healthy periodontium reported by maximum CPITN score. In 2014-15, among adults aged 65 years and over, proportion of adults with deep pockets (4.7% vs 12.0%) was less and proportion of adults with shallow pockets (46.4% vs 37.6%) and calculus (35.1% vs 29.5%) was more than in 2000-02. In the dentate sample the highest proportion of adults had dentine exposed on less than one-third of a tooth surface and very few adults had no wear. There was a gradual decrease in tooth wear with age, which is probably a reflection of fewer retained teeth with age. When gender difference was considered, more females were recorded as having no wear. Similarly, more females had wear on less than one-third of a tooth surface whereas there was the opposite trend in respect of wear on more than one-third of teeth the tooth surface. Furthermore, it was also evaluated that adults with medical card, less education, and living in a rural area had poor oral health compared to adults without medical card, higher levels of education and living in Dublin/Co. Dublin.

Objective 2: the self-reported (subjective) complete denture wearing and objectively measured edentulism (9.8% vs 9.9%) were similar in the OHA sample (n=2504). Overall, 9.2% fewer respondents reported the self-reported denture treatment need (46.6%) as compared to clinically assessed denture treatment need (55.8 %). The self-reported denture treatment need (repair or replacement) cannot be used as a replacement of objectively measured denture treatment need because a much lower proportion of adults self-reported treatment need for lower dentures only and a higher proportion of adults self-reported treatment need for upper dentures only, when compared with clinically examined treatment need. In this research, self-reported oral health status (excellent, very good, good, fair and poor) had a statistically significant relationship ($p<0.05$) with the objectively measured number of teeth (Kruskal-Wallis test) and 10 or more tooth contacts (Chi-square). Self-reported eating and speaking difficulty had a statistically significant relationship with ($p<0.05$) fewer than 10 tooth contacts. Self-reported difficulties with teeth did not have a statistically significant relationship with objectively measured periodontal health. Self-reported frequency of dental visits was also a good indicator of objectively measured mean number of teeth, mean DMFT and tooth contacts.

Objective 3: among dentate adults in the OHA sample (n=2255), there was no statistically significant relationship of periodontal health with diabetes, osteoporosis, and cognition, both before and after controlling for cofactors of age, gender, BMI, smoking, education, and area of residence. This research found atherosclerotic cardiovascular disease (ACD) was a risk indicator for shallow and deep pockets relative to the healthy periodontium. However, after controlling for the other cofactors of age, gender, BMI, smoking, education, area of residence, there was no relationship between atherosclerotic CVD, and periodontal health.

In relation to edentulism in the OHA (n=2504) sample, diabetes (RRR=1.58, CI= 1.12-2.23) and cognition (RRR=0.94, CI= 0.89-0.98) were risk indicators for being edentate relative to having 20 or more teeth, before and after controlling for other cofactors; age, gender, BMI, smoking, education and area of residence. ACD and osteoporosis were also risk indicators for being edentate relative to have 20 or more teeth, but there was no relationship between ACD and edentulism and osteoporosis and edentulism after controlling for other cofactors; age, gender, BMI, smoking, education, and area of residence. This research also found that in the OHA sample (n=2504), diabetes (RRR=1.38, CI =1.10-1.73), CVD (RRR =1.33, CI=1.07-1.65), osteoporosis (RRR = 1.30, CI=1.02-1.67) and cognition (RRR=0.88, CI=0.86-0.91) were individual risk indicators for having 1-19 teeth relative to have 20 or more teeth, both before and after controlling for other cofactors of; age, gender, BMI, smoking, education and area of residence.

Conclusions

When the findings of this research were compared with the previous Irish oral health survey of 2000-02, the results suggested a considerable improvement in the oral health status of community dwelling adults aged 50 years and over, in Ireland. However, loss of teeth is still common, particularly among older adults. Self-reported edentulism was the same as clinically examined edentulism and could be used as a replacement of clinically examined edentulism, but self-reported denture treatment need (repair and replacement) cannot replace clinically assessed denture treatment need (repair and replacement). Self-reported oral health status, difficulties with teeth and frequency of dental visits were good indicators of objectively measured number of teeth and 10 or more tooth contacts but were not good indicators of objectively measured periodontal health.

Systemic health diseases (diabetes, CVD, osteoporosis, and cognition) were risk indicators for having fewer teeth in presence of cofactors of age, gender, education level, area of residence, BMI, smoking, education level and area of residence. So older adults with these systemic diseases should be prioritised for restorative treatment need relating to missing teeth or no teeth.

These findings provide a valuable resource for oral health policymakers, regarding oral health status and treatment needs of adults aged 50 years and over, and its relationship with sociodemographic and systemic health conditions, in Ireland. This research has also highlighted the high-risk groups for treatment needs, in relation to sociodemographic and systemic health conditions. These groups should be prioritised for oral health care in Ireland.

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Abbreviations

AAP	American Association of Periodontology
ACD	Atherosclerotic Cardiovascular Disease
ADHS	Adult Dental Health Survey (UK)
AMTS	Abbreviated Mental Test Score
AOR	Adjusted Odds Ratio
ARIC	Atherosclerosis Risk in Communities
ASA	American Society of Anesthesiologists
AVD	Atheromatous Vascular Disease
BASCD	British Association for Study of Community Dentistry (UK)
BMD	Bone Mineral Density
BMI	Body Mass Index
CAD	Coronary Artery Disease
CAL	Clinical Attachment Loss
CAPI	Computer Assisted Personal Interview
CDA	Complete Dental Arch
CDC	Centre for Disease Control (US)
CEJ	Cemento-enamel Junction
CHMS	Canadian Health Measure Survey
CPITN	Community Periodontal Index of Treatment Need
CPITN-E	Community Periodontal Index of Treatment Need for Epidemiology
CSO	Central Statistics Office
CVD	Cardiovascular Disease
D	Decayed
DDUH	Dublin Dental University Hospital
DHAP	Dental Health Action Plan
DLS	Dental Longitudinal Study
DMFS	Decayed, Missing and Filled Surface
DMFT	Decayed, Missing and Filled teeth
DMFT-c	Decayed, Missing and Filled teeth at cavitation level
DMFT-v	Decayed, Missing and Filled teeth at visual caries level
DMS	German Survey of Oral Health
DSST	Digit Symbol Substitution Test
DT	Decayed teeth

DTBS	Dental Treatment Benefit Scheme
DTSS	Dental Treatment Services Scheme
DVM	Delay Verbal Memory
DWR	Delayed Word Recall
DXA	Dual Energy X-ray Absorptiometry
EFP	European Federation of Periodontology
ELSA	English Longitudinal Study of Ageing
ER	Exposed Roots
F	Filled
FDI	World Dental Federation
FNOHS	First Nation Oral Health Survey (in Canada)
FPL	Federal Poverty Level (Economic level in USA)
FT	Filled Teeth
HbA1c	Glycosylated Haemoglobin
Hispanic EPESE	Hispanic Established Populations for Epidemiologic Studies of the Elderly
HR	Hazard Ratio
HRB	Health Research Board
HSE	Health Service Executive
ICHOM	International Consortium for Health Outcomes Measurement
IDS-TILDA	Intellectual Disability Supplement to The Irish Longitudinal Study on Ageing
IHD	Ischaemic Heart Disease
IOHS	Inuit Oral Health Survey (Canada)
M	Missing
m-BMD	Meta-carpal Bone Mineral Density
MC	Medical Card
MIP	Maximum Inter-cuspal position
MMSE	Mini Mental State Examination
MT	Missing Teeth
NHANES III	National Health and Nutrition Examination Survey (USA)
NOHP	National Oral Health Policy
NSAOH	National Survey of Adult Oral Health (Australia)
NZOHS	New Zealand Oral Health Survey
OHA	Oral Health Assessment
OHC-CHMS	Oral Health Component of Canadian Health Measures Survey

OR	Odds Ratio
OTWI	Occlusal Tooth Wear Index
PDSS	Public Dental Service Scheme
PR	Prevalence Ratio
PWV	Pulse Wave Velocity
QNHS	Quarterly National Household Survey
RCI	Root Caries Index
RRR	Relative Risk Ratio
SCQ	Self-completed Questionnaire
SCT	Spatial Copying Task
SDA	Shortened Dental Arch
SDLT	Serial Digit Learning Test
SDST	Symbol Digit Substitution Test
SLAN	Survey of Lifestyle Attitude and Nutrition in Ireland
SRT	Story Recall Test
SSS	Serial Subtractions Score
SUNT	Sound Untreated Natural Teeth
TCD	Trinity College Dublin
THA	TILDA Health Assessment
TILDA	The Irish Longitudinal Study on Ageing
TTS	Total TILDA Sample
TWI	Tooth Wear Index
UCC	University College Cork
VA	Department of Veterans Affairs (US)
WFT	Word Fluency Test
WHO	World Health Organization
WHS	World Health Survey

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1 Introduction

This chapter describes the context for the current study by introducing the worldwide changes in population structure, the Irish Longitudinal Study on Ageing (TILDA) and the oral health component of the TILDA study. This chapter also summarises the TILDA study aims and objectives, cohort profile and maintenance, and self-reported and clinically assessed measurements in the TILDA study. The sample selection, methods, and data collection of each TILDA wave are described in Methods (Chapter 3). This chapter concludes with the importance and value of an oral health assessment in the TILDA study of ageing.

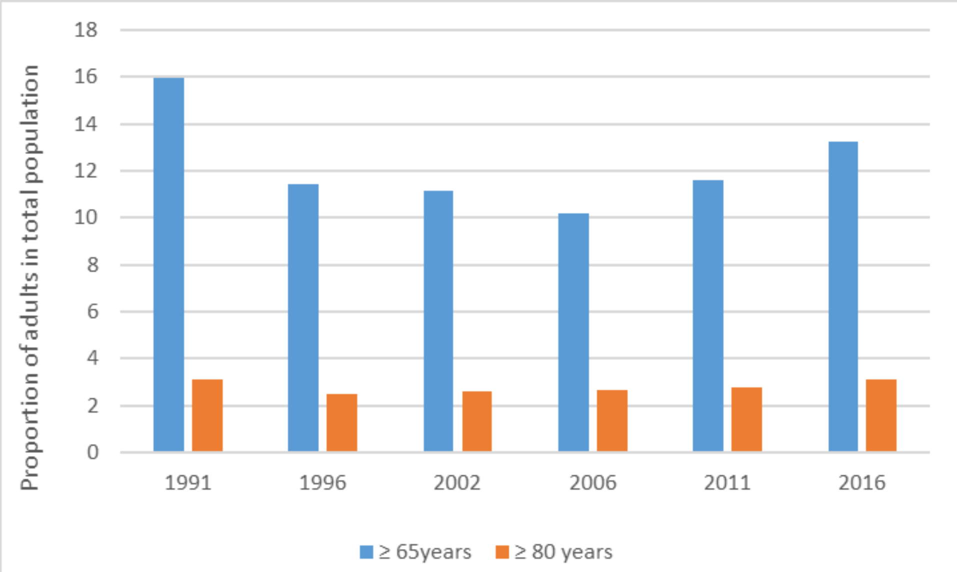
1.1 Population ageing

The population of older people is growing worldwide, and it is projected to grow more rapidly in the coming decades. The definition of older adults varies among different countries and related to the retirement age. For example, in Ireland retirement age is 65 years while in Africa it is 50-55 years which change the definition of older adults in different regions of world. WHO defines age 65-74 years as early old age and 75 years and over as late old age (Orimo et al., 2006).

Globally, the number of adults aged 60 years and over, increased by 48.4% from 2000 to 2015, and is projected to more than double by 2050 as compared to its size in 2015 (2.1 billion from 901 million) (United Nations, 2015). Globally in 2015, adults aged 65 years and over, constituted 8.5% of the total world population, it is estimated to increase to 12% by 2030 and 16.7% by 2050 (He et al., 2016). The United Nations reported "Overall adults called the "oldest old" (80 years and over) are growing faster than older adults (60 years and over) and are projected to more than triple from 2015-50 (125 to 434 million)" (United Nations, 2015, Sanderson et al., 2017).

Europe is a region containing a high proportion of older people, the population of those aged 60 years and over, increased by 19.8% from 2000-15 and is expected to increase by 23.1% from 2015-30. This will result in this age group comprising 25% of the overall population in Europe by 2030 (United Nations, 2015, Sanderson et al., 2017).

Ireland has also followed the trends in population ageing. In 2017, the figures from the Central Statistics Office showed, that in Ireland, from 1991 to 2016, the percentage increase of adults aged 65 years and over, was 56.3% (from 402,900 to 637,567) and of adults aged 80 years and over, was 87.7% (from 78,741 to 148,592). From 2011 to 2016, there has been an increase of 19.1% in the population of adults aged 65 years and over, along with an increase of 19.6% in community-dwelling adults in this age group (Central Statistics Office, 2017). From 2011 to 2016, in Ireland, among adults aged 65 years and over, there was an increase of 22% in males (53,523 to 296,837) and 16.7% in females (48,651 to 340,730) (Central Statistics Office, 2017).

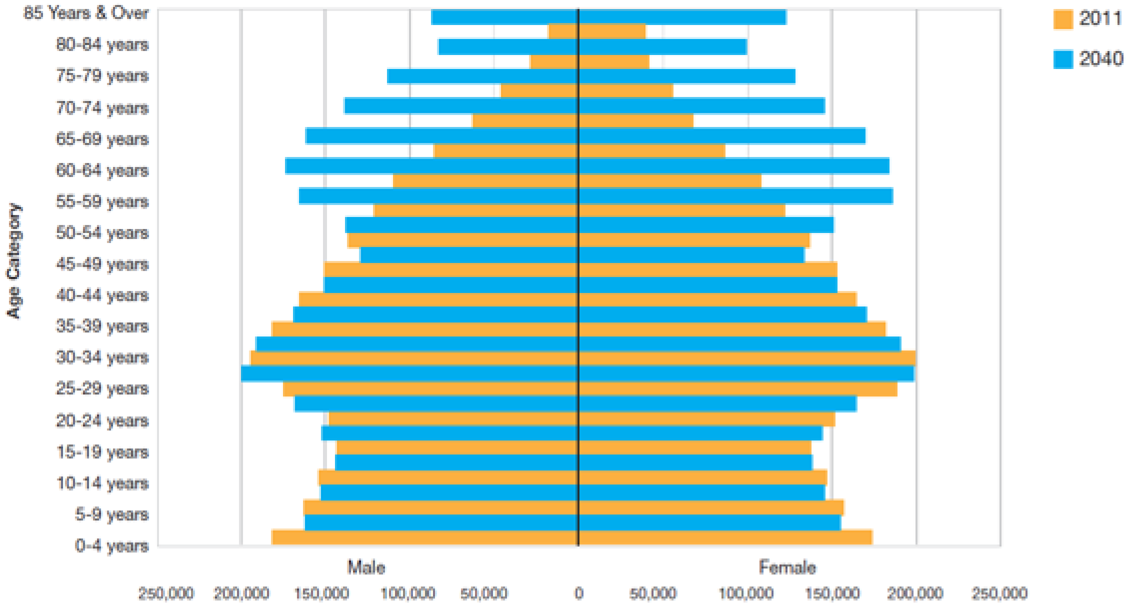


(Central Statistics Office, 2017)

Figure 1-1: Change in the proportion of adults aged 65 years and over and 80 years and over from 1991 to 2016 in the total population of Ireland.

Figure 1-1 also shows that there has been an increase in the proportion of adults aged 65 years and over and those aged 80 years and over, in Ireland from 2006 to 2016. Since 1996, the increase in the proportion of adults aged 65 years and over and 80 years and over, was highest between 2011 to 2016 (Central Statistics Office, 2017).

Figure 1-2 shows the age distribution of the Irish population in 2011 and the projection for 2040. The projected increase in the numbers of people aged 50 years and older is clear, though there is a similar projected increase in adults in the working-age groups for 2040 (Central Statistics Office, 2013). In 2011, adults aged 65 years and over, comprised 11.4% of the total population and this proportion was projected to double by 2041 to 22.4%. Whereas the projected increase for adults above 80 years, is to increase by 2.6 times from 2011 to 2040 (Central Statistics Office, 2013).

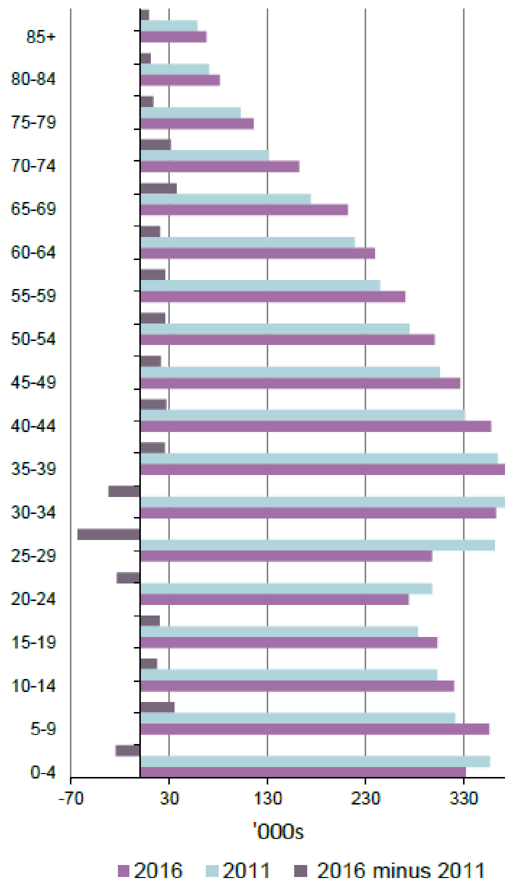


(Central Statistics Office, 2013)

Figure 1-2: Population projections for Ireland, from 2011 to 2040.

Figure 1-3 which shows data from the 2016 census, indicates a very similar population structure as in 2011, though with a reduction in the number of people in the 20-24 years, 25-29 years and 30-34 years' age groups. This reduction has been attributed to outward migration during the recent recession. The greatest increases are seen in those aged 65-69 years and 70-74 years in 2016.

The above-mentioned population drift reflects that in Ireland and as is worldwide, the number of older adults is growing faster than any other age group. To accommodate this population change, countries need to have a new intergenerational shift in systems; political, economic, social and health care (United Nations, 2015). In order to favour healthy ageing in older adults, new healthcare policies are required which will necessitate assessment and evaluation in order to provide the evidence-base for the care of those with chronic and non-communicable diseases in this age group. Therefore, the evaluation of oral health-related chronic diseases and their interrelation with systemic health conditions is very valuable for ensuring healthy ageing.



(Central Statistics Office, 2017)

Figure 1-3: Changes in the population structure in Ireland, from 2011 to 2016.

1.2 Oral health and population ageing

The FDI World Dental Federation (FDI) defines oral health as "An ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expression with confidence without pain, discomfort and disease of the craniofacial complex" (Glick et al., 2017).

"General well-being" is part of a larger concept covering health-related quality of life which, according to some authors, is synonymous with "quality of life" (Whitehead, 1991). As oral health is related to general health, so oral health-related quality of life impacts on general well-being (Naito et al., 2006). Oral health directly or indirectly mirrors the health of the entire body and mind with the result that poor oral health has been called a silent epidemic (Benjamin, 2010). A healthy mouth is integral to being healthy. To demonstrate the effect of oral health on quality of life, different measures have been developed to evaluate the functional, psychological, social and economic implications of oral health (Allen, 2003).

Oral health is a multidimensional term and is fundamental to systemic, physical and mental health of an individual. It also plays a major role in the physiological, psychological and social well-being of an individual (Glick et al., 2017). These effects are more pronounced in older adults because of deterioration in oral health, systemic health, physical health and cognitive health with age. Oral health has a bidirectional relationship with systemic, physical and mental health (Avlund et al., 2001, Petersen and Ueda, 2008, Okoro et al., 2012, Liljestrand et al., 2015). For example, older adults may, as a result of poor oral function, eat a poor-quality diet and avoid social interaction with the result of that this poor oral health impacts on physical, systemic or mental health.

In Ireland, from 2007 to 2017, oral disorders have been reported as the tenth most common cause of years lived with disability among the total population (Institute for Health Metrics and Evaluation, 2019). In 2014, the Intellectual Disability Supplement to The Irish Longitudinal Study on Ageing (IDS-TILDA) reported that in Ireland, in the nationally representative sample of adults with intellectual disabilities, the edentulism prevalence was more than double that of the TILDA population sample (34.1% vs 14.9%) and that age was an important predictor for being edentate among adults with intellectual disabilities in Ireland (Mac Giolla Phadraig et al., 2015). In Ireland, adults with intellectual disabilities who lived with family had the lowest level of edentulism as compared to those who lived in residential care (28.6% vs 39.9%) (Mac Giolla Phadraig et al., 2015).

Inglehart and colleagues reported that individuals with oral pain were not only unable to eat properly but that uncomfortable, damaged or missing teeth also led them to avoid social interaction because of inconvenience and embarrassment (Inglehart and Bagramian, 2002). Most oral health surveys have reported a deterioration in oral health with age and indicated that the discomfort associated with poor oral health was more pronounced in older adults (Whelton et al., 2007, Steele et al., 2012). Among community-dwelling adults and in geriatric inpatients, poor nutrition level because of the reduced masticatory function and poor oral health have also been associated with the progression of pre-frailty and frailty (Horibe et al., 2018, Shwe et al., 2019). Poor oral health either in the form of few retained teeth or painful mouth or uncomfortable dentures, changes food preferences (Brodeur et al., 1993, Moynihan et al., 1994, Krall et al., 1998, Sheiham et al., 2001). High intake of soft and sugary diet as a replacement of fibrous diet leads to multiple health issues such as obesity, diabetes and cardiovascular disease. Apart from pathophysiological and common risk factor links between oral health and systemic health conditions, the poor nutrition because of poor oral health is also an important link between oral health and systemic health conditions.

It is a basic requirement that older people should be at least free from pain and sepsis, can effectively masticate and enjoy food, as well as engage in social interaction without embarrassment due to poor oral health status and as a result, enjoy a good quality of life. Oral health is not just about teeth and periodontal health it also includes comfort and appropriate use of dental prostheses. Oral health also implies freedom from potentially debilitating or life-threatening diseases, such as oral cancer.

The increase in the population of older adults highlights the importance of good oral health among this age group in the coming years (see Section 1.1) because oral health may not only affect quality of life, it is also related to the general health and wellbeing of older adults.

1.3 Research on the ageing population in Ireland

1.3.1 Background

In the coming years, population ageing will be one of the greatest challenges worldwide and the promotion of active healthy ageing is a global social challenge. In 2008, the European Union set a target for researchers and policymakers to increase the average healthy life span by two years before 2020 (European Commission, 2008).

Different countries have undertaken longitudinal studies on ageing to analyse the effect of current health policies on this change in population age, to make future recommendations to accommodate these changes and to increase the healthy life span. In Ireland, the first longitudinal research into ageing, “The Irish Longitudinal Study on Ageing” (TILDA) has been underway since 2009, it is the first comprehensive study of adults and ageing in Ireland. It is led by Trinity College Dublin (TCD) in collaboration with other academic institutes (University College Dublin and Royal College of Surgeons) and Mercer’s Institute for Successful Ageing (MISA), St James’s Hospital Dublin, in Ireland. The purpose of the TILDA study is to change the quantity, quality and priorities of ageing research and information in Ireland.

To maintain cross country comparisons, TILDA is designed to maximise the comparability with other recognised longitudinal studies. Particularly, it is comparable with English Longitudinal Study on Ageing (ELSA), Health and Retirement Survey (HRS) in the United States and Survey of Health Ageing and Retirement in Europe (SHARE) (Kenny, 2013). Being newer in a series of other longitudinal studies, the design of the TILDA study is to answer the questions raised by other studies and is helping to fill gaps in knowledge for international comparisons (Kenny, 2013).

1.3.2 Aims and objectives of the TILDA study

The Irish Longitudinal Study on Ageing (TILDA) is a large-scale, nationally representative, cohort study on ageing in Ireland. It was started in 2009 and is repeated every 2 years. It provides the evidence base to inform the current and emerging health, socioeconomic and policy issues in relation to the above-mentioned population drift. The overarching aim of the TILDA study is " **To make Ireland the best place in the world in which to grow old"** (Kearney et al., 2011). TILDA aims to

- Provide comprehensive internationally comparable baseline data on older people in Ireland, leading to improvements in policy and planning
- Provide new insights into the causal pathways underlying the ageing process
- Add to the prominence of ageing as an issue of public interest and allow the voice of older people to be heard more clearly, by effectively disseminating results to various audiences.
- Lead to a further extensive analysis by academic researchers both in Ireland and abroad, helping to create an enhanced infrastructure for ageing research in Ireland and to attract international scholars and funding, by making its anonymised dataset openly available.

(Available at https://tilda.tcd.ie/about/aims/ accessed in 2017)

The objectives of the TILDA study are to assess

- the health status and health needs of older people
- the social and economic status and needs of older people
- the health, economic and social needs of families and carers of older people
- the biological and environmental components of "successful ageing"
- the contributions that older people are making to society and the economy
- how each of these key components (health, wealth, happiness) interact such that we can ensure that Ireland meets the needs and choices of its citizens in a personalised and positive environment and with due dignity and respect (Kenny, 2013).

1.4 Oral health assessment and the TILDA study

The TILDA study has three modes of data collection; Computer Assisted Personal Interview (CAPI), Self-Completed Questionnaire (SCQ), and health assessment. Table 1-1 indicates the CAPI and SCQ components of the data collection, which collect information about demographics, social circumstances, employment, retirement and expectation, income and assets, transport, medication, health care utilization, physical health, mental health, cognitive health, behavioural health and ageing perception of participants (Kearney et al., 2011).

In late 2012 and early 2013, when the TILDA management group was planning for Wave 3 of the study, a proposal was made to the TILDA team to include an oral health assessment in the health assessment. Given the longitudinal nature of the study, there were many applications for other research projects to be included and clearly, not all could be included. The critical constraint was the time required to carry out the oral health assessment and an alternative approach was considered to avoid the need for a traditional dental examination but it was not feasible. The decision was then made to undertake a clinical examination using the WHO methodology but limiting the examination time to a maximum of 10 minutes. It was also decided to add some oral health-related questions to the CAPI. TILDA Wave 1 and Wave 2 had included two oral health-related questions in the CAPI. These were drawn from the Survey of Lifestyle, Attitude and Nutrition (SLAN) in Ireland (The Economic and Social Research Institute Ireland, 2007, Morgan et al., 2008). In TILDA Wave 3, five oral health-related questions were included in the CAPI (Appendix 1). These questions were drawn mainly from questions validated in other studies and two of these questions were originally from the SLAN survey and were same as included in Waves 1 and 2 of TILDA (The Economic and Social Research Institute Ireland, 2007, Morgan et al., 2008). Out of these five questions in the Wave 3 CAPI, three questions were designed to assess self-reported oral health, dentures/teeth and difficulties with teeth. Whereas the other two questions assessed the self-reported frequency of dental visits and dental care provider.

It was almost nineteen years since the previous Irish national survey on the oral health status of adults was carried out. It was timely to carry out an oral health assessment of a subset of the TILDA respondents. So, in TILDA Wave 3, along with self-reported oral health, an objectively measured oral health evaluation of a TILDA subsample was introduced. It is expected that this oral health assessment will allow for monitoring of changes in the oral health status of the TILDA cohort over time and will be used to evaluate the oral health status (excluding mucosal diseases) of older adults in Ireland. The oral health assessment was optional for TILDA Wave 3 health assessment participants. It was carried out at the end of all other health assessments and was limited to a maximum of 10 minutes by TILDA management. For this reason, only the most important oral health indicators were recorded (see Chapter 3 for details).

Table 1-1: Summary of data collected in TILDA Computer-assisted Personal Interview (CAPI) and Self-completed Questionnaire (SCQ).

Demographic data	**Physical health**
Childhood health	Self-rated health
Education	Limiting long-standing illness/disability
Marital status and marriage history	Sensory function
Migration history	Cardiovascular disease
Social circumstances	Non-cardiovascular chronic illness
Transfers to and from children	Fall/fear of falling/steadiness
Transfers to and from parents	Chronic pain
(Instrumental) activities of daily living	Incontinence
Helpers	Medical screening
Social connectedness	**Mental health**
Participation in social/recreational activities	Self-reported mental health
Relationship quality (SCQ)	Depression
Employment and lifelong learning	Life satisfaction
Employment situation	Anxiety (SCQ)
Job history	Worry (SCQ)
Lifelong learning	Loneliness (SCQ)
Retirement and expectations	Perceived stress (SCQ)
Planning for retirement	Stressful life events (SCQ)
Expectations	Quality of life (SCQ)
Income and assets	**Cognitive health**
Sources of income	Self-rated memory
Assets	Orientation
Transport	Word-list learning (immediate and delayed recall)
Transportation	Verbal fluency
Driving	Prospective memory
Medications	**Behavioural health**
Health-care utilisation	Smoking
	Physical activity
	Sleep
	Alcohol (SCQ)
	Ageing perceptions

(Kearney et al., 2011)

1.5 Oral health, general health and the TILDA study

At the time of writing two waves of TILDA (Wave 1 and Wave 3) included a health assessment. In Wave 1, health assessments were carried out in two TILDA health assessment centres, in Trinity College Dublin (TCD) and University College Cork (UCC). In Wave 3, there was only one health assessment centre at TCD. TILDA health assessments were carried out by trained nurses and took more than 3 hours. Table 1-2 shows details of the TILDA health assessments. In TILDA Wave 3, the health assessment also included brain magnetic resonance imaging (MRI) for a sub-sample of participants. In non-health assessment waves, interviewers conduct two physical function tests during the CAPI (grip strength, Timed Up-and-Go) (Donoghue et al., 2017).

Oral health has a significant relationship with the general health of individuals. The relationship between general health and oral health is bidirectional with systemic conditions affecting oral health and vice versa. To demonstrate the effect of oral health on quality of life, different measures have been developed to evaluate the functional, psychological, social and economic implications of oral health (Allen, 2003). These findings suggest that any investigation of the health status of older people in a population should use some measure of oral health status as it is clearly linked to health and well-being of an individual (Allen, 2003). The relationships between oral health and general health conditions (cognitive, physical, systemic) have been researched for many years in countries such as the USA, UK and Australia. In Ireland, the last national oral health survey in 2000-02 used the American Society of Anaesthesiologists (ASA) classification as a proxy for health status for comparison between oral health and systemic health of the population (Whelton et al., 2007).

There is no previous population-based research in Southern Ireland that has evaluated the relationship between oral health and objectively measured components of general health (cognitive, physical, systemic) in the same group of older people. As indicated in Table 1-2, the TILDA study assesses physical health, cognitive health, psychological health, behavioural health, self-reported quality of life and health care utilisation in a nationally representative cohort. All these assessments provided an excellent opportunity to explore the relationship between oral health and general health (cognitive, physical, systemic) of older adults in Ireland. The TILDA participants are representative of the whole country, so the research involving this age group will provide information to inform the oral health care programmes that will not only improve oral health but will also improve the general health and wellbeing of older adults in Ireland.

Table 1-2: Summary of health assessments carried out by TILDA.

Variables	**Centre**	**Home**	**Number of measurements**	**Equipment used**
Height	Yes	Yes	1	SECA 240 wall-mounted measuring rod
Weight	Yes	Yes	1	SECA electronic floor scales or SECA seated scales
Waist size	Yes	Yes	2	Standard tape measure
Hip size	Yes	Yes	2	Standard tape measure
Blood pressure	Yes	Yes	3-2 seated and 1 standing	OMRON™ digital automatic BP monitor
Heart rate	Yes	No	3	OMRON™ digital automatic BP monitor
Grip strength	Yes	Yes	4-2 readings on each hand	Basic hydraulic hand dynamometer
Depression	Yes	Yes	1	8-item CES-D scale
Global cognition	Yes	Yes	2	Montreal Cognitive Assessment (MOCA) Mini Mental State Examination (MMSE)
Attention	Yes	Yes	1	Sustained attention response time (laptop)
Visual memory	Yes	Yes	1	CAMDEX picture memory test (acquisition, free recall, recognition)
Speed of processing	Yes	Yes	1	Choice reaction time test (laptop)
Executive function	Yes	Yes	3	Visual reasoning CAMDEX Timed colour trails 1 and 2
Timed up and go	Yes	Yes	1	Standard tape measure /chair/tape
Phasic blood pressure	Yes	No	6-1 at baseline, 1 nadir and 4 at 30s intervals after active stand	
Pulse wave velocity	Yes	No	2	Vicorder
Heart rate variability	Yes	No	1 (10 minute) recording	Medilog Darwin AR12
Visual acuity	Yes	No	2 – left and right eye	Logmar chart
Contrast sensitivity	Yes	No	2 - dim light with and without glare	Stereo Optical Co, Functional Visual Analyzer
Retinal photograph	Yes	No	2 – left and right	NIDEX Non-Mydriatic Auto Fundus Camera
Macular pigment optical density	Yes	No	12-6 measurements per eye	Macular Metrics Densitometer™
Bone density	Yes	No	1 – non-dominant foot	Achilles Insight Heel Ultrasound
Assessment of gait	Yes	No	3 – normal walk, walk with manual task, walk with cognitive task	GAITrite sensored mat
Blood sample	Yes	Yes	25ml	Normal blood-taking equipment

(Kearney et al., 2011)

2 Review of the literature

This chapter reports an overview of the most significant and reliable literature related to the aims of this research. It provides context to the research and explains where this research fits into existing knowledge related to the research question.

2.1 Structure of the chapter

The structure of the literature review chapter is as follows:

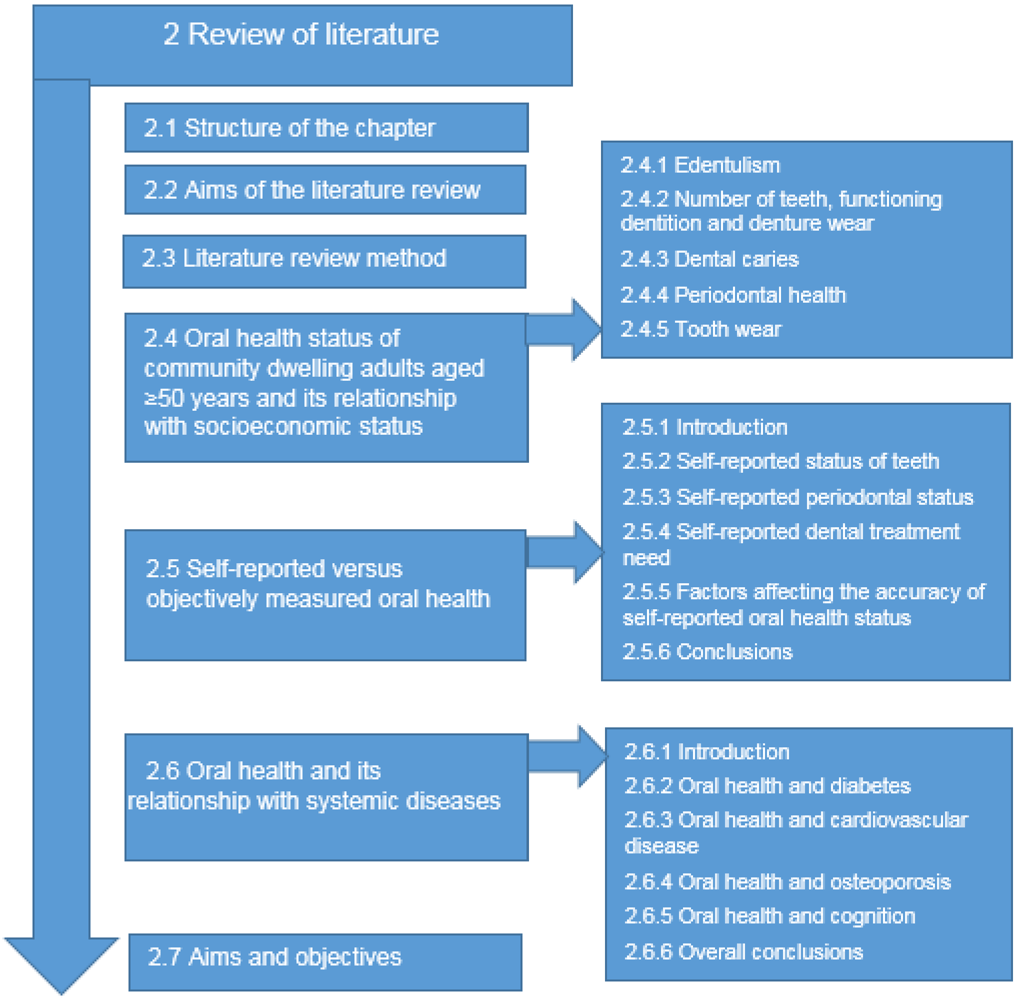


Figure 2-1: Structure of the literature review chapter.

2.2 Aims of the literature review

This chapter has three aims:

1. To review the literature on oral health status including, edentulism, number of teeth, minimum functioning dentition, periodontal health, dental caries and tooth wear among adults aged 50 years and over, and the relationship of these oral health conditions with age, gender and socioeconomic status, with emphasis on the epidemiology of these oral health conditions.
2. To review the literature on comparison and validation of self-reported oral health status with clinically examined oral health
3. To review studies on evaluation of the relationship of oral health conditions with systemic health conditions including diabetes, cardiovascular disease, osteoporosis and cognition.

2.3 Literature review method

A narrative or traditional literature review method was used in this chapter. In contrast to a systematic literature review, the narrative literature review is broader and does not have specified and explicit criteria for the inclusion of articles (Ferrari, 2015). It consists of searches from databases and rationales for future research where methods used to select articles may not be described. A narrative review was used in this research because it can better tackle the methodological diversities in literature and can address more than one research question at a time (Green et al., 2006, Ferrari, 2015). A narrative review was important for this research to provide previous information related to the research questions. The narrative review described and discussed the oral health of older adults and its relationship with certain general health conditions from a theoretical and contextual point of view. Although there are no formal methods for selection of articles in the narrative review of the literature it does have some limits applied to search literature according to the research questions (Green et al., 2006).

2.3.1 Search and retrieval of literature

The narrative literature review consists of findings from the scientific literature retrieved from searches of computerized databases, hand searches, and authoritative text (Green et al., 2006). In this research, the scientific literature was retrieved from

- Online databases: PubMed, Science Direct, Google Scholar and Cochrane Database of systematic reviews.
- Professional organisation websites; World Health Organization (WHO), Department of Health Ireland, Central Statistics Office (CSO) Ireland, United Nations Organization (UNO). British Association for the Study of Community Dentistry (BASCD), British Dental

Association (BDA), Centre for Disease Control (CDC), United Nations Department of Economic and Social Affairs, The Irish Longitudinal Study on Ageing (TILDA), Australian Research Centre for Population Oral Health, Ministry of Health New Zealand, American Dental Association (ADA) and World Dental Federation (FDI).

- Onsite search was done at Dublin Dental University Hospital (DDUH) and Trinity College Dublin (TCD) libraries for relevant literature of community dentistry, oral epidemiology, statistics and oral health relationship with systemic conditions.

2.3.2 Search terms

Search terms used were, oral health, dental status, dental health, edentulism, denture use, tooth loss, number of teeth, functional dentition, dental caries, tooth decay, root caries, cervical caries, root caries index, dental disease, caries prevalence, periodontal health, gingivitis, periodontitis, gum health, gingival recession, periodontal attachment loss, tooth wear, cervical tooth wear, older adults, community-dwelling older adults, adults aged 50 years and over, education level, socioeconomic status, self-reported or subjective oral health, clinically examined or objective oral health, diabetes, cardiovascular disease, atherosclerosis, osteoporosis, cognitive health.

2.3.3 Search limits and strategy

As narrative review does not have specific inclusion criteria for literature during a database search, so no formal tool was used for inclusion of studies in this literature review. However, the following limitations were applied:

1. Searches were carried out on articles published up to December 2018, however some recent and relevant articles were also included up to June 2019. Where needed the references from articles were also reviewed.
2. Searches were limited to data and articles published or translated into English.
3. Most of the literature reviewed was specific to the age group 50 years and over. However, if an age group involved adults from 45-54 years and where age-related comparisons were required, studies of adults in younger age groups were sometimes included.
4. In the literature review section 2.4, “Oral health status of community-dwelling adults and its relationship with socioeconomic status” the search was also limited to focus on the oral health or dental health status including edentulism, tooth loss, mean number of teeth, 20 or more teeth, dental decay, periodontal health and tooth wear and its relationship with age, gender and socioeconomic status. Most of the literature for oral health status and its relationship with socioeconomic status was retrieved from national oral health cross-sectional surveys from different countries, as these provide a reliable assessment of oral health status of older population by using a nationally representative sample along with trained and calibrated

examiners. Furthermore, these surveys use standardised methods to provide reliable, nationally representative data on a range of oral health conditions (Locker, 2000). However, a few small population-based, cross-sectional studies and cohort studies were also included.

5. In the literature review section 2.5, "Self-reported versus objectively measured oral health" most of the cross-sectional studies were reported by the narrative review method.
6. In the literature review section 2.6, "Oral health and its relationship with systemic diseases" (diabetes, cardiovascular disease, osteoporosis and cognition), a narrative method of literature review was used with a preference to include the large sample size studies of adults. The studies reported by narrative review method included randomised control trials, cohort studies, case-control studies and cross-sectional studies.

2.4 Oral health status of community-dwelling adults and its relationship with socioeconomic status

The proportion of older people in national populations continues to grow worldwide, especially in developing countries and the most rapidly growing age group consists of persons aged 80 years or over. The number of very old people was expected to increase from less than 90 million in 2005 to almost 400 million in 2050 (United Nations, 2007).

In 1995, in response to the global challenges of ageing populations, the World Health Organization (WHO) launched a programme on ageing and health (World Health Organization, 2002). In 2000, the WHO reiterated the priority of health for older people through the programme 'Ageing and Life Course', which focussed on the concept of 'Active ageing'. Oral health was an important component of 'Active Ageing'. This programme focused on oral health in old age and provided data related to oral health conditions (Petersen, 2005). The WHO has set the target of having at least 20 natural teeth in older age (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004).

All over the world, tooth loss has been seen as a natural consequence of ageing. Because of limited access to oral health care services in many developing countries, teeth are often left untreated or are removed because of pain or discomfort. Although in recent years some industrialized countries have reported a reduction in tooth loss among adults, nonetheless the proportion of edentate adults aged 65 years and older was still high in other countries (Petersen, 2003, Petersen et al., 2010).

Oral health assessment of a population is important as it provides a snapshot of the oral health status of the population at a particular point in time and changes over time are recorded by sequential studies. Evaluation and monitoring of the oral health of populations is important to ensure the development of oral health care systems at national level in order to improve oral health for all. In order to ensure consistent standards at national and international level and to undertake international comparisons the World Health Organisation (WHO) has recommended the collection and reporting of oral health status using standardised methods. For this reason, in previous Irish studies and in studies of other countries, the methods described in WHO Oral Health Surveys Basic Methods were used (World Health Organization, 2013). These methods provide standardised criteria for recording clinical oral health conditions focusing on dentition status, dental caries and treatment needs, developmental anomalies of teeth and enamel fluorosis, periodontal disease and treatment needs, oral mucosal lesions and prosthetic status and treatment needs (World Health Organization, 2013). This manual also makes recommendations on various procedures to ensure the collection of high-quality data.

Different countries have used different age groups, for example, in the 1989-90 Irish survey, the age bands used were 16-24 years, 35-44 years, 45-54 years, 55-64 years and 65 years and older but in 2000-02 the age bands were 16-24 years, 35-44 years and 65 years and older (O'Mullane and Whelton, 1992, Whelton et al., 2007). These age groups were also different from the UK adult surveys, where the 65 years and older sample was further stratified into age bands of 65-74 years and 75 years and older which coincides with the current WHO recommendations. These differences need to be taken into account when comparing data from the international research (Walker and Cooper, 2000).

In common with general health, socioeconomic status affects oral health. The WHO data from 2005 showed profound oral health inequalities were present among older people worldwide, in a region or country, in relation to socioeconomic status. In poor countries, limited access to dental care and lack of resources led to poor oral health among older adults. However, in developed countries, the difference in oral health was also pronounced among different social classes (Petersen et al., 2010). Peterson and colleagues also reported that worldwide more adults with lower levels of education and lower income levels were edentate than adults with higher education and higher income levels. In old age, tooth loss had an incremental relationship with social gradient (Petersen et al., 2010). Although complete and partial tooth loss has reduced over the years in industrialised countries, intercountry inequalities were still present according to tooth loss and most older adults with a functional dentition belonged to the higher social classes (Petersen et al., 2010).

The aspects of oral health reviewed in this literature review are; edentulism, mean numbers of natural teeth, 20 or more teeth, denture wearing status, coronal and root caries, periodontal status and tooth wear. The comparisons between different countries are also reported where comparable data is available.

2.4.1 Edentulism

Edentulism is known as the "final marker of disease burden for oral health" because it is a debilitating and irreversible condition (Cunha-Cruz et al., 2007). The retention of some natural teeth into older age is now a common occurrence and is evident from various oral health surveys such as in Ireland, Australia, the United Kingdom and Canada (Walker and Cooper, 2000, Whelton et al., 2007, Health Canada, 2010, Fuller et al., 2011). However, overall progress towards the goal of older people retaining many natural teeth is influenced by the existing burden of disease experience (both treated and untreated) among older adults.

Globally, poor oral health amongst older people has been evident by high levels of tooth loss along with other oral health problems (Thorstensson and Johansson, 2010). In older adults understanding the value of retaining natural teeth and their minimum functioning number is very important as increased retention of natural teeth and reduction in the levels of total tooth loss, are vital for the health and wellbeing of this age group (Sheiham et al., 1999, Thorstensson and Johansson, 2010).

Research suggests that where teeth are lost, there may be a significant effect on diet, nutrition, general well-being and quality of life (Thorstensson and Johansson, 2010). Furthermore, the number of retained teeth may affect the periodontal status and health of remaining teeth, as the few teeth share more of the masticatory burden (Clarke and Hirsch, 1991). A functional dentition is necessary for biological and social functions such as chewing, oral comfort, speech, self-esteem and aesthetics. Tooth loss and reduced masticatory function have been associated with cognitive decline (Gatz et al., 2006, Cerutti-Kopplin et al., 2016, Weijenberg et al., 2019). Cognitive decline worsens oral health and poor oral health reduces masticatory activity and ability, which in turn may cause further decline in cognition (Weijenberg et al., 2019). This section reports edentulism in Ireland and international comparisons are made as well as the relationship between edentulism and socioeconomic status is also reported.

2.4.1.1 Edentulism in Ireland

In the two previous Irish national surveys (1989-90 and 2000-02), total loss of natural teeth was determined by clinical examination and by a telephone interview in the 1979 survey (O'Mullane and McCarthy, 1981, O'Mullane and Whelton, 1992, Whelton et al., 2007). It should be noted that a person was considered to be dentate if there was one tooth or portion of a tooth present in the oral cavity, irrespective of the condition of the tooth. In Table 2-1 comparison of the 2000-02 figures with those reported from 1979 and 1989-90 shows that there was a considerable decline in levels of edentulism during that period.

Table 2-1: Percentage of edentate adults according to age group, gender and year of examination in Ireland (Base-edentate and dentate).

Year of examination	Age groups	% Male	% Female	% Total
2000-02	**35-44 years**	1.0	0.9	0.9
	65 years and over	34.6	45.6	40.9
1989-90	**35-44 years**	3.0	5	4
	45-55 years	13	21	18
	55-65 years	30	50	41
	65 years and over	33	61	48
1979	**35-44 years**	10	15	12
	45-55 years	31	37	34
	55-65 years	54	60	57
	65 years and over	64	79	72

(O'Mullane and McCarthy, 1981, O'Mullane and Whelton, 1992, Whelton et al., 2007)

Edentulism in 2000-02 was still higher for females than males aged 65 years and over (45.6% vs. 34.6%) though the difference in reported levels of edentulism between females and males in the 65 years and over age group, was 15% in 1979 compared with 28% in the 1989-90 survey and this difference decreased to 11% in 2000-02. Thus, the gender gap in terms of edentulism had decreased in the 65 years and over age group (O'Mullane and McCarthy, 1981, O'Mullane and Whelton, 1992, Whelton et al., 2007).

In recent Irish studies, medical card possession was used as a proxy for the socioeconomic status of adults. In Ireland, adults on low incomes are entitled to a medical card which provides eligibility for some health and social services, including very basic dental care. Table 2-2 shows that in 2000-02, the percentage of adults who were edentate was considerably higher among medical card holders, both males and females. In the 65 years and older age group, the difference due to medical card status was more pronounced than adults aged 35-44 years (O'Mullane and Whelton, 1992, Whelton et al., 2007).

Table 2-2: Percentage of edentate adults by age group, medical card status and year of examination, in Ireland (Base-edentate and dentate).

Year of survey	Age groups	Medical card holders			Non-Medical holders		
		M	**F**	**Total**	**M**	**F**	**Total**
2000-02	**35-44 years**	1.2%	1.5%	1.4%	0.1%	0.7%	0.4%
	65 years and over	40.1%	49.2%	45.6%	23.9%	35.2%	29.4%
1989-90	**35-44 years**	3.2%	7.8%	6.3%	2.7%	3.4%	3.4%
	45-55 years	22.6%	31.9%		9.8%	17.7%	
	55-64 years	42.4%	64.2%		22.6%	39.3%	
	65 years and over	48.2%	72.2%	62.2%	17.0%	42.9%	30.8%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Looking at the change in levels of edentulism among those aged 65 years and over, the level among male and female medical card holders in 2000-02 was lower than that in 1989-90. However, the level of edentulism reported for male non-medical card holders was higher in 2000-02 (23.9%) than in 1989-90 (17.0%). It is not clear why this increase may have occurred, it may have been due to changes in the Irish economy between the times of the two surveys, causing the profile of adults without a medical card to change or more male non-medical card holders may have accessed dental care during that period resulting in more teeth with a hopeless prognosis being extracted. A scheme to provide basic dental care for adult medical card holders was introduced in 1994, which was phased in commencing with the provision of dentures. In the 1989-90 survey, there was a very striking gender difference in the levels of edentulism in both medical card and non-medical card holders. This difference was less remarkable in 2000-02 as a considerable decrease in edentulism in women had occurred during that time period (Table 2-2).

In the Irish oral health national surveys, the American Society of Anaesthesiologists (ASA) classification was used for general health status. People who were classified as ASA 1 were healthy, without systemic disease. Those having mild to moderate systemic disease were classified as ASA 2, those having severe systemic disease that limited activity but was not incapacitating were classified as ASA 3 and those having severe systemic disease that limited activity and was incapacitating, classified as ASA 4 (O'Mullane and Whelton, 1992). In the 1989-90 survey, the relationship between edentulism and general health was evaluated only for adults aged 55 years and older. Table 2-3 shows that edentulism was higher among adults with ASA 3 and ASA 4 (54.5%) as compared with adults of same age group with ASA 1 (42.8%) (O'Mullane and Whelton, 1992).

Table 2-3: Percentage edentate by age group, general health status (ASA) and year of examination, in Ireland (Base-edentate and dentate).

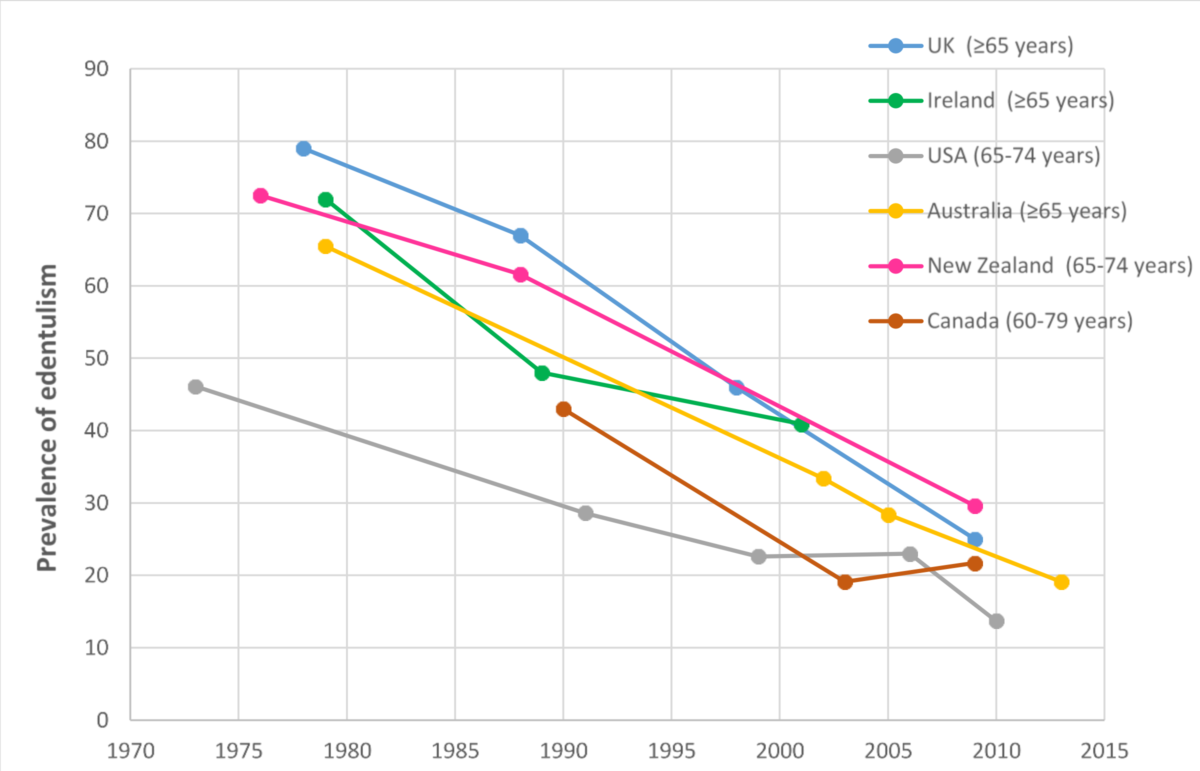
Year of survey	Age group	ASA 1	ASA 2	ASA 3 + ASA 4	Total
2000-02	**65 years and over**	35.1	53.8	47.7	40.9
1989-90	**55 years and over**	42.8	50.6	54.5	NA

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-3 shows, in 2000-02, 35.1% of the adults aged 65 years and over who were classified as healthy, without systemic disease (ASA 1), were edentate. In the same age group, the percentage of edentate adults was higher at 53.8% among those having mild to moderate systemic disease (ASA 2) compared with 47.7% in those classified as having severe systemic disease that limits activity but is not incapacitating (ASA 3) (Whelton et al., 2007). Systemic health conditions may be among the reasons explaining the increase in edentulism with age. From these results, it can be concluded that edentulism increased with age and systemic health conditions (ASA 2 and ASA 3+4) among older Irish adults.

2.4.1.2 International comparisons

In most of the oral health surveys reported below, edentulism prevalence was recorded by examination except in Australian 2004-06 (by phone interview), the UK 2009 (self-reported) survey and New Zealand 2009 where edentulism was self-reported and only those adults who self-reported being dentate were invited for examination (Haisman et al., 2010, O’Sullivan et al., 2011, Slade et al., 2014).



(Sanders et al., 2004, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Statistics Canada, 2010, Steele et al., 2012, Harford and Islam, 2013, Dye et al., 2015)

Figure 2-2: Trends in edentulism among adults aged 60 years and older in different countries.

Figure 2-2 shows the changes in edentulism from 1976 to 2013 among adults aged 60 years and over in different countries. The age groups and years of the examination are somewhat different, such as in the Canadian surveys the age group was 60-79 years and New Zealand and USA survey the similar age group was 65-74 years. Figure 2-2 indicates that over time, there was a decrease in edentulism in the different countries except in Canada where there has been a slight increase in edentulism from 2003 to 2009 in adults aged 60-79 years. This may be because of a change in sample size or the 2009 OHS-CHMS data had more variations than previous calculations of edentulism for the age group 60-79 years in Canada.

Figure 2-2 demonstrates that while the rate of decrease in edentulism varied among these countries between different years, the overall downward trend is very similar. Apart from the variations in the decline of edentulism among different countries, it is important to note that both the US and Canada had much lower levels of edentulism at their first data points compared with the other countries. Sanders and colleagues reported that in 1957-58, in the USA, 55.4% of those aged 65-74 years were edentate (Sanders et al., 2004). This explains why among all the countries reported above from 1971-75 to 2013, the USA had the lowest proportion of edentate adults aged 65-74 years, with only 46.1% in 1971-75 which fell to 13.7% in 2009-12. If the age group 65-74 years, in the USA is compared with those aged 65 years and over in Ireland, the USA figure in

1988-94 was 25.7% whereas in Ireland, in 1989-90 it was 48%. In the USA in 1999-2000, it was 22.6% compared with Ireland in 2000-02 when it was 40.9%. In 2003 Canadian adults aged 60-79 years had the lowest (19.1%) edentulism prevalence when compared with adults aged 65 years and over in Australia in 2002 (33.4%) and Ireland in 2000-02 (40.9%) and adults aged 65-74 years in the USA in 1999-2000 (22.9%) though the USA figure fell to 13.7% in 2009-12 (Figure 2-2) .

Table 2-4 shows that when adults aged 65-74 years were compared in Canada (2007-09), Australia (2004-06), New Zealand (2009), USA (2003-04), UK (2009) and Finland (2000), the United Kingdom in 2009, had the lowest percentage of edentulism (15%) compared with Finland (36%) in 2000. The figure for Canada in 2007-09 was higher (24.6%) than that of the USA (22.3%) in 2003-04 (Walker and Cooper, 2000, Närhi et al., 2000, Dye et al., 2007, Health Canada, 2010, Steele et al., 2012). Whereas, among all five countries, New Zealand had the highest prevalence of edentulism in adults aged 65-74 years (29.6%), although the New Zealand survey was carried out in 2009. New Zealand had almost double the proportion of edentate adults aged 65-74 years compared to the UK (15%), although both surveys were done in the same year.

These variations in edentulism in this age group might reflect a difference in access to oral health care and different socioeconomic level of 65-74-year-olds among different countries. Though the difference between the UK and Canada is surprising given that both countries have had well developed dental care systems for many years and the Canadian figures exclude some First Nations and Inuit groups who may have had less access to dental services.

2.4.1.3 Factors associated with the edentulism

This section reports edentulism in different countries by age, gender and socioeconomic status. Table 2-4 presents the prevalence of edentulism in different countries by age group and years of the surveys. While there was a similar trend of increased edentulism with age in all countries, this trend was less in more recent studies. For example, in Ireland from those aged 35-44 years to 65 years and over, the increase in edentulism was 40% in 2000-02 and 44% in 1989-90. In 2009, in the UK prevalence of edentulism was 10% higher among adults aged 65-74 years compared to adults aged 55-64 years. However, the highest difference of edentulism was of 17% between adults aged 74-85 years and those aged 85 years and over.

When the different countries were compared in relation to the difference in edentulism among adults aged 55-64 years and 65-74 years, the prevalence of edentulism among adults 65-74 years was 15.1% more in New Zealand in 2009, followed by Australia in 2004-06 (10.5%) and least in UK in 2009 (10%) as compared to adults aged 55-64 years. However, the difference in edentulism prevalence between adults aged 55-64 years and 65-74 years was similar in Australia (10.5%) and UK (10%), when the difference in the years of the studies is considered. When different countries are compared by age group, it is interesting to see that in those aged 55-64 years and above, edentulism prevalence was lower in Australia in 2004-06 than in New Zealand 2009, although the New Zealand survey was carried out three to five years later than Australian survey. However, for adults 65 years and over, edentulism prevalence was similar for the USA in 2010-12 and Australia in 2013 (19.1% vs 19%) (Table 2-4).

In 2009, for the very old age group, (85 years and over) edentulism prevalence in the UK, was higher (47%) than for those aged 80 years and over, in six middle income countries (India, China, Ghana, Mexico, Russia and South Africa) (37.3%) reported by Study on Global Ageing and Adult health (SAGA) wave 1 in 2007-2010 (Peltzer et al., 2014). Among adults aged 65-74 years, in Australia in 2004-06, edentulism prevalence was 20.3% which was higher when compared with the UK in 2009 (15%), given the UK survey was done 3 years later. However, in those aged 55-64 years, in Australia in 2004-06, there was almost double the prevalence of edentulism (9.8%) compared to the UK (5%) in 2009.

Peltzer and colleagues, (2014) also reported that overall self-reported edentulism edentulism was 11.7%, among six countries, while India, Mexico, and Russia had a higher prevalence (16.3%-21.7%) than China, Ghana, and South Africa (3.0%-9.0%) showing wide variations among the six countries (Peltzer et al., 2014). The study also found that the prevalence of edentulism in the six middle income countries was lower than in comparable studies in the USA (19%) (Duncan and Foerster, 2001, Wu et al., 2012) (Note this was a self-reported whereas the USA studies were done with a clinical examination). This relatively lower prevalence in Africa was consistent with other studies done in other African countries (Hobdell et al., 1997, Esan et al., 2004). Some researchers believed that African populations had much less dental caries which in turn affected the tooth loss patterns due to lower consumption of sugars compared with industrialised nations such as the US (Thorpe, 2006). Thorpe also suggested that levels of edentulism might be artificially low in developing countries due to the much lower percentage of the old and very old populations because of shorter life expectancy (Thorpe, 2006).

Table 2-4: Prevalence of edentulism by age group, country and years.

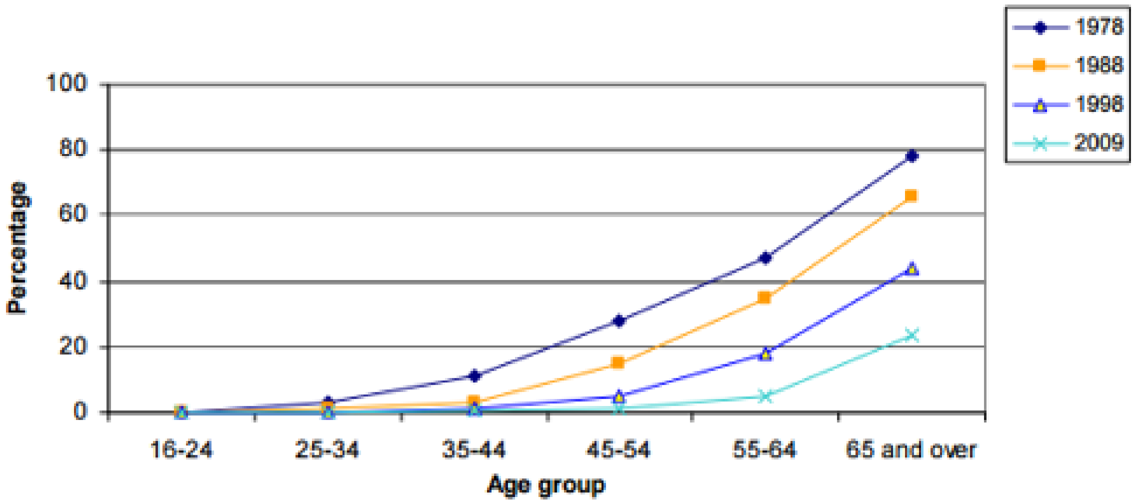
Country	Year of Survey	Age group	% Edentate
Ireland	2000-02	35-44 years	0.9%
		65 years and over	40.9%
	1989-90	35-44 years	4%
		65 years and over	48%
UK	2009	55-64 years	5 %
		65-74 years	15 %
		75-84 years	30 %
		85 years and over	47 %
	1998	65 years and over	46%
	1988	65 years and over	67%
Canada	2007-09	65-74 years	24.6%
	2009	40-59 years	4.4%
		60-79 years	21.7%
	2003	40-59 years	4.0%
		60-79 years	19.1%
	1990	40-59 years	20%
		60-79 years	43%
USA	2010-12	65-74 years	13.0 %
		75 years and over	25.8 %
		65 years and over	19.0%
	2005-08	45-64 years	3.2%
		65 years and over	23%
	2003-04	65-74 years	22.3%
Australia	2013	65 years and over	19.1%
	2004-06	55-64 years	9.8%
		65-74 years	20.3%
		75 years and over	36.5%
New Zealand	2009	55-64 years	14.5 %
		65-74 years	29.6 %
		75 years and over	39.6 %
	1988	65-74 years	61.6%
	1976	65-74 years	72.3%
Six countries	2007-2010	50-59 years	4.9%
(India, China, Ghana,		60-69 years	10.8%
Mexico, Russia and		70-80 years	24.2%
South Africa)		80 years and over	37.3%
Finland	2000	65-74 years	36%

(O'Mullane and Whelton, 1992, Sanders et al., 2004, Whelton et al., 2007, Slade et al., 2007, SuominenTaipale et al., 2008, Haisman et al., 2010, Health Canada, 2010, Statistics Canada, 2010, Steele et al., 2012, Dye et al., 2012, Harford and Islam, 2013, Peltzer et al., 2014, Dye et al., 2015)

However, in 2000, Enwonwu and colleagues reported that the levels of edentulism were higher in poor countries than developing countries because of limited access to oral health services and lack of materials for dental treatment, which led to more teeth being extracted. For example, in Madagascar, edentulism was reported at 25% nationally for people aged 65-74 years (Enwonwu et al., 2000). The 2010 Global Burden of Disease also revealed a slow decline in age-standardized Disability-Adjusted Life Year (DALY) rates for edentulism, from 144/100,000 in 1990 to 89/100,000 in 2010 (Institute for Health Metrics Evaluation, 2013).

In countries where there was data from a number of surveys, a cohort effect can be seen when the data from the different years are presented. This effect can be seen in the sequential data from the UK and the US.

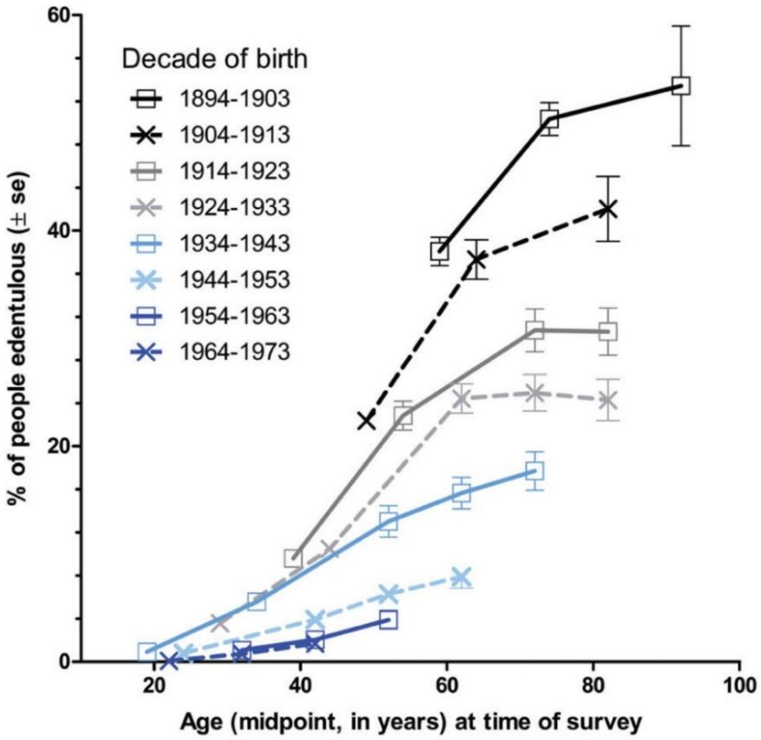
Figure 2-3 shows the trends in edentulism in the adult population of England for 1978, 1988, 1998 and 2009. It illustrates an age-related curve which has moved downwards (indicating a decline in total tooth loss) with each decade. These age trends suggest that being edentate was more about generation than about age, as in 2009, adults younger than 65 years had rarely lost all their natural teeth. Those adults who were edentate at a young age in the post-war years and who were represented in the early adult dental health surveys were now dying out and were being replaced by a dentate generation. This had been apparent and predicted since the publication of the 1988 adult dental health survey but the process is now very well developed (Gray et al., 1970, Walker and Cooper, 2000).



(Steele et al., 2012)

Figure 2-3: The percentage of edentate adults by age group in England from 1978 to 2009.

Figure 2-4: Illustrates the age cohort effect in the USA, which like in England suggests that as younger adults were no longer becoming edentate then edentulism in older age reduced considerably.



(Slade et al., 2014)

Figure 2-4: Age cohort plot of edentulism prevalence in 8 birth cohorts of U.S. adults in 5 national surveys, 1957-1958 to 2009-2012.

There has been a decline in edentulism in all the countries reported in Table 2-4. The USA and Canada had the lowest levels of edentulism in all years compared to the UK, Ireland, Australia and New Zealand. Where there was data from several national surveys available there was a clear indication of a cohort effect, increased tooth retention in younger adults appears to translate into less edentulism in the older age groups. Longitudinal cohort studies are required to determine the effect of age progression of edentulism.

A 24-year longitudinal population study of Swedish women also reported that the level of edentulism was 15% among 54-year-olds examined in 1969, 22% in 1981 at age 62 years and 26% in 1993 at age 78 years (an estimated annualised incidence of 0.46 percentage points). The corresponding figures for 46-year-olds were 8%, 12% and 15% (an estimated annualised incidence of 0.29 percentage points). It was concluded that there was a decrease with time in the incidence of edentulism (Ahlqwist et al., 1999). In many of the studies, and in different countries, women had a higher prevalence of edentulism which appears to have reduced over time (Suominen-Taipale et al., 1999, Mojon, 2003, Mack et al., 2003, Müller and Nitschke, 2005).

Table 2-5: Edentulism prevalence in different countries by gender and year of examination.

Country	Years of Survey	Age group	% Edentate	
			Male	**Female**
Ireland	2000-02	35-44 years	1%	0.9%
		65 years and over	34.6%	45.5%
	1989-90	35-44 years	3%	5%
		65 years and over	33%	61%
UK	2009	35-44 years	0%	1%
		45-54 years	2%	1%
		55-64 years	4%	7%
		65-74 years	16%	15%
		75-84 years	27%	33%
		85 years and over	28%	55%
Canada	FNOHS 2009-10	ALL	7.6%	11.1%
	IOHS 2008-09	ALL	6.0%	6.8%
	CHMS 2007-09	ALL	6.3%	6.5%
USA	2010-12	65 years and over	17.5%	19.4%
Australia	2013	45 years and over	3.9%	4.9%
	2004-06	55-64 years	1.6%	1.8%
		65-74 years	11.8%	16.0%
		75 years and over	31.0%	38.9%
New Zealand	2009	All	8.8%	9.9%
Six countries (India, China, Ghana, Mexico, Russia and South Africa)	2007-2010	50 years and over	10.4%	13.0%

(O'Mullane and Whelton, 1992, Sanders et al., 2004, Whelton et al., 2007, Slade et al., 2007, SuominenTaipale et al., 2008, Haisman et al., 2010, Health Canada, 2010, Statistics Canada, 2010, Inuit Oral Health Survey, 2011, Steele et al., 2012, Dye et al., 2012, The First Nations Information Governance Centre, 2012, Harford and Islam, 2013, Peltzer et al., 2014, Dye et al., 2015)

From the data reported in Table 2-5, a higher proportion of women than men were edentate in the older age groups in Ireland, Australia, New Zealand, USA and Canada. This gender difference varied in different countries in different years. For example, among adults aged 65 years and over, the gender difference was just 1.9% in the USA in 2011-12 compared with 10.9% in Ireland in 2000-02. For those aged 65-74 years, the gender difference was just 1% in the UK in 2009 when more males were edentate than females, it was 4.2% in Australia in 2004-05 where more females were edentate than males. In 2004-06, Australia had a higher gender difference of 7.9% (M = 31.1% vs F = 38.9%) in those aged 75 years and over compared with the UK for those aged 75-84 years (M = 27% vs F = 33%) in 2009. These changes suggest there has been a decrease in gender difference over time.

The trend in relation to gender difference was similar, and most of the studies including Irish studies, reported that edentulism was more prevalent in females and this gender difference was greater in the older age groups. It has been suggested that the gender difference might have changed over time in each country because of the decrease in the prevalence of edentulism among females (Mojon, 2003, Whelton et al., 2007). Similar trends are shown in Table 2-5, in Ireland, from 1989-90 to 2000-02, the proportion of edentate males aged 65 years and over, increased from 33% to 34.6% and proportion of edentate females decreased from 61% to 45.5%, which led to the decrease in gender difference over that time in Ireland (O'Mullane and Whelton, 1992, Whelton et al., 2007).

As might be expected, the studies reviewed indicated a negative effect of poor socioeconomic status on edentulism (except among First Nation adults in Canada), although the variables used to represent socioeconomic status were different between the countries reviewed. For example, in Ireland possession of medical card was used as a proxy for poor economic status, in the UK occupation was used as an indicator of socioeconomic status while in Australia and Canada it was level of education (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012, Dye et al., 2012).

It is important to note that a few countries reported edentulism prevalence by socioeconomic variables in the whole sample and some in each age group. Nonetheless, the effect of these socioeconomic factors was the same when stratified by age group or where reported in the whole sample.

Table 2-6 shows, in Ireland for those aged 65 years and over, more medical card holders were edentate than non-medical card holders, these findings were same in those aged 35-44 years as seen in Table 2-2. The trend was similar in the UK, Australia and in six countries (India, China, Ghana, Mexico, Russia and South Africa). However, in FNOH survey of Canada, more adults with an income of more than $20,000 per year were edentate than adults with an income level less than $20,000 per year. As this was a survey of an ethnic group, it suggests that there were possibly other reasons for this result. Table 2-6 also shows that a lower level of education had a negative effect on edentulism. However, in Canada in the FNOH survey, more adults with more than high school education were edentate (7.6%) than adults with high school or less education (5.7%).

Table 2-6: Percentage of edentate adults in different countries by socioeconomic status and ethnic group.

Country and year of survey	Socioeconomic Variables	Categories of Socioeconomic Variables	Age Groups	Edentulism
Ireland 2000-02	**Medical card possession**	No medical card	65 years and over	29.4%
		Medical card		45.6%
UK 2009	**Occupational status**	Managerial and professional occupations	All	2%
		Intermediate occupations		5%
		Routine and manual occupations		10%
	Countries	England	All	6%
		Wales		10%
		Northern Ireland		5%
USA	**Racial groups 2011-12**	Non-Hispanic white	65 years and over	16.9%
		Non-Hispanic black		29.2%
		Hispanic		14.9%
		Non-Hispanic Asian		24.2%
	Poverty level 2005-08	Below 100% of poverty level	65 years and over	36.8%
		100% or less than 200% poverty level		31.4%
		200% or higher poverty level		16.1%
Canada FNOH 2009-10	**Income level**	< $20000	All	5.8%
		≥ $20000		6.9%
	Education level	High school or less	All	5.7%
		More than high school		7.6%
	Area of residence	Urban community	All	5.9%
		Non-Urban community		7.9%
Australia 2004-06	**Level of schooling**	Year 9/less	All	21.9%
		Year 10/more		4.1%
	Indigenous Identity	Indigenous	All	7.9%
		Non-indigenous		6.4%
	Residential location	Capital city	All	5.0%
		Other areas		9.0%
	Eligibility for public dental care	Eligible	All	17.1%
		Ineligible		2.7%
New Zealand 2009	**Ethnic groups**	Maori	All	10.4%
		Pacific		4.0%
		Asian		1.3%
		European /others		10.2%
Six countries (India, China, Ghana, Mexico, Russia and South Africa) 2007-2010	**Education level**	None	50 years and over	17.8%
		1-4 years		11.9%
		5-8 years		9.7%
		9/more years		7.3%
	Wealth	Lowest	50 years and over	16.9%
		Low		13.1%
		Medium		12.3%
		High		9.4%
		Highest		8.6%

(Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012, Dye et al., 2012, Peltzer et al., 2014, Dye et al., 2015)

It can be seen that not only socioeconomic factors influenced edentulism prevalence, the proportion of edentate adults also varied in different areas in each country. For example, in Australia, fewer adults living in a state capital city were edentate (5%) than adults living in other areas (9%) and in Canada, fewer adults in urban communities were edentate (5.9%) than adults in

non-urban communities (7.9%). In 2009, in the UK, Wales had the highest proportion of edentate adults (10%) and Northern Ireland had the lowest (5%) which again demonstrates regional variation. Furthermore, Table 2-6 also shows that the proportion of edentate adults also varied among different ethnic groups in each country. For example, in 2011-12, in the USA, non-Hispanic black people had the highest edentulism prevalence among adults aged 65 years and over, compared to other racial groups at 29.2% compared with the Hispanic group at 14.9%.
These comparisons also suggest that the effects of socioeconomic status were the same in both developed countries such as USA and UK and in six middle-income countries (India, China, Ghana, Mexico, Russia and South Africa) except in Canada.

2.4.2 Numbers of teeth, functioning dentition and denture wear

This section discusses the number of natural teeth present among older adults according to the mean number of teeth, percentage of adults with 20 or more natural teeth and percentage with 18 or more sound, untreated natural teeth (18+SUNT). Though the mean number of teeth is a somewhat crude oral health statistic as it takes no account of the caries or periodontal status of the remaining teeth, it is nonetheless a simple indicator of oral health status. The retention of 20 or more natural teeth is a more discriminating figure as it is widely used to define the minimum number of teeth consistent with a functional dentition (Wayler et al., 1982, World Health Organisation, 1992, Sheiham et al., 1999, Hobdell et al., 2003, Gotfredsen and Walls, 2007, Koltermann et al., 2011). The presence of 20 teeth in functional occlusion (i.e. biting against or in contact with opposing teeth) is thought to be sufficient to enable good oral function. Studies have suggested that 20 teeth in contact are the minimum sufficient for normal masticatory functions without the need for replacement of missing teeth (Sheiham et al., 1999, Hobdell et al., 2003, Gotfredsen and Walls, 2007, Koltermann et al., 2011). Previous studies had also concluded that 20 natural teeth were sufficient for satisfactory chewing function (Elias and Sheiham, 1998), diet and nutritional status (McGrath and Bedi, 2002). Adults with fewer than 20 teeth were reported to be more likely to suffer impaired oral health-related quality of life compared to adults with more teeth (Sheiham et al., 2002).

While retention of teeth and a minimum functioning dentition are important to ensure good oral function, the retention of teeth in an undamaged state is an important indicator of the effectiveness of the measures to prevent dental caries. The term ‘sound and untreated teeth’ is defined as where there is no visible decay or restoration of any kind, including those, such as veneers and crowns, which are not always placed to manage disease in the teeth. This parameter not only represents the historical absence of disease but also reflect trends in dental care towards prevention and is analogous to the proportion caries free in surveys of children and adolescents

(O'Sullivan et al., 2011). So the retention of 18 or more sound and untreated teeth (18+SUNT) was an additional marker of oral health in a population (O'Sullivan et al., 2011).

2.4.2.1 Mean number of natural teeth, more than 20 natural teeth, 18+SUNT and denture wearing in Ireland

Table 2-7 shows that in Ireland from 1989-90 to 2000-02, the mean number of natural teeth present increased from 21.0 to 25.2 in 35-44 year-olds and 7.3 to 8.5 in those aged 65 years and older (O'Mullane and Whelton, 1992, Whelton et al., 2007).

Furthermore, it was reported that in adults aged 65 years and older, males tended to possess more natural teeth than females. The mean number of natural teeth present among females aged 65 years and over was 7.4 compared with 9.9 for males in 2000-02, and in 1989-90 in the same age group males had 10.1 and females 4.9 respectively. Between 1989-90 and 2000-02 there was an increase in the mean number of teeth present particularly among females, which narrowed the gender gap in terms of the mean number of natural teeth present (O'Mullane and Whelton, 1992, Whelton et al., 2007). It reflects a trend over time among females towards the increased retention of natural teeth (Table 2-7).

Table 2-7: Mean number of natural teeth by years of examination, age group, gender and medical card status, in Ireland (Base-edentate and dentate).

Year of survey	**Age groups**	**Mean number of teeth by age group and gender**			**Mean number of teeth by age group, gender and medical card status**					
					Medical card holders			**Non-Medical holders**		
		M	**F**	**Total**	**M**	**F**	**Total**	**M**	**F**	**Total**
2000-02	**35-44 years**	25.3	25.1	25.2	23.2	23.5	23.4	25.9	25.7	25.8
	65 years and over	9.9	7.4	8.5	8.1	6.6	7.2	13.3	9.8	11.6
1989-90	**35-44 years**	22.1	20.2	21.0	22.4	20.1	20.9	22.0	20.3	21.1
	65 years and over	10.1	4.9	7.3	8.3	3.1	5.3	11.9	7.7	9.9

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

The mean number of natural teeth present by age group, gender and medical card status showed that those in possession of medical cards tended to have fewer natural teeth present than those who did not possess a medical card. This difference was highest in those aged 65 years and older (Table 2-7). The data indicate that gender differences had decreased both for the less well off (medical card holders) and the rest of the population, particularly in those aged 65 and older between the two surveys (O' Mullane and Whelton, 1992, Whelton et al., 2007).

The mean numbers of natural teeth present stratified by general health status (ASA) and age group are shown in Table 2-8. As with edentulism, those with no systemic disease (ASA 1) generally had more teeth than those with systemic disease (ASA 2 and ASA 3).

*Table 2-8: Mean number of natural teeth present according to general health status (ASA) by age group and year of examination, in Ireland. NA stands for not available and *n<30 (Base-edentate and dentate).*

Year of examination	**Age groups**	**ASA 1 Mean**	**ASA 2 Mean**	**ASA 3 & 4 Mean**	**Total**
2000-02	**35-44 year**	25.3	23.3	NA	25.2
	65 years and over	9.5	6.6	6.0*	8.5
1989-90	**55 years and over**	8.9	6.0	5.9	NA

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

In the Irish adult surveys, the possession of more than 20 natural teeth was reported according to age, gender and general health status. Table 2-9 shows that there was a lower proportion of females with more than 20 natural teeth in all age groups. In 2000-02, in the 65 and older age group, 20.8% of males possessed more than 20 natural teeth compared with 13.5% of females. These percentages increased from 15.3% for males and 6.9% for females in 1989-90. In all the age groups shown in Table 2-9, there were fewer females than males with a minimum functioning dentition but a reduction of the gender difference over time is also apparent. It is interesting to look at the females in those aged 55-64 years in 1989-90 and compare them with the females in 65 years and over age group in 2000-02 (approximately 10 years later). There was only a very small reduction in the proportion of these females with more than 20 natural teeth which suggests that the previous pattern of increasing tooth loss with age was changing. All of these changes reflect encouraging improvements in the oral health of these age groups of adults.

Table 2-9: Percentage of adults with more than 20 teeth by age group, gender and year of examination, in Ireland (Base-edentate and dentate).

Year-of examination	Age groups	Male (%)	Female (%)	Total
2000-02	**35-44 years**	90.7	88.8	89.7
	65 years and over	20.8	13.5	16.7
1989-90	**35-44 years**	68.2	58.3	62.5
	45-54 years	41.6	28.0	34.0
	55-64 years	24.1	13.7	18.1
	65 years and over	15.3	6.9	10.7

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-10 shows that in the 2000-02 survey, the percentage of males and females with more than 20 natural teeth was lower in those who had a medical card when compared with non-medical card holders in the 65 years and over age group.

Table 2-10: Percentage of adults with more than 20 teeth by age group, gender and medical card status in 2000-02, in Ireland (Base-edentate and dentate).

More than 20 teeth	35-44 years		65 years and over	
	MC Yes	**MC No**	**MC Yes**	**MC No**
Total	79.7%	92.5%	11.4%	29.3%
Male	80.7%	93.3%	12.4%	36.4%
Female	79.0%	91.8%	10.7%	21.9%

(Whelton et al., 2007)

In the 2000-02 survey, for those aged 65 years and over, 3.4 times as many male non-medical card holders had more than 20 teeth as medical card holders (36.4% vs. 12.4%). For females, twice as many non-medical card holders had more than 20 teeth as medical card holders (21.9% vs. 10.7%) (O'Mullane and Whelton, 1992, Whelton et al., 2007).

Table 2-11 shows that in 2000-02 the possession of more than 20 natural teeth appears to be associated with general health status. In the 1989-90 survey, no relationship was found between general health status and possession of more than 20 natural teeth in those aged 55 years or more. For example, 15.7% adults with ASA 1 had more than 20 teeth and only 7.4% with ASA 2 had more than 20 teeth but this percentage again increased in the ASA 3+4 group (15.2%).

*Table 2-11: Percentage of adults with more than 20 natural teeth by age, general health status and year of examination, in Ireland. NA stands for not available and *n<30 (Base-edentate and dentate).*

Year of examination	Age group	ASA 1	ASA 2	ASA 3+4	Total
2000-02	**35-44 years**	90.0%	83.4%	*	89.7%
	65 years and over	19.4%	13.1%	4.6%	16.7%
1989-90	**55 years and over**	15.7%	7.4%	15.2%	NA

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

A key outcome measure of good oral health in a population is the retention of a high proportion of natural teeth that have not decayed, been filled or traumatised. The number of teeth that were not decayed, filled, otherwise restored or traumatised on their coronal surfaces was also counted in the Irish national oral health surveys. It is accepted that teeth counted as sound (no disease) in a survey might have caries, visible only with a full clinical examination and with the use of radiographs to aid diagnosis. All dental surveys (depending upon examination criteria used), to some extent, underscore the true level of caries in the population. In the Irish surveys for possession of 18+ SUNT, visual caries was not considered and the number of teeth that were not decayed (at cavitation level), filled otherwise restored or traumatised on their coronal surfaces were counted (Whelton et al., 2007).

The percentages of adults with 18+SUNT in relation to age, gender, and years of examination are shown in Table 2-12. It can be seen that in 1989-90 only a small percentage of the adult population in Ireland achieved this level of oral health. However, in 2000-02, the situation had improved, as the percentage for those aged 65+ the increased from 2.1% to 3.3%, from 1989-90 to 2000-02. For all age groups, the percentage of females with 18+ SUNT tended to be lower than males. However, like other parameters measured, the gender difference decreased in 2000-02 from 1989-90.

Table 2-12: Percentage of adults with 18+ SUNT by age, gender and year of examination, in Ireland (Base-edentate and dentate).

Years of examination	Age groups	Male (%)	Female (%)	Total (%)
2000-02	**35-44 years**	38.9	34.7	36.8
	65 years and over	5.6	1.6	3.3
1989-90	**35-44 years**	21.8	12.1	16.2
	45-54 years	11.7	4.0	7.4
	55-64 years	6.9	2.6	4.4
	65 years and over	4.5	0.0	2.1

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

The percentages of adults with 18+ SUNT in relation to age, gender and medical card status were also calculated in the Irish surveys. Table 2-13 shows that the presence of 18+ SUNT was not consistently related to disadvantage in the different age groups, as measured by possession of a medical card. It also shows that from 1889-90 to 2000-02, among the 65 and older age group, for medical card holders there was 0.1% decrease in adults with 18 +SUNT and for the same age group among non-medical card holders the percentage of adults with 18+ SUNT increased 0.9% to 4.4%.

Table 2-13: Percentage of adults with 18+ SUNT according to age, gender, year of examination and medical card status, in Ireland (Base-edentate and dentate).

Year of survey	Age group	Medical card holders			Non-Medical holders		
		M (%)	F (%)	Total (%)	M (%)	F (%)	Total (%)
2000-02	**35-44 years**	31.8	43.6	38.7	40.2	32.3	36.4
	65 years and over	4.8	1.7	2.9	7.2	1.5	4.4
1989-90	**35-44 years**	32.3	18.8	23.3	19.9	9.7	14.2
	65 years and over	7.1	0.0	3.0	1.9	0.0	0.9

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-14 shows in those aged 65 years and older, 4.2% of those without systemic disease had 18+ SUNT compared with 1.9% with mild systemic disease.

*Table 2-14: Percentage of adults with 18+SUNT by age, general health status and year of examination, in Ireland. NA stands for not available and *n<30 (Base-edentate and dentate).*

Years of examination	Age groups	ASA 1	ASA 2	ASA 3+4	Total
2000-02	**35-44 years**	36.8%	35.7%	*	36.8%
	65 years and over	4.2%	1.9%	0.0%	3.3%
1989-90	**55 years and over**	3.0%	2.5%	6.1%	NA

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

As previously discussed, there has been an increasing trend of natural teeth being retained among older adults over the years in Ireland, which in turn affected the level of wearing complete or partial dentures. The data from the previous two studies 2000-02 and 1989-90 are compared in Table 2-15. It shows that in the 2000-02 Irish survey the percentage of older adults wearing all types of dentures was greater in the older age group and few people wore full lower dentures only. From 1989-90 to 2000-02, the level of all types of denture use decreased for 35-44-year-olds as 68.0% of this group did not wear a denture in 1989-90 when compared with 83.6% in 2000-02 which reflects a positive trend towards the retention of natural teeth.

Table 2-15: Percentage of adults wearing complete upper and lower (C/C), complete upper only (C/-), complete lower only (-/C) and partial dentures (P/P, P/-, -/P) and combination of both (C/P, P/C) according to age group and years of survey, in Ireland (Base-edentate and dentate).

Years of survey	Age Group	No Dentures	C/C	C/-	-/C	P/P	P/- or -/P	P/C or C/P
2000-02	**35-44 years**	83.6	0.6	1.3	0.0	1.6	12.7	0.2
	65 years and over	26.0	31.0	12.8	0.3	8.0	16.4	5.4
1989-90	**35-44 years**	68.0	3.3	4.8	0.0	2.1	21.0	0.7
	65 years and over	42.6	29.8	12.0	0.8	4.6	5.8	4.6

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Wearing complete dentures in either one or both arches changed little amongst the 65 years and older age group. In 2000-02, more adults aged 65 and older were wearing partial dentures which may explain the fall in the percentage in the "No Dentures" category in 2000-02. The increase in the partial denture category may be a reflection of increased access to dental care in this age group.

2.4.2.2 International comparisons

This section will report comparisons and trends of the mean number of teeth and of retention of 21 or more teeth between different countries, against a background of some methodological variations in oral health studies among these countries. For example, some oral health surveys such as in the UK, Australian and New Zealand oral health surveys, reported the mean number of teeth among the dentate sample, while the Irish surveys reported mean number of teeth among the complete sample (edentate and dentate). Furthermore, the Australian surveys reported the mean number of missing teeth instead of the mean number of teeth present (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Steele et al., 2012).

Table 2-16 shows the mean number of teeth in different countries, although the age groups are somewhat different among these countries, nonetheless, that there has been a trend of more retained teeth among older adults in these countries. However, in Ireland in 2000-02 the mean number of teeth in those aged 65 years and over, was much lower than in all the other countries in the table. For example, the UK figure for 2009 in those aged 85 years and over was 14.0 compared with the Irish figure of 8.5 for those aged 65 years and over, which represents a large discrepancy given that the UK group was as much as 20 years older. Some of this discrepancy may be explained by the calculation being based on the dentate sample in the UK and higher levels of edentulism in Ireland in this age group. The most recent figures for those aged 35-44 years in Ireland and the UK are closer (25.2 and 27.6) which may be an indication of an improvement in retention of teeth in older adults in Ireland and given that only 0.9% of that age group was edentulous and the method of calculation had only a minor impact on the figure.

Table 2-16 also shows that the difference in the mean number of teeth between different countries varied by age group and year of study. For example, in 2009, adults aged 65-74 years in the UK had a slightly higher mean number of teeth (20.9) than adults of the same age group in New Zealand (19.7). Adults aged 75 years and over, in New Zealand had nearly the same mean number of teeth (18.1) compared to the same age group in Australia (17.9) although the Australian survey was done 3-5 years before the New Zealand survey. The UK adults aged 75-84 years had a similar mean number of teeth (17.1) as adults aged 75 years and over in New Zealand

(18.1) both for 2009. There were very similar figures in those aged 55-64 years, in New Zealand in 2009 (24.0), in the UK (23.2) in 2009 and those aged 40-59 years in Canada in 2007-09 (21.2).

As might be expected given the low mean numbers of teeth in Ireland, the proportion of adults with 21 or more teeth was also much lower in Ireland than in all the other countries in Table 2-16. It is notable that 54% of those aged 75 years and over in New Zealand had 21 or more teeth and in Canada, 57.8% of those aged 60-79 years had 21 or more teeth. The proportions in Australia and the UK were quite similar, 44.9% of those aged 75 years and over in Australia and 40% of those in the UK aged 75-84 years with 21 or more teeth. The 2000-02 figure in Ireland for those aged 65 years and over of 16.7% lags very far behind the other countries in the table and the method of calculation might only explain some of this difference.

Table 2-16: Mean number of teeth per person and percentage of adults with ≥21 more teeth by age group, country and examination year (Dentate sample).*

Country	Year of Examination	Age group	Mean number of teeth	% of adults with ≥21 teeth
Ireland	**2000-02**	**35-44 years**	25.2	89.7
		65 years and over	8.5	16.7
	1989-90	**35-44 years**	21.0	62.5
		65 years and over	7.3	10.7
UK*	**2009**	**35-44 years**	27.6	97
		45-54 years	26.0	91
		55-64 years	23.2	75
		65-74 years	20.9	61
		75-84 years	17.1	40
		85 years and over	14.0	26
Canada	**FNOHS 2009-10**	**40 years and over**	20.5	55.2
	IOHS 2008-09	**40 years and over**	15.8	31.0
	CHMS 2007-09	**40-59 years**	24.1	83.5
		60-79 years	19.4	57.8
New Zealand*	**2009**	**45-54 years**	25.6	87.6
		55-64 years	24.0	83.6
		65-74 years	19.7	54.9
		75 years and over	18.1	54.0
Australia*	**2004-06**	**35-54 years**	26.8	93.2
		55-74 years	21.8	71.4
		75 years and over	17.9	44.9

(Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Inuit Oral Health Survey, 2011, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012)

2.4.2.3 Factors associated with mean number of teeth and 21 or more teeth

Table 2-16 shows that age was an important factor in relation to the mean number of teeth. In general, there was a lower mean number of teeth in the older age groups and this decrease in mean number of teeth with age varied among different countries, though direct comparisons between countries are difficult as the age groups used, and years of the studies varied.

In Ireland (2000-02) the difference in mean number of teeth between adults aged 35-44 years and 65 years and over, was higher (25.2 vs 8.5) as compared to the difference in the UK (2009) between adults aged 35-44 years and 64-75 years (27.6 vs 20.9). In 2009, between adults aged 45-55 years and 65-74 years, in the UK and New Zealand the difference of the mean number of teeth was similar, (26.0 to 20.9) and (25.6 to 19.7). Table 2-16 also shows that in the younger age group the mean numbers of teeth were somewhat similar in the different countries.

As might be expected from the figures on the mean number of teeth, the proportion of adults with 21 or more teeth decreased with age, and again this decrease varied among different countries (Table 2-16). For example, in 2000-02, in Ireland, the proportion of adults with 21 or more teeth decreased from 87.6% in those aged 35-44 years to 16.9% in those aged 65 years and over. In 2009, among adults aged 65-74 years, the UK had a higher proportion of adults with 21 or more teeth (61%) compared to New Zealand (54.9%). Among adults 75 years and over, New Zealand in 2009, had a higher proportion of adults (54.0%) with 21 or more teeth than Australia in 2004-06 (44.9%). Furthermore, the UK in 2009, had the lowest proportion of adults aged 75-84 years with 21 or more teeth (40%) compared with New Zealand (54.0%) and Australia (44.9%) for those aged 75 years and over.

Table 2-17 demonstrates the gender difference in the mean number of teeth and the proportion of adults with 21 or more teeth in different countries. Some studies reported the gender difference in the whole sample and others in different age groups which makes comparisons difficult.

It can be seen in Table 2-17 that the gender difference was present in relation to mean number of teeth and proportion of adults with 21 or more teeth in every country, with females generally having lower mean numbers of teeth and lower percentages with 21 or more teeth. In different countries, and in different years the trends of in relation to gender difference in the mean number of teeth were similar to Ireland, females tended to have a lower mean number of teeth than males though the differences in many cases were very small. The exceptions were in the

FNOHS and in Australia where females had more teeth than males (M= 17.2 vs F= 18.3) in those aged 75 years and over.

It is interesting to note the trends in relation to the change in gender difference with age. For example, in 2000-02 in Ireland, the gender difference increased from those aged 35-44 years (M=25.3 vs F=25.1) to those aged 65 years and over (M=9.9 vs F=7.4) which may be a reflection of better access to dental care in the younger age group. In 2004-06, in Australia, the gender differences were very small in all age groups even in those aged 75 years and over.

*Table 2-17: Mean number of teeth per person and percentage of adults with 21 or more teeth by gender, age group in different countries (*Dentate sample).*

Country	Year of Survey	Age group	Mean number of teeth		% of adults with ≥21 teeth	
			Male	Female	Male	Female
Ireland	**2000-02**	**35-44 years**	25.3	25.1	90.7%	88.8%
		65 years and over	9.9	7.4	20.8%	13.5%
UK*	**2009**	**All**	25.8	25.5	86%	86%
Canada	**FNOHS 2009-10**	**All**	22.8	24.1	76.7%	81.9%
	IOHS 2008-09	**All**	21.1	19.6	68.0%	56.9%
	CHMS 2007-09	**All**	24.7	24.4	85.9%	85.0%
Australia*	**2013**	**45 years and over**	27.4	26.6	N/A	N/A
	2004-06	**35-54 years**	27.1	26.4	93.4%	93%
		55-74 years	21.8	21.7	73.4%	69.3%
		75 years and over	17.3	18.3	43.7%	45.8%
New Zealand *	**2009**	**All**	26.1	25.8	87.6%	89.5%

(Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Inuit Oral Health Survey, 2011, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012)

Table 2-17 also shows that a gender difference was present in relation to the proportion of adults with 21 or more teeth in all countries reported except in the UK in 2009, where a similar proportion of males and females had 21 or more teeth (86%). It is of note that there is not a clear trend in the direction of the gender difference as in some studies such as Ireland (65 years and over in 2000-02) Canada (CHMS), Australia (55-74 years in 2004-06) the figure was higher for males. However, in 2007-09 in FNOH and in 2009 in New Zealand, a higher proportion of females had 21 or more teeth than males.

It can also be seen in Table 2-17 that the gender difference in relation to the proportion of adults with 21 or more teeth also varied with age. In Ireland in 2000-02, the gender difference in relation to the proportion of adults with 21 or more teeth increased from the age group 35-44 years to 65 years and over. In Australia, in 2004-06 it also increased from the age group 35-54 years to age group 55-74 years but reversed in the age group 75 years and over, where a higher proportion of females had 21 or more teeth than males.

Table 2-18 shows that poor socioeconomic status had a negative impact on the mean number of natural teeth and on the proportion of adults with 21 or more teeth present, among older adults except in Canada. For example, in Ireland, adults aged 65 years and over with medical card had a lower mean number of teeth (7.2) than adults of the same age group with no medical card (11.6). In the UK, overall the adults with routine and manual occupations had a lower mean number of teeth (24.7) compared with adults with managerial and other professional occupations (26.6). However, in FNOHS survey of Canada, adults with more than $20,000 per year income had the same mean number of teeth (22.9) as adults with income level less than $20,000 per year (23.0).

Table 2-18 also shows, that in Ireland for those aged 65 years and over, a lower proportion of medical card holders had 21 or more teeth (11.4%) compared with non-medical card holders (25.9%), these finding were also same in those aged 35-44 years (Whelton et al., 2007). The effect of poor economic status was similar in other countries. However, in the FNOHS survey of Canada, a lower proportion of adults with more than $20,000 per year income had 21 or more teeth (74.4%) compared with adults with income level less than $20,000 per year (78.4%). These comparisons suggest that in the UK, USA, Australia, New Zealand and Ireland, the effects of socioeconomic status on mean number of teeth and the proportion of adults with 21 or more teeth were same.

*Table 2-18: Mean number of teeth per person and percentage of adults with 21 or more teeth in different countries by socioeconomic status, area of residence and ethnic group (*Dentate sample).*

Country & examination year	Socioeconomic Variables	Categories of Socioeconomic Variables	Age group	Mean number of teeth	% of adults with ≥ 21 teeth
Ireland 2000-02	Medical card possession	No medical card	65 years and over	11.6	29.3%
		Medical card		7.2	11.4%
UK* 2009	Occupational Status	Managerial & professional occupations	All	26.6	92%
		Intermediate occupations		25.3	85%
		Routine and manual occupations		24.7	79%
	Countries in the UK	England	All	25.7	86%
		Wales		24.3	80%
		Northern Ireland		25.1	85%
Canada FNOH 2009-10	Income level	< $20000	All	23.0	78.4%
		≥ $20000		22.9	74.4%
	Education level	High school or less	All	23.3	77.5%
		More than high school		24.7	90.3%
	Area of residence	Urban community	All	23.6	80.4%
		Non-Urban community		22.8	75.1%
Australia* 2004-06	Level of schooling	Year 9/less	All	22.0	66%
		Year 10/more		26.4	91.4%
	Indigenous Identity	Indigenous	All	24.6	89.6%
		Non-indigenous		25.9	88.6%
	Residential location	Capital city	All	26.3	90%
		Other areas		25.2	86%
	Eligibility for public dental care	Eligible	All	23.3	72.9%
		Ineligible		26.8	93.3%
New Zealand*	Ethnic groups	Maori	All	25.9	87.0%
		Pacific		26.8	87.6%
		Asian		28.0	95.0%
		European /others		25.7	88.4%

(Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Inuit Oral Health Survey, 2011, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012)

Table 2-18 also shows that in all reported countries, the lower levels of education had a negative effect on mean number of teeth and the proportion of adults with 21 or more teeth. Not only socioeconomic factors influenced the mean number of teeth and the proportion of adults with 21 or more teeth, but they also varied in different areas in each country. For example, in Australia adults living in a capital city had a higher mean number of teeth (26.3) and had a higher proportion of adults with 21 or more teeth (90%) than adults living in other areas (with a mean number of teeth of 25.2 and the proportion of adults with 21 or more teeth of 86%) and in

Canada adults in urban communities had a higher mean number of teeth (23.6) and a higher proportion of adults with 21 or more teeth (80.4%) than adults living in other areas (with mean number of teeth of 22.8 and the proportion of adults with 21 or more teeth of 75.1%). Similar variation in the mean number of teeth and the proportion of adults with 21 or more teeth were also seen among the different countries of the UK.

Table 2-18 also shows that the proportion of adults with 21 or more teeth also varied among different ethnic groups in each country. For example, in New Zealand, Maori (87%) had the lowest and Asian had the highest proportion of adults with 21 or more teeth (95%). In Canada, non-aboriginals had the highest mean number of teeth compared with the First Nation and Inuit adults (Inuit Oral Health Survey, 2011, The First Nations Information Governance Centre, 2012). Slade and colleagues in 2007, also reported that the mean number of teeth and the proportion of adults with 21 or more teeth, also varied with area of residence in the same country for the same age group. The adults living in a capital city had a higher mean number of teeth compared with adults living in areas other than capital cities (Slade et al., 2007).

Studies have reported that with age, the use of dentures increased and because of the increase in retained teeth in past decades, there has been a change in the type of dentures from complete to partial dentures among older adults (Whelton et al., 2007, Slade et al., 2007). For example, in Ireland, there was an increase in the number of older people wearing partial dentures (P/P) in 2000-02 compared with 1989-90 (4.6% to 8.0%). In those aged 65 years and over with no natural teeth, 6.0% had no dentures in 2000-02 which had improved from 1989-90 when 21.4% had no dentures (Whelton et al., 2007). In 2007, Slade and colleagues also reported that in Australia the proportion of dentate adults with partial dentures increased with age because of the increase in the mean number of missing teeth with age. Petersen and colleagues in 2005 reported that the prevalence of removable dentures also showed considerable variation by socioeconomic status. The rates were high among the socioeconomically poor countries. The speculated reason was, as the dentures are the cheapest way to replace teeth when compared with implants and bridges (Petersen and Yamamoto, 2005).

From the data reported in this section, it can be concluded that over time there has been an increase in tooth retention among older adults in the different countries reviewed. Age, gender socioeconomic status and area of residence had a significant impact on the number of teeth present.

2.4.3 Dental Caries

Dental caries and periodontal disease are the two most common dental diseases which may affect many older populations in the world (Greene and Suomi, 1977, Petersen et al., 2005, Frencken et al., 2017). While in recent years the levels of dental caries have been falling, particularly in developed countries, Frenken and colleagues in 2017 concluded that untreated, cavitated dentine carious lesions in permanent teeth remained the most prevalent health (not oral health) condition across the globe in 2010, affecting 2.4 billion people (Frenken et al 2017).

It is vital to have an accurate measure of dental caries prevalence among populations in order to provide an evidence-base for oral health policy (Selwitz et al., 2007). The DMFT index was developed in the 1930s and for many years the WHO has recommended its use as a standardised method of recording dental caries (Klein et al., 1938, World Health Organization, 2013). Most of the studies reviewed here have used this WHO recommended index (DMFT) for assessment of caries prevalence. The DMFT index not only provides information about the current level caries status of the teeth, but it also accounts for the caries status of each tooth or space, so the cumulative caries history of each tooth is recorded from sound, to decay, to filled due to caries and to extracted due to caries. Analysis of the components of DMFT provides insight into access to and the type of dental services available to a population (Radike, 1968). Using the WHO criteria, DMFT records caries at cavitation level that can be confirmed by placing the probe in the cavity. So, it provides a record of caries at quite an advanced level of disease rather than complete absence or presence of disease. As a result, in 1990 the British Association for the Study of Community Dentistry (BASCD) amended its examination criteria and included a diagnosis of visual caries in its DMFT score (Pitts et al., 1997). Both in Irish and UK surveys, BASCD visual caries (caries visible as a shadow under intact enamel or restoration with no cavitation) was included in the DMFT criteria since the mid-1990s (Whelton et al., 2007, Fuller et al., 2011).

Mean DMFT has been used widely as a measure of dental caries in populations from many years, but it has a shortcoming when it is used in older age groups because the reasons for tooth loss may be uncertain and perhaps not due to dental caries (Petersen et al., 2010). However, with falling levels of dental caries, ascertaining the reasons for tooth loss will become less problematic. Notwithstanding the limitations of this index, most studies have used the DMFT index to assess the crown caries prevalence among older adults and have reported the importance of past caries experience for predicting the future caries risk and variations in prevalence of dental caries in association with demographic, socioeconomic and behavioural characteristics of adults (Kavanagh, 1994, Powell, 1998, Petersen et al., 2005). As a result of the difficulty in being sure about the reasons that teeth are missing in adults, in recent years some countries (the UK, US and

Australia) have reported their caries data somewhat differently reporting the prevalence of untreated caries rather than mean DMFT (Slade et al., 2007, Fuller et al., 2011, Dye et al., 2015). Canada, Australia and New Zealand reported both mean DMFT and the proportions with untreated caries (Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010).

Reporting untreated caries is useful for service planning as it provides an estimate of the normative need for treatment for caries. Whereas mean DMFT, despite the difficulties in ascertaining the reasons for tooth loss in adults, does provide an indication of the overall trend in caries prevalence in the population (Frencken et al., 2017). Comparisons made between different countries using these indicators are still useful provided the limitations of each measure are borne in mind as well as the period of time when the data were collected.

2.4.3.1 Dental caries in Ireland

As mentioned above, in 1990 the DMFT criteria were amended by British Association for Study of Community Dentistry (BASCD), therefore in the Irish national survey of 2000-02, DMFT was recorded both at cavitation DMFT-c and at visual caries DMFT-v level. In the 1989-90 Irish survey, DMFT was recorded only at cavitation level DMFT-c (O'Mullane and Whelton, 1992, Whelton et al., 2007). This section will describe the level of dental caries among older adults in Ireland. The two Irish national surveys of 1989-90 and 2000-02 reported caries prevalence by DMFT; crown caries prevalence was reported by mean number of decayed, missing and filled teeth and the percentage of total mean DMFT which was attributable to the decayed, missing and filled components, according to age, gender, medical card status and general health, at cavitation level and at visual caries level in 2000-02. As in old age, roots tend to become exposed because of gingival recession, there is increased potential for root caries to develop and as a result root surface caries is an important aspect of oral health.

Table 2-19 shows that in 2000-02, there was very little difference between the mean DMFT-c and the mean DMFT-v in both age groups. There was a much larger reduction in mean DMFT values (19.0 to 15.0) in those aged 35-44 years between 1989-90 and 2000-02, compared to the 65 years and older age group (27.3 to 25.9). This suggests that there was a considerable improvement in oral health status in younger age groups during that time period. In both Irish surveys, mean DMFT at cavitation level was higher in females than males but this gender difference had almost disappeared in the younger age group between 1989-90 and 2000-02. Table 2-19 also shows that the gender difference in mean DMFT values was greater in the older age group.

Table 2-19: Mean DMFT-c and DMFT-v by age group, gender and years of examination in Ireland.

Survey Years	Age groups	Mean DMFT at cavitation level			Mean DMFT at cavitation and visual level		
		Male	Female	Total	Male	Female	Total
2000-02	**35-44 years**	14.8	15.3	15.0	15.2	15.7	15.4
	65 years and over	24.7	26.9	25.9	24.8	27.0	26.0
1989-90	**35-44 years**	17.9	19.8	19.0	N/A	N/A	N/A
	65 years and over	25.6	28.8	27.3	N/A	N/A	N/A

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-20 shows that in both surveys, the differences between medical card holders (a proxy for socioeconomic status) and non-medical card holders were greater in the 65 years and older age group where it was 2.4 in 1989-90 and 2.5 in 2000-02, as compared to younger age group.

Table 2-20: Mean DMFT-c and DMFT-v by age group, medical card possession and year of examination in Ireland.

Age group	DMFT-c				DMFT-v	
	MC Yes		MC No		MC Yes	MC No
	1989/90 Mean	2000/02 Mean	1989/90 Mean	2000/02 Mean	2000/02 Mean	2000/02 Mean
35-44 years	18.0	15.2	19.2	14.9	15.9	15.2
65 years and over	28.3	26.7	25.9	24.2	26.7	24.4

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-21 shows that in 2000-02, in those aged 65 years and older, healthy adults (ASA 1) had a lower mean DMFT-c score when compared with adults with mild and moderate systemic disease (ASA 2 or ASA 3). The asterisk denotes that the number of adults was lower than 30 in that group and results were not statistically reliable. The results were similar in 1989-90, where only the group aged 55 years and older was reported for the comparison between general health and

DMFT at cavitation level. Adults with ASA 3 and ASA 4 together the mean DMFT was 27.6 compared with adults with ASA 1 (26.4).

*Table 2-21: Mean DMFT at cavitation level by age group, general health status and year of examination among adults in Ireland. *n<30*

Survey years	Age group	ASA 1	ASA 2	ASA 3	ASA 4	Total
2000-02	**35-44 years**	15.0	16.3	*	*	15.0
	65 years and over	25.3	27.0	27.8	*	25.9
1989-90				**ASA 3+4**		
	55 years and over	26.4	28.0	27.6		N/A

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

The analysis of components of the total DMFT score indicates the extent and pattern of dental caries treatment. The decayed (DT) component in DMFT indicates unmet treatment need, the filled component (FT) indicates successful treatment and missing component (MT) indicate failed treatment. In Table 2-22 it is interesting to note that the proportion of untreated caries was low in both age groups in both surveys.

Table 2-22: Mean and percentage of DMFT-c which was attributable to decayed (DT), missing (MT) and filled (FT) by age group and year of examination among adults in Ireland.

Survey year	Age groups	Caries at cavitation level						
		Mean DMFT				% of DMFT		
		Total	DT	MT	FT	DT	MT	FT
2000-02	**35-44 years**	15.9	1.0	5.7	8.3	6%	38%	55%
	65 years and over	25.9	0.5	22.8	2.6	2%	88%	10%
1989-90	**35-44 years**	19.0	N/A	N/A	N/A	6%	56%	38%
	65 years and over	27.3	N/A	N/A	N/A	4%	90%	6%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

In those aged 35-44 years the decayed proportion remained static between the two national surveys and was lower in the older age group in 2000-02. It is very interesting to note the trend in the younger age group towards a higher filled component (56%) in 2000-02 compared with 38% in 1989-90. There was the opposite trend in the missing component in the same age group, with a reduction from 38% to 55% in the missing component in the same period. The trends were modest in the 65 years and older age group with a reduction from 90% to 88% in the missing component and a small improvement in the filled component from 6% to 10% (Table 2-22).

Table 2-23 demonstrates the impact of medical card status on the components of mean DMFT. Irrespective of medical card status and in both surveys the proportion of untreated caries was low overall and in those aged 35-44 years, it was slightly higher in medical card holders. In the same age group between 1989-90 and 2000-02, there was a considerable improvement in the proportion of mean DMFT due to missing teeth in non-medical card holders (from 54% to 34%). The difference between medical card and non-medical card holders was 7% in 1989-90 compared to 17% in 2000-02. Again in the same age group, the proportion of filled teeth improved by 10% in medical card holders and by 18% in non-medical card holders (O'Mullane and Whelton, 1992, Whelton et al., 2007). These figures indicate an overall improvement in access to dental treatment, but which was less in medical card holders. In adults 65 years and over, medical card holders had fewer missing teeth and more filled teeth than non-medical card holders.

Table 2-23: Percentage of DMFT-c which is attributable to decayed(DT), missing (MT) and filled (FT) by age group, medical card possession and year of examination in Ireland.

Survey Years	**Age group**	**DMFT-c**					
		% DT-c		**% MT**		**% FT**	
		MC Yes	**MC No**	**MC Yes**	**MC No**	**MC Yes**	**MC No**
2000-02	**35-44 years**	8%	6%	51%	34%	40%	59%
1989-90		9%	5%	61%	54%	30%	41%
2000-02	**65 years and over**	2%	3%	91%	80%	7%	17%
1989-90		3%	5%	94%	83%	3%	12%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

The trend of increased retention of teeth among older adults increases the risk of root surface caries as gingival recession increases with age, leaving root surfaces exposed which are then vulnerable to root surface caries. The Irish national oral health surveys used the Root Caries Index along with the mean number of teeth present, mean number of exposed roots and mean number of decayed and filled roots for estimation of root caries prevalence (Table 2-24). The Root Caries Index (RCI) of Katz is defined as, “The proportion of exposed roots with root caries lesions or restorations due to root caries” (RCI = (rDFT/nrt) x 100**)** (Katz, 1980). All four surfaces of each tooth were recorded for gingival recession and the presence of any root surface with either a restoration or root caries.

Table 2-24 shows in Ireland, among adults 65 years and over, there has been a decrease in RCI with increase in retained teeth, from 1989-90 to -2000-02.

Table 2-24: Mean number of teeth and root caries index (RCI) according to age, gender and year of examination among adults in Ireland.

Age group	**35-44 years**						**65 years and over**					
	Males		**Females**		**Total**		**Males**		**Females**		**Total**	
Year of survey	**Mean no of teeth**	**RCI**	**Mean no of teeth**	**RCI**	**Mean no of teeth**	**RCI**	**Mean no of teeth**	**RCI**	**Mean no of teeth**	**RCI**	**Mean no of teeth**	**RCI**
2000-02	25.6	1.8	25.4	3.1	25.5	2.5	15.2	12.7	13.7	10.6	14.4	11.6
1989-90	22.8	3.3	21.2	6.8	21.9	5.3	15.2	20.9	12.6	14.9	14.1	18.5

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

In the 2000-02 national survey, the health status of participants was recorded using the American Society of Anesthesiologists classification (ASA). Table 2-25 shows that healthy adults (ASA 1) had more teeth, fewer roots exposed, less decayed and filled roots and a lower RCI score in both age groups as compared to those with mild systemic disease ASA 2. In those aged 65 years and older the figures were 10.4 in the ASA 1 group and 16.0 in the ASA 2. These figures clearly indicate the effect of poorer health status on root caries prevalence irrespective of age.

*Table 2-25: Number of adults (n), mean number of teeth present (nt), mean number of decayed and filled roots (rDFT), mean number of roots with recession (nrt) and root caries index (RCI= 100 rDFT/nrt) according to age and general health status in 2000-02 in Ireland.*n<30*

Age group	ASA 1					ASA 2					ASA 3	
	n	**Nt**	**nrt**	**rDFT**	**RCI**	**N**	**Nt**	**Nrt**	**rDFT**	**RCI**	**N**	*
35-44 years	907	25.6	6.1	0.2	2.3	55	24.0	8.4	0.4	5.2	5	*
65+ years	295	14.6	8.3	0.8	10.4	104	14.5	9.5	1.5	16.0	21	*

(Whelton et al., 2007)

2.4.3.2 International comparisons of DMFT

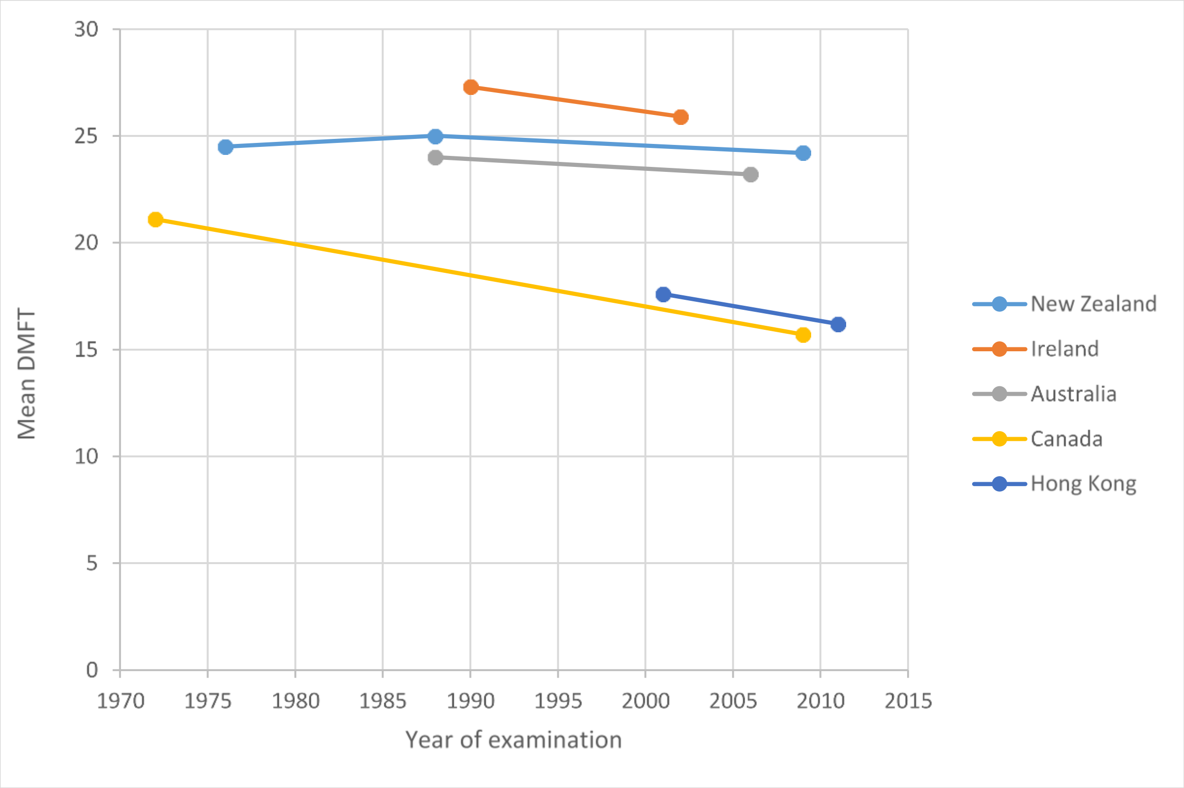
Along with tooth loss, treated and untreated caries are important indicators of oral health and have been used to monitor oral health status and treatment needs among populations groups. These measurements are important for monitoring the progress toward health promotion goals set by Healthy People 2020 (Scully, 2000, Koh et al., 2014). In 2018, Frencken and colleagues reported that among adults aged 50 years and over, the mean decayed component of DMFT was low and decreased significantly between 1983 and 2013. But among adults aged 85 years and over, the mean decayed component of DMFT increased significantly between 2008-2013 (Frencken et al., 2017). This increase was probably a reflection of the increase in retained teeth in the age group 85 years and over, between 2008 and 2013 (Petersen et al., 2004). The second national oral health survey in China also reported that the mean DMFT increased from 2.1 in 35-44 years old to 12.4 in 65-74 years old.

Differences in the prevalence of dental caries have been observed between different countries. Developed countries tend to have a higher prevalence of caries which may be due to dietary factors and changes to a more Western diet in developing countries may cause an increase in mean DMFT.

Figure 2-5 indicates over time that there was a modest reduction in mean DMFT values in older age groups (60 years and over and 65-74 years) in Ireland, New Zealand and Australia between the late 1980s and the 2000s. This decrease over time also varied among different countries. For example, in Ireland for adults aged 65 years and over there was decrease of 1.4 in mean DMFT from 1989-90 to 2000-02, in Australia for adults 64-74 years, the decrease in mean DMFT was of 0.8 from 1987-88 to 2004-06 and in Hong Kong the decrease in mean DMFT was 1.4 from 2001 to

2011 (Figure 2-5) (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Mullane and Whelton, 1992, Department of Health Hong Kong, 2011).

Figure 2-5 also shows that dental caries prevalence has been falling in Ireland, Australia, New Zealand in a very similar manner since the 1970s and 1980s, though the decline in New Zealand in those aged 65-74 years has been very small, with a slight increase in mean DMFT among adults aged 65-74 years from 1976 to 2009.



(O'Mullane and Whelton, 1992, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Statistics Canada, 2010, Department of Health Hong Kong, 2011)

Figure 2-5: Changes over time in mean DMFT, among adults 60 years and over and 65-74 years in different countries.

Table 2-26 shows that the caries prevalence in Canada in was lower than in the other countries. This was especially notable in those aged 60-79 years in Canada in 2007-09 when the mean DMFT was 15.7 compared with 25.9 in Ireland in 2000-02 (in those aged 65 years or older), 24.3 in New Zealand in 2009 (in those aged 64-74 years) and 24.2 in Australia in 2004-06 (in those aged 65-74 years). A similar pattern between Canada and the other countries can be seen in the younger age groups from Table 2-26. In 2007-09 adults aged 40-59 years in Canada had a lower mean DMFT value (12.3) than adults aged 35-44 years in Ireland in 2000-02 (18.5) which was similar to adults aged 40-49 years in 1970-72 (18.4) in Canada.

Table 2-26: Changes over time in mean DMFT among different countries by age group (Dentate sample).*

Country	Year of Examination	Age group	Mean DMFT
Ireland	**2000-02**	35-44 years	15.9
		65 years and over	25.9
	1989-90	35-44 years	19.0
		65 years and over	27.3
New Zealand	**2009***	45-54 years	18.3
		55-65 years	21.7
		64-74 years	24.2
		75 years and over	24.8
	1988	35-44 years	20.8
		64-74 years	25.0
	1976	35-44 years	19.8
		64-74 years	24.5
Australia	**2004-06***	45-54 years	18.7
		55-64 years	21.7
		65-74 years	23.2
		75 years and over	24.6
	1987-88	45-54 years	20.4
		55-64 years	22.4
		65-74 years	24.0
		75 years and over	25.1
Canada	**CHMS 2007-09**	40-59 years	12.3
		60-79 years	15.7
	FNOHS 2009-10	40 years and over	16.2
	IOHS 2008-09	40 years and over	19.5
Hong Kong	**2011**	35-44 years	6.9
		65-74 years	16.2
	2001	35-44 years	7.4
		65-74 years	17.6

(O'Mullane and Whelton, 1992, Slade et al., 2007, Whelton et al., 2007, Haisman et al., 2010, Health Canada, 2010, Statistics Canada, 2010, Department of Health Hong Kong, 2011, Inuit Oral Health Survey, 2011)

Table 2-26 also shows that changes over time in the reported age groups varied among different countries. For example, in Australia from 1987-88 to 2004-06 the mean DMFT decreased from

20.4 to 18.7 in those aged 45-54 years. In Ireland, from 1989-90 to 2000-02 mean DMFT only decreased from 27.3 to 25.9 in those aged 65 years and over. But there was very little decrease in mean DMFT among those aged 65-74 years in New Zealand from 1976 to 2009 (24.5 to 24.2). Table 2-26 also shows that age is an important factor related to DMFT and DMFT decrease over time also varied among different countries. For example, in Ireland for adults aged 65 years and over there was a decrease of 1.4 in mean DMFT from 1989-90 to 2000-02, in Australia for adults 65-74 years, the decrease in mean DMFT was of 0.8 from 1987-88 to 2004-06 and in Hong Kong, the decrease in mean DMFT was 1.4 from 2001 to 2011.

2.4.3.3 Factors associated with DMFT

Studies have reported that age, gender, socioeconomic status and population groups were important factors associated with mean DMFT score. Older age and being female were also associated with higher mean DMFT values (O'Mullane and Whelton, 1992, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Inuit Oral Health Survey, 2011, The First Nations Information Governance Centre, 2012). Table 2-27 compares the mean DMFT between different countries by gender and age group, although age groups varied somewhat between different countries.

In Table 2-27 it can be seen that mean DMFT was higher in the older age groups and this trend was similar among different countries such as Canada, Australia, New Zealand and Ireland. When mean DMFT in Ireland is compared with other countries, in 2000-02 Ireland had highest (25.9) mean DMFT among adults aged 65 years and over, compared with adults aged 75 years and over in Australia (24.6) and New Zealand (24.8) and adults aged 60-79 years in Canada (15.7).

The methods used for recording DMFT were the same in the Australian survey of 2004-2006 and New Zealand survey in 2009 (Slade et al., 2007, Haisman et al., 2010). When comparisons are made between these surveys, the mean DMFT scores among adults from both countries were very similar with the highest mean DMFT values in those aged 75 years and over, in both countries. For the those aged 65–74 years, the DMFT score was higher for adults in New Zealand than for Australian adults (24.2 to 23.2) although the New Zealand study was done 3 years later than Australian study (Table 2-27).

Table 2-27 also shows that gender difference was present in relation to mean DMFT among all age groups in the reported countries. In all countries, females had higher mean DMFT values than males except in those aged 64-75 years in 2009 in New Zealand, when females had the same mean DMFT as males (24.2). Gender difference in relation to mean DMFT also varied between different countries in different age groups. For example, the highest gender difference in mean DMFT (2.6) was among adults aged 55-64 years in New Zealand, followed by Inuit adults aged 40 years and over (2.3) in Canada in 2008-09 and adults aged 65 years and over, in Ireland in 2000-02 (2.2). The gender difference was least among adults aged 45-55 years in New Zealand (0.4) in 2004-05.

Table 2-27: Mean DMFT in different countries by age group, gender and year of examination (Dentate sample).*

Country	Year of Examination	Age group	Mean DMFT		
			Males	**Females**	**Total**
Ireland	**2000-02**	35-44 years	14.8	15.3	15.9
		65 years and over	24.7	26.9	25.9
New Zealand*	**2009**	45-54 years	18.1	18.5	18.3
		55-65 years	20.5	23.1	21.7
		65-74 years	24.2	24.2	24.2
		75 years and over	24.4	25.1	24.8
Australia*	**2004-06**	35-54 years	13.9	14.9	14.4
		55-74 years	21.5	23.0	22.3
		75 years and over	23.5	25.0	24.6
Canada	**CHMS 2007-09**	All	10.1	11.3	10.7
		40-59 years	N/A	N/A	12.3
		60-79 years	N/A	N/A	15.7
	FNOHS 2009-10	40 years and over	13.2	13.6	16.15
	IOHS 2008-09	40 years and over	15.4	17.7	19.5

(O'Mullane and Whelton, 1992, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Inuit Oral Health Survey, 2011, The First Nations Information Governance Centre, 2012)

The WHO reported that dental caries was a major public health problem in older adults and that it was closely linked to social and behavioural factors (Petersen, 2003). Table 2-28 shows the variations in mean DMFT associated with economic status, education level, area of residence and ethnic groups in different countries. Although some countries reported these variations in different age groups and some reported in the whole sample, and different measures of socioeconomic status were used, nonetheless trends can be identified.

Table 2-28: Mean DMFT among different countries by socioeconomic status, education and ethnic group.

Country & examination years	Socioeconomic Variables	Categories of Socioeconomic Variables	Age groups	Mean DMFT
Ireland 2000-02	Medical card possession	No medical card	35-44 years	14.9
			65 year and over	24.2
		Medical card	35-44 years	15.2
			65 year and over	26.7
Canada CHMS 2007-09	Highest household education	Less than degree/diploma	All	11.9
		Equal to degree/diploma		10.3
	Origin	Aboriginal	All	12
		Non-aboriginal		10.6
	Insurance	Public insurance	All	13.4
		Private insurance		10.3
Canada FNOH 2009-10	Income level	< $20000	All	13.3
		≥ $20000		13.9
	Education level	High school or less	All	13.2
		More than high school		13.7
	Area of residence	Urban community	All	13.0
		Non-Urban community		15.3
	Origin	First Nation adults 2009-10	40 years and over	16.2
		Inuit adults 2008-09	40 years and over	19.5
Australia 2004-06	Level of schooling	Year 9/less	All	17.2
		Year 10/more		12.3
	Eligibility for public dental care	Eligible	All	15.8
		Ineligible		11.8
	Indigenous Identity	Indigenous	All	14.8
			35-54 years	15.8
			55-74 years	23.3
			75 years and over	N/A
		Non-indigenous	All	12.8
			35-54 years	14.3
			55-74 years	22.2
			75 years and over	24.4
	Residential location	Capital city	All	12.3
			35-54 years	14.4
			55-74 years	21.9
			75 years and over	24.1
		Other areas	All	13.8
			35-54 years	15.1
			55-74 years	22.7
			75 years and over	24.8
New Zealand	Ethnic groups	Maori	All	12.3
		Pacific		9.6
		Asian		6.8
		European /others		15.0

(O'Mullane and Whelton, 1992, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, The First Nations Information Governance Centre, 2012)

Table 2-28 shows, that adults with poor economic status had higher mean DMFT values and this trend was same in Ireland, UK, Australia and New Zealand. The exception to this trend was in adults from the First Nation Oral Health Survey (FNOHS) in Canada, those with less than $20,000 income had a very slightly lower mean DMFT (13.3) compared with adults with $20,000 or more income (13.9). Table 2-28 also shows that adults with lower levels of education had higher mean DMFT values compared with adults with higher level of education (except adults of FNOHS, those with high school and less education had less mean DMFT (13.2) while adults with more than high school education had a mean DMFT of 13.7). Furthermore, Table 2-28 also shows that in in all reported countries the adults living in capital cities and in urban areas had lower DMFT value than adults living in non-urban areas.

The data in Table 2-28 suggest that levels of education, access to private health insurance were closely related to economic status and mean DMFT values. As income levels in urban areas also tend to be higher than in rural areas, a similar trend was seen in caries prevalence as with education level. Mean DMFT also varied among different ethnic groups in a country. First Nation adults and Inuit adults aged 40 years and over, had a higher mean DMFT than adults aged 40-59 years in the Canadian Health Measures Survey 2007-09. In 2004-06, and in New Zealand, the European population group had the highest mean DMFT (15.0) compared with the other ethnic groups, such as the Pacific and Asian groups who had much lower values (9.6 and 6.8). This suggests an effect of cultural habits on dental caries prevalence.

The studies reported above were carried out in different years (from 2000-02 to 2009-10) using various measures of socioeconomic status and yet all (except FNOHS) demonstrated that poor socioeconomic status had a negative effect on mean DMFT. So it can be concluded that over time the effect of poor socioeconomic status on mean DMFT had not changed although different studies reported different variables to represent socioeconomic status.

2.4.3.4 Untreated coronal caries

Assessment of untreated caries provides an estimate of dental treatment needs in different populations, which is useful for formulating oral health policy, but it gives no insight into the overall trends in the prevalence of dental caries. In recent years Australia, Canada, England and the USA have reported the proportion of their populations with untreated caries. In the UK, there was a decrease in the prevalence of crown and root caries from 1998 to 2009, the total untreated coronal caries decreased from 46% to 29% between 1998 and 2009 (Kelly et al., 2000, O'Sullivan et al., 2011). In 2016, another study of two clinical examination surveys of dentate adults living in care homes in the UK, reported that untreated caries was more prevalent among care home adults than adults living in residential addresses; it was 73% in Wales and 56% in the West Midlands when compared with 2009 Adult Dental Health Survey data of community dwellers (Moore and Davies, 2016).

*Table 2-29: Percentage of adults with untreated coronal caries by age group, country and year of examination (*Dentate sample).*

Country	Year of Examination	Age group	Untreated coronal caries
Australia*	**2004-06**	35-54 years	27.1%
		55-74 years	22.6%
		75 years and over	22.0%
Canada	**CHMS 2007-09**	40-59 years	18.5%
		60-79 years	16.0%
	FNOHS 2009-10	40 years and over	9.3%
	IOHS 2008-09	40 years and over	9.6%
England*	**2009**	55-64 years	25%
		65-74 years	21%
		75 years and over	34%
	1998	55-64 years	41%
		65-74 years	40%
		75 years and over	41%
UK*	**2009**	45-54 years	26%
		55-64 years	26%
		65-74 years	22%
		75-84 years	35%
		85 years and over	28%
USA	**2011-2012**	59-64 years	25.5%
		65-74 years	18.5%
		75 years and over	19.4%
	1999-2004	59-64 years	22.1%
		65-74 years	17.1%
		75 years and over	19.5%
	1989-1994	59-64 years	25.9%
		65-74 years	25.4%
		75 years and over	30.3%

(Slade et al., 2007, Dye et al., 2007, Health Canada, 2010, Inuit Oral Health Survey, 2011, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012, Dye et al., 2012, Steele et al., 2012, Dye et al., 2015)

Table 2-29 shows that there was a considerable improvement in untreated caries in England between 1998 and 2009 and the figure for 65-74 years old with untreated caries fell almost by half. In the USA there was a fall in untreated caries between 1989-1994 and 1999-2004 but the 2011-2012 figures showed a rise in the youngest age groups.

The changes in untreated caries in Australia, Canada, England, UK and USA (Table 2-29) indicate that in all countries the proportion of adults with untreated caries decreased in all age groups. The prevalence of untreated caries varied among different age groups in different countries. As with mean DMFT, Canada had lower levels of untreated caries than the other countries, for example, it was 16.0% in 60-79-year-olds compared with 21% in 65-74 year olds in England in 2009. Those aged 75 years and over, in the USA in 2011-12 had the lowest prevalence of untreated caries (19.4%) compared with Australia in 2004-06 (22.0%) and England in 2009 (41%). In those aged 65-74 years in the UK (2009), 22% had untreated coronal caries compared with 18.5% in the USA in 2011-12. However, 22% of adults aged 65-74 years in the UK had untreated caries as did Australian adults aged 75 years and over in 2004-06 (22%).

2.4.3.5 Factors associated with untreated coronal caries

Table 2-29 and Table 2-30 show that age is an important factor in relation to untreated caries, which have decreased over time among different countries. For example, among adults aged 65-74 years, the proportion with untreated caries in USA, reduced from 25.4% in 1989-1994 to 18.5% in 2011-2012, and in England it reduced from 40% in 1998 to 21% in 2009 (Dye et al., 2007, Dye et al., 2012, Steele et al., 2012, Dye et al., 2015). In Australia and Canada, the proportion of adults with untreated coronal caries decreased with age and in the USA and England, untreated caries decreased from those aged 55-64 years to 65-74 years and increased again in adults aged 75 years and over (Table 2-30).

*Table 2-30: Percentage of adults with untreated decay by age group in different countries (*Dentate sample).*

Country	Year of Examination	Age groups	% adults with untreated decay
Australia*	**2004-06**	35-54 years	27.1%
		55-74 years	22.6%
		75 years and over	22.0%
Canada	**CHMS 2007-09**	40-59 years	18.5%
		60-72 years	16%
UK*	**2009**	45-54 years	26%
		55-64 years	26%
		65-74 years	22%
		75-84 years	35%
		85 years and over	28%
USA	**2011-12**	59-64 years	25.5%
		65-74 years	18.5%
		75 years and over	19.4%

(Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011, Dye et al., 2015)

Table 2-31 shows that like age, a gender difference was also associated with untreated coronal caries in all countries. Higher proportions of males than females had untreated coronal caries and this trend was the same in all age groups. Similarly, in 2000-02, in Ireland, females had a lower proportion of decayed teeth in the mean DMFT than males (Table 2-22). If gender difference in relation to untreated coronal caries is compared with gender difference in mean DMFT, it can be concluded that although in all countries females had higher mean DMFT values than males, females also had less untreated coronal decay than males (Table 2-27). This suggests that the higher mean DMFT values in females were either because of more filled or more missing teeth.

Table 2-31 shows that in Australia in 2004-06, the gender difference in untreated caries increased with age. For example, between males and females it was 8.7% vs 5.6% in those aged 35-54 years and in those aged 75 years and over, it was 25% in males compared with 11.5% in females.

*Table 2-31: Percentage of adults with untreated coronal caries by gender, country and year of examination (*Dentate sample).*

Country	Years of examination	Age groups	% of adults with untreated coronal caries	
			Male	Female
Australia*	**2004-06**	35-54 years	8.7%	5.6%
		55-74 years	14.5%	10.5%
		75 years and over	25.0%	11.5%
Canada	**CHMS 2007-09**	All	23.4%	16.1%
UK *	**2009**	All	32%	26%
USA	**1999-2004**	65 years and over	20.4%	16.4%
	1989-1994	65 years and over	31.9%	24.5%

(Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011, Dye et al., 2015)

The gender difference in untreated coronal caries in the USA among adults aged 65 years and over in 1999-2004 (M=20.4% vs F= 16.4%) was same as in Australian adults aged 55-74 years in 2004-06 (14.5% vs 10.5%). In the USA, in those aged 65 years and over, the gender difference of untreated coronal decay, between males and females decreased from 1989-94 (M=31.9% vs F=24.5%) to 1999-2004 (M= 20.4% vs F= 16.4%) as shown in Table 2-31. However, in 2017, from a systematic review of the global burden of untreated cavitated dentine caries, Frencken and colleagues reported that there was no significant difference in untreated dentine caries between males and females, and the prevalence reached a peak at the age of 25 and later at 70 years in different countries of the world (Frencken et al., 2017).

Table 2-32 shows the variations in untreated coronal caries by economic status, education level, area of residence and ethnic groups in different countries. Poor economic status and low education level had a negative effect on untreated caries in all countries.

Table 2-32 also shows, in 2009, untreated coronal caries also varied among different countries in the UK. Wales had the highest proportion of adults with untreated caries (43%) followed by England (28%) and Northern Ireland (27%). Like mean DMFT, the untreated coronal caries also varied by residential location and ethnic groups in a country and among different countries. For example, the adults living in regional capital cities and urban areas had lower untreated decay than adults living in non-urban areas.

Table 2-32: Percentage of adults with untreated coronal caries among different countries by socioeconomic status, education and ethnic group.

Country and examination years	Socioeconomic Variables	Categories of socioeconomic Variables	Age group	% of adults with untreated coronal caries
UK 2009	**Occupational status**	**Managerial and professional occupations**	**All**	**24%**
		Intermediate occupations		**28%**
		Routine and manual occupations		**36%**
	Countries in UK	**England**	**All**	**28%**
		Wales		**43%**
		Northern Ireland		**27%**
USA	**Population groups 2011-12**	**Non-Hispanic white**	**65 years and over**	**15.5%**
		Non-Hispanic black		**40.9%**
		Hispanic		**26.7%**
		Non-Hispanic Asian		**27.3%**
	Federal poverty level (FPL) 1999-2004	**Less than 100% FPL**	**65 years and over**	**33.2%**
		100-199% FPL		**23.8%**
		More than 200% FPL		**14.2%**
Canada CHMS 2009	**Highest household education**	**Less than degree/diploma**	**All**	**28.3%**
		Equal to degree/diploma		**19.3%**
	Origin	**Aboriginal**	**All**	**34.4%**
		Non-aboriginal		**19.3%**
	Insurance	**Public insurance**	**All**	**35.8%**
		Private insurance		**15.9%**
Australia 2004-06	**Level of schooling**	**Year 9 /less**	**All**	**29.2%**
		Year 10/more		**25.0%**
	Eligibility for public dental care	**Eligible**	**All**	**32.9%**
		Ineligible		**22.9%**
	Indigenous Identity	**Indigenous**	**All**	**57.1%**
			35-54 years	**58.2%**
			55-74 years	**44.2%**
			75 years and over	**N/A**
		Non-indigenous	**All**	**35.1%**
			35-54 years	**26.6%**
			55-74 years	**22.4%**
			75 years and over	**22.2%**
	Residential location	**Capital city**	**All**	**21.5%**
			35-54 years	**23.2%**
			55-74 years	**21.1%**
			75 years and over	**20.3%**
		Other areas	**All**	**32.8%**
			35-54 years	**34.4%**
			55-74 years	**25.1%**
			75 years and over	**25.1%**

(Dye et al., 2007, Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011, Fuller et al., 2011)

Although the reported variables of socioeconomic status were different in different countries, the trends were similar in these countries showing that poor socioeconomic status had a negative effect on untreated coronal caries.

2.4.3.6 Root surface caries

As the name describes, the root surface caries is dental caries on the root surface of a tooth, that has become exposed because of gingival recession. Root caries is more common in older populations because periodontal tissue destruction and gingival recession are more pronounced with age. When roots are exposed they are vulnerable to root caries. Another risk factor for older adults is that they are commonly taking a range of medications, many of which reduce salivary flow. Root caries on some root surfaces can be more difficult to treat than coronal caries. In recent years, root caries has gained prominence because of the increasing trend of retention of natural teeth among older adults (Hariyani et al., 2017).

Hayes and colleagues reported, “Root caries is not evenly distributed across the population and identification of high-risk groups or individuals would facilitate targeted prevention strategies”. It was not possible to have definitive figures on the global prevalence or incidence of root caries because of diversity in available data and the methods used to report root caries. Published studies have reported wide ranges for the prevalence of root caries (25-100%) and the mean Root Caries Index (9.7-38.7) (Hayes et al., 2017).

Root caries prevalence differed in different countries. In Canada in 2007-09, in the group aged 60-79 years, the mean number of teeth with decayed or filled roots was 1.56 (Health Canada, 2010). Whereas in Ireland in those aged 65 years and over it was 1.4 in 1989-90 and 0.9 in 2000-02 (Whelton et al., 2007). In Australia in 2004-06 the mean root decayed or filled surfaces was 2.7. Among adults aged 60 years and over, root caries prevalence was 62% and the prevalence ratio of decayed surfaces was 0.86 (Hariyani et al., 2017). In 2011, in Hong Kong, untreated root caries prevalence was 21.8% among adults aged 65-74 years (Department of Health Hong Kong, 2011).

Because of the diversity in data reporting methods, it was difficult to make comparisons of root caries between different studies. Table 2-33, Table 2-34 and Table 2-35 show the available and comparable data from different countries.

*Table 2-33: Percentage of adults with untreated root caries by age group, country and year of examination (*Dentate sample).*

Country	Years of examination	Age groups	Untreated root caries
Australia*	**2004-06**	35-54 years	7.1%
		55-74 years	12.6%
		75 years and over	17.3%
UK*	**2009**	55-64 years	11%
		65-74 years	10%
		75-84 years	20%
		85 years and over	17%
Canada	**2007-09**	40-59 years	8.0%
		60-79 years	11.2%

(Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011, Hariyani et al., 2017)

Like untreated coronal caries, untreated root caries was lower in Canada than Australia and the UK, although the UK and Canadian studies were done in similar years. There was an obvious increase in untreated root caries with age in all three countries except in the UK among those aged 85 years and over, in whom root caries decreased. The possible reason may be that there were fewer retained teeth in those aged 85 years and over (Table 2-33).

2.4.3.7 Factors associated with untreated root caries

Like untreated coronal caries, age, gender, socioeconomic status, area of residence and population groups were important factors associated with variations in untreated root caries as reported in national studies of oral health (Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011, Hariyani et al., 2017). Dye and colleagues reported that root caries decreased from 1988-94 to 1999-2004 but increased with age. For adults aged 50-69 years to those age 75 years and older, root caries increased from 30.8% to 49.7% in 1988-94 and from 21.6% to 42.3% in 1999-2004. This increase in root caries with age from 1988-94 to 1999-2004 possibly reflects a trend of more retained teeth in older-aged adults leading to more root caries (treated/untreated) (Dye et al., 2007).

Because of differences in the reported age groups, it is difficult to make exact comparisons between countries by age groups. But adults aged 60-79 years in Canada had less untreated root caries than adults aged 55-74 years in Australia. Australian adults aged 75 years and over had less untreated root caries (17.3%) than adults aged 75-84 years in the UK (20%) (Table 2-33).

Table 2-34 shows gender difference was present in relation to untreated root caries in the three reported countries which was similar to untreated coronal caries. A lower proportion of females had untreated root caries compared with males. In Australia, the gender difference in untreated root caries increased with age. For those aged 55-74 years, in males, it was 14.5% compared with females at 10.5%. In those aged 75 years and over, it was 25% in males and 11.5% in females. Hariyani and colleagues also reported that in 2004-06, among adults aged 60 years and over, the prevalence ratio of decayed root surfaces was 1.0 in males and 0.71 in females (Hariyani et al., 2017).

*Table 2-34: Percentage of adults with untreated root caries by gender and country (*Dentate sample).*

Country	Years of examination	Age groups	Untreated root caries	
			Male	**Females**
Australia*	**2004-06**	35-54 years	8.7%	5.6%
		55-74 years	14.5%	10.5%
		75 years and over	25%	11.5%
Canada	**2007-09**	All	7.5%	6.0%
UK*	**2009**	All	8%	6%

(Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011)

Overall, the association of socioeconomic variables with untreated root caries was same as with untreated coronal caries reported above. Table 2-35 shows that adults with lower levels of education had more untreated root caries than adults with higher levels of education and poor economic status had a negative effect on untreated root caries in all countries (Table 2-35).

In 2009, like untreated coronal caries, untreated root caries also varied among different countries in the UK. Wales had the highest proportion of adults with untreated root caries (10%) followed by England (7%) and Northern Ireland (5%). Table 2-35 also shows, like mean DMFT and untreated coronal caries, untreated root caries also varied by different population groups and residential location in a country and among different countries. For example, in Australia, overall and in reported older age groups, adults living in regional capital cities had less untreated root caries than adults living in other areas (Table 2-35).

Table 2-35: Percentage of adults with untreated root caries in different countries by socioeconomic status, education and population group.

Country	Socioeconomic Variables	Categories of socioeconomic Variables	Age groups	% of adults with untreated root caries
UK 2009	**Occupational Status**	**Managerial and professional occupations**	All	5%
		Intermediate occupations		7%
		Routine and manual occupations		9%
	Countries in the UK	**England**	All	7%
		Wales		10%
		Northern Ireland		5%
Canada CHMS 2007-09	**Highest household Education**	**Less than degree/diploma**	All	12.7%
		Equal to degree/diploma		4.5%
	Origin	**Aboriginal**		N/A
		Non-aboriginal		6.6%
	Insurance	**Public insurance**		17.6%
		Private insurance		4.4%
Australia 2004-06	**Level of schooling**	**Year 9/less**	All	13.0%
		Year 10/more		6.0%
	Eligibility for public dental care	**Eligible**	All	10.5%
		Ineligible		5.4%
	Indigenous Identity	**Indigenous**	All	7.7%
		Non-indigenous		6.7%
	Residential location	**Capital city**	All	6.0%
		Other areas		8.1%

(Slade et al., 2007, Health Canada, 2010, O'Sullivan et al., 2011)

Although the reported variables of socioeconomic status were different in different countries, the trends were similar in these countries and poor socioeconomic status had a negative effect on untreated root caries.

Hariyani and colleagues also reported that in 2004-06 in Australia, among adults aged 60 years and over (n=1557), the prevalence ratio of decayed root surfaces was 1.0 in adults with high school or less education and 0.87 in adults with university or higher degree and adults with less than $40,000 income/year had double the prevalence ratio of decayed root surface (1.00) than adults with more than $80,000 income/year (0.47). Furthermore, in adults aged 60 years and older, those who were current or past smoker had almost twice (PR=1.97) the prevalence ratio of decayed root surfaces compared with those who never smoked (PR=1.00) (Hariyani et al., 2017).

2.4.4 Periodontal Health

Along with tooth loss and dental caries, assessment of periodontal disease has been used to monitor oral health status and treatment needs among populations groups. Periodontal disease is an inflammatory disease of the supporting structures (gingivae, periodontal ligament and alveolar bone) that surround the root(s) of the tooth which attach it to the bony socket in the supporting alveolar bone of the jaws. As with dental caries, the effects of periodontal disease are cumulative and are a major cause of tooth loss in older people (Harris and Garcia-Godoy, 2004, Kassebaum et al., 2014).

The two main types of periodontal disease are gingivitis and periodontitis both caused by accumulations of dental plaque around the teeth. Gingivitis is inflammation involving the gingivae surrounding the necks of teeth and is characterised by redness, swelling and bleeding on brushing, symptoms which are reversible with the implementation of good oral hygiene practices.

Periodontitis is also plaque-related inflammation which is not reversible as it involves the destruction of the bone and periodontal ligament around the teeth. This destruction is a side effect of the inflammatory process. It typically presents as a periodontal pocket (an abnormal space between teeth and surrounding structure). Although gingivitis is the earliest stage of periodontal disease, not all adults affected by gingivitis progress to periodontitis. Host response and genetic predisposition are important factors for the development of periodontal disease along with factors like accumulations of dental plaque due to poor oral hygiene practices. While individual susceptibility to both gingivitis and periodontitis varies, it is acknowledged that gingivitis does precede periodontitis (Kinane et al., 2005).

Periodontal health status is measured by bleeding on probing, depth of the pocket, attachment loss and tooth mobility. Probing pocket depth (PPD) is the distance between the gingival margin and the base of the pocket. Whereas attachment loss is the measurement of the distance between cemento-enamel junction (CEJ) and the base of the pocket. Periodontal pockets can be true or false; gingival enlargement with no loss of periodontal attachment around a tooth is a false pocket. In true pockets, the junctional epithelium has migrated onto the root surface after the destruction of the periodontal ligament and as a result, the probe can be placed between the tooth root and gingivae. Whereas the probe cannot be placed between the tooth root and gingivae when there is clinical attachment loss. Pocket depth indicates the severity of the periodontal disease, (greater pocket depth more severe disease). Gingival recession is when the root of the tooth becomes exposed in the mouth as the gingivae have receded apically and some of the bone of the socket is resorbed due to the disease process. Chronic periodontitis is a painless disease with the result that patients may be unaware of the initial signs until they present with gingival recession or looseness of the tooth. If left untreated, tooth loss may occur (Harris and Garcia-Godoy, 2004).

In 1982, the WHO developed the Community Periodontal Index of Treatment Needs (CPITN) to quantify the periodontal treatment needs among populations and it has been widely used in epidemiological studies since (World Health Organization, 2013). Although CPITN provides a good estimation of treatment needs, the severity and extent of periodontal disease among population groups, it does not measure attachment loss in teeth with recession but no pockets. Clinical attachment loss (CAL) is intended to estimate the extent of lost fibrous attachment to the teeth (from CEJ to pocket depth) and in teeth with recession but no pockets it gives an indication of previous periodontal disease. Different studies have used CPITN and CAL for periodontal health evaluation, especially for older adults with recession who may have attachment loss but no pockets then CAL is measured (Armitage, 2003, Whelton et al., 2007, World Health Organization, 2013). Loss of attachment is a useful indicator to supplement information on periodontal pocketing, particularly for older dentate adults, because it shows the effect of past disease or trauma. When interpreting findings on the loss of attachment, it is important to consider the person’s age (Leroy et al., 2010).

In relation to the worldwide prevalence of severe periodontitis, in 2014, Kassebaum and colleagues from a systematic review of the incidence and prevalence of severe periodontitis in all countries, (among 20 age groups and in both sexes from 1990-2010) reported that severe periodontitis was found to be the sixth most common condition in the world from 1990-2010. Between 1990 and 2010 the global age-standardised prevalence of severe periodontitis was static 11.2% (10.4%-11.9% in 1990 and 10.5%- 12% in 2010). The age-standardised incidence of severe periodontitis in 2010 was 701 cases per 100,000 person-years and there was no significant increase in incidence of severe periodontitis since 1990 (Kassebaum et al., 2014).

During the past three decades, numerous international reports on the prevalence of periodontal treatment needs according to the CPITN (or CPI) index have been published. The WHO Global Data Bank on oral health and disease records summaries of these studies. Data from the Community Periodontal Index from the WHO global data bank indicates that in all regions of the world gingival bleeding was highly prevalent among adult populations, advanced disease with deep periodontal pockets (+6 mm) affected 5-20% of adults worldwide (Petersen and Ogawa, 2005, Petersen, 2008). Intercountry variations in the prevalence of periodontal disease conditions were high and epidemiological data on periodontal health were also scarce in developing countries (Petersen, 2003, Petersen et al., 2010). The Global Burden of Disease Study (1990-2010) stated, “Severe periodontitis was sixth most prevalent disease worldwide having an overall prevalence of 11.2% with about 743 million people affected. Overall periodontal disease prevalence increased by 57.3% from 1990-2010” (Tonetti et al., 2017).

Previously the WHO recommended the examination of index teeth for periodontal pocketing depth evaluation (CPITN) in epidemiology studies. In 2013, these criteria were changed to examine all teeth using the CPITN index (World Health Organization, 2013). A study by Hunt reported, “Periodontitis prevalence is underestimated when performing half mouth examinations”. He used a full CPITN version in his study by examining all teeth. But he also considered full mouth examination as a partial instrument because the multiplicity of sites was not considered for the diagnosis when a single score was applied for each sextant (Hunt, 1987, Eley and Cox, 1998). Another study by Diamanti-Kipioti and colleagues, compared the partial mouth CPITN recordings to a full examination and reported the underestimation of sextants presenting scores higher than four and the frequency of individuals presenting scores higher than four and number of deep pockets (Diamanti-Kipioti et al., 1993).

Because of the shortcomings when used as a stand-alone means of assessing the extent and severity of periodontal disease, in 1997, WHO suggested including information on loss of periodontal attachment in oral health surveys (Pilot, 1998, World Health Organization, 2013). So, in both of the Irish national surveys, attachment loss was also recorded along with CPITN.

2.4.4.1 Periodontal health in Ireland

This section reports, the level of periodontal disease (CPITN and clinical attachment loss) among older Irish adults and variations according to age, gender, medical card possession and general health status. The proportion of adults with the various maximum CPITN scores indicates the severity of periodontal disease among the population groups.

The two Irish national surveys used the WHO recommended Community Periodontal Index of Treatment Need (CPITN) for measurement of periodontal disease among adults in Ireland. (O'Mullane and Whelton, 1992, Whelton et al., 2007). For epidemiological studies, in the CPITN examination in younger adults, the mouth is divided into six parts or sextants, and normally only the worst score per sextant is recorded on index teeth. There are different methods of presenting

CPITN data. In the previous two national surveys in Ireland, the percentage of adults with one or more sextants affected by scores H (Healthy), B (Bleeding), C (Calculus), P1 (Shallow pockets 4-5mm) and P2 (Deep pockets ≥6 mm) and X for all sextants excluded, as a maximum (worst) score were presented. This indicates the severity of the periodontal condition. The mean number of sextants affected by the different scores is used to indicate the extent of the periodontal condition (World Health Organization, 2013). In this approach, it is not known whether, for example, there was also calculus in a sextant scored as having pockets, as being a higher score than calculus, only the pockets are recorded. Using this original method, it would not be possible to determine the prevalence of calculus in the population. Therefore, in 2000-02, Irish survey examiners were asked to record the presence or absence of each condition in each sextant and where there were several conditions, multiple scores were recorded per sextant. These data can be analysed for all conditions present or according to the highest score present (Whelton et al., 2007).

Table 2-36 indicates that the highest proportions of the population were recorded with a maximum CPITN score of either calculus or shallow pockets. The figures in 2000-02, for those aged 65 years and older, was 29.5% for calculus and 37.6% for shallow pockets. It suggests that the periodontal treatment need in this age group was for simple treatment consisting of oral hygiene advice, and scaling and polishing. A similar trend was seen in 1989-90. When comparisons are made between the two Irish national surveys, a number of factors need to be borne in mind; (i) in the 1989-90 Irish oral health survey periodontal examinations were not carried out in a dental chair as they were in 2000-02, (ii) the numbers in some of the cells in the 1989-90 data are very small, (iii) CPITN data are reported on the dentate base and there was an increase in the retention of natural teeth between the two surveys as well as (iv) increased life expectancy over that period.

In the 2000-02 survey, the percentage of adults that required more complex periodontal treatment (those whose maximum score was shallow pockets 4-5mm ‘PI’, or deep pockets 6mm or more 'P2'), such as root planing or surgical intervention, increased with age. The percentage of adults who had a score of 'X' (excluded because the required teeth were not present or were designated for extraction) for all sextants, also increased with age as tooth loss increased.

Section 2.4.2 reported that amongst the Irish population more teeth were retained from 1989-90 to 2000-02, and therefore there was increased susceptibility to periodontal disease (see Table 2-36). Those not affected by pocketing, had either gingival inflammation or calculus. The presence of calculus as a maximum score was the most common periodontal condition recorded amongst Irish adults in both surveys 1989-90 to 2000-02 (Table 2-36).

Table 2-36: The number and percentage of dentate adults with maximum CPITN score of H (healthy), B (bleeding), C (calculus), P1 (shallow pockets), P2 (deep pockets), all X (sextant excluded) according to age group, in Ireland (Base-dentate).

Year of survey	Age groups		H	B	C	P1	P2	X	UR
2000-02	**35-44 years**	**n**	63	49	417	348	48	12	0
		%	8.4%	4.9%	45.2%	33.9%	6.3%	1.3%	0
	65 years and over	**n**	23	15	129	144	38	38	3
		%	6.9%	3.6%	29.5%	37.6%	12%	9.8%	0.7%
1989-90	**35-44 years**	**n**	15	13	176	30	2	5	1
		%	6%	5%	73%	12%	1%	2%	0%
	45-54 years	**n**	7	3	68	19	2	7	0
		%	6%	3%	64%	18%	2%	7%	0%
	55-64 years	**n**	3	1	24	3	1	2	0
		%	9%	3%	71%	9%	3%	6%	0%
	65 years and over	**n**	10	0	16	2	1	8	1
		%	26%	0%	42%	5%	3%	21%	3%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 3-37 shows that the mean number of sextants per dentate adult affected by the different CPITN scores and reflects the extent of the various conditions recorded. It can be concluded from both national surveys that the mean number of healthy sextants decreased with age, and the mean number of sextants with pockets slightly increased with age. The small increase in the extent of periodontal disease in the older age groups is accounted for by the increase in levels of tooth loss in these groups. It is worth noting that in spite of the larger number of sextants excluded due to missing teeth the periodontal treatment needs in all age groups were mostly for simple periodontal care in 2 to 3 sextants.

Table 2-37: Mean number of sextants per person affected by the different CPITN scores of H (healthy), B (bleeding), C (calculus), P1 (shallow pockets), P2 (deep pockets) or all X (all sextants excluded) according to age group, in Ireland (Base-dentate).

Survey Years	**Age group**	**H**	**B**	**C**	**P1**	**P2**	**X**
2000-2002	**35-44 years**	1.9	0.8	1.8	0.9	0.1	0.4
	65 years and over	0.8	0.2	1.0	1.1	0.2	2.7
1989-1990	**35-44 years**	1.6	0.7	2.3	0.2	0.0	1.0
	45-54 years	1.2	0.5	2.0	0.3	0.0	1.9
	55-64 years	0.9	0.3	2.0	0.3	0.1	2.4
	65 years and over	0.7	0.2	1.9	0.3	0.1	2.5

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-38 shows that in the two Irish oral health surveys, males tended to have higher levels of calculus than females in most of the age groups. Males also had slightly higher levels of periodontal pockets. In both surveys, in those aged 65 years and over, the higher level of tooth loss among females is illustrated by the higher number of sextants with a score of X (sextant excluded) for females as compared to males. It can be concluded that in Ireland, higher levels of periodontal disease in older males related to a higher number of teeth present in older males compared with females.

Table 2-38: Mean number of sextants per person affected by the different CPITN scores of H (healthy), B (bleeding), C (calculus), P1 (shallow pockets), P2 (deep pockets) or all X (all sextants excluded) according to age group and gender, in Ireland (Base-dentate).

Survey Years	Age Group	H		B		C		P1		P2		X	
		M	F	M	F	M	F	M	F	M	F	M	F
2000-02	**35-44 years**	1.8	2.0	0.8	0.8	1.9	1.7	1.0	0.9	0.1	0.1	0.3	0.5
	65 years and over	0.8	0.7	0.2	0.3	1.0	1.0	1.2	0.9	0.2	0.1	2.4	2.9
1989-90	**35-44 years**	1.6	1.7	0.7	0.8	2.7	2.1	0.3	0.2	0.0	0.0	0.7	1.2
	45-54 years	1.1	1.3	0.5	0.6	2.2	1.8	0.4	0.2	0.0	0.0	1.7	2.0
	55-64 years	0.9	0.9	0.3	0.3	2.3	1.6	0.3	0.3	0.0	0.1	2.2	2.7
	65 years and over	0.6	0.7	0.1	0.2	1.9	1.8	0.3	0.1	0.1	0.0	2.3	2.8

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 2-39: Mean number of sextants per person affected by different CPITN scores of H (healthy), B (bleeding), C (calculus), P1 (shallow pockets), P2 (deep pockets) or all X (all sextants excluded) according to age group and medical card status, in Ireland (Base-dentate).

Survey years	Age Groups	H		B		C		P1		P2		X	
		MC Yes	MC No	MC Yes	MC No	MC Yes	MC No	MC Yes	MC No	MC Yes	MC No	MC Yes	MC No
2000-02	**35-44**	1.2	2.1	0.8	0.8	1.9	1.8	1.2	0.9	0.2	0.1	0.7	0.3
	65 years and over	0.6	1.0	0.2	0.2	0.9	1.2	0.9	1.3	0.2	0.2	3.0	2.1
1989-90	**35-44**	1.4	1.7	0.7	0.8	2.7	2.2	0.3	0.2	0.0	0.0	0.9	1.0
	45-54	0.7	1.4	0.4	0.6	1.9	2.0	0.3	0.3	0.0	0.0	2.5	1.7
	55-64	0.3	1.2	0.5	0.2	1.9	2.0	0.5	0.2	0.1	0.0	2.7	2.3
	65 years and over	0.5	0.8	0.2	0.2	1.7	2.0	0.3	0.2	0.1	0.0	2.8	2.3

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Section 2.4.2 demonstrated that in Ireland medical card holders tended to have fewer teeth than non-medical card holders. This trend is reflected by the higher mean number of sextants with a maximum CPITN score of X, in older adults with medical card compared with non-medical card holders of same age group. Non-medical card holders tended to have healthier sextants than medical card holders in the older age groups as shown in Table 2-39.

Table 2-40 shows the proportion of adults with different levels of attachment loss by age groups in the two national surveys. Both in 2000-02 and 1998-90 the proportion of adults with attachment loss equal to or greater than 4 mm and excluded sextants increased with age. In those aged 35-44 years and 65 years and over, the proportion of adults with attachment loss equal to or greater than 4 mm increased from 1989-90 to 2000-02 because of the decrease in excluded sextants due to increased tooth retention (Table 2-40).

Table 2-40: Percentage of dentate adults with a maximum score of attachment loss by age group in Ireland.

Survey Years	**Age groups**	**Maximum loss of attachment score**					
		≤ 3mm	**4-5mm**	**6-8mm**	**9-11mm**	**≥12mm**	**X**
2000-2002	**35-44 years**	67.9%	22.9%	5.8%	1.7%	0.4%	1.3%
	65 years and over	24.2%	39.8%	15.5%	6.7%	4.9%	8.4%
1989-1990	**35-44 years**	71%	20%	4%	0%	0%	3%
	45-54 years	62%	22%	4%	0%	0%	7%
	55-64 years	46%	21%	10%	3%	0%	13%
	65 years and over	48%	18%	5%	0%	0%	23%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

2.4.4.2 International comparisons

Periodontitis has been related to quality of life among adults and is a part of the Healthy People 2020 initiative in the USA (Scully, 2000, Koh et al., 2014). Countries like Ireland and Canada appear to have used the same WHO recommended CPITN index and clinical attachment loss, to assess the periodontal health and treatment needs but with slight variations. For example, Ireland and Canada used full mouth examinations of periodontal health by (CPITN) index in previous surveys. Along with the CPITN index, the Canadian study also recorded gingivitis by the Gingival Index (GI) of Löe and Silness (Löe and Silness, 1963, Health Canada, 2010). For periodontal health CHMS reported, gingivitis score, pocket depths and attachment loss at cut points of ≥4mm and ≥6 mm (Löe and Silness, 1963, Health Canada, 2010).

The UK, USA, Australia and New Zealand used different methods for assessment of periodontal health from Ireland. In the UK, periodontal health was measured in terms of gingivitis, probing pocket depths of 4mm or more and 6mm or more as well as attachment loss (O’Sullivan et al., 2011). In the USA, Australia and New Zealand, periodontal health was measured by gingival recession, gingivitis, clinical attachment loss and depth of periodontal pockets attachment (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011, Eke et al., 2015).

In the Australian and New Zealand surveys, gingival recession was measured using a periodontal probe at three sites on each tooth and gingivitis or gingival inflammation was assessed on six index teeth by the Gingival Index (GI) of Löe and Silness (Löe and Silness, 1963, Slade et al., 2007, Ministry of Health New Zealand, 2010, Mason et al., 2010). A gingival index score of two or more indicated bleeding on probing or spontaneous bleeding and was classified as indicating gingival inflammation (gingivitis). In the Australian survey, the examiners assessed gingivitis by visual inspection and by application of pressure to the gingivae closest to the neck of the teeth (Slade et al., 2007). Pocket depth was measured at three sites on each tooth with a periodontal probe.

In Australia and New Zealand, a periodontal probe that had 2mm markings was used for assessments of probing pocket depth and gingival recession. There was one difference in examination criteria, the Australian protocol, the periodontal measurements were recorded at the mesio-buccal, mid-buccal, and disto-buccal aspects of all teeth present, except for third molars, whereas New Zealand used mesio- buccal, mid-buccal and disto-lingual sites (Slade et al., 2007, Ministry of Health New Zealand, 2010, Mason et al., 2010). Attachment loss was not measured clinically and was calculated from the gingival recession and periodontal pocket depths (Slade et al., 2007, Ministry of Health New Zealand, 2010, Mason et al., 2010).

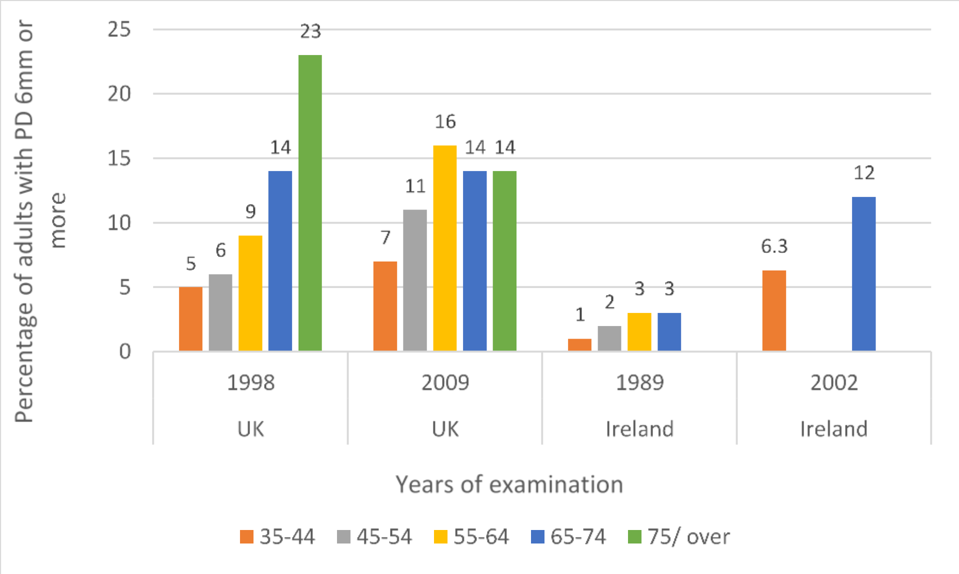
In NHANES 2009-10 and 2011-12, the prevalence, severity and extent of periodontitis were calculated by combinations of clinical attachment loss (CAL) and periodontal probing depth (PD) from six sites per tooth on all teeth, except third molars. It is also important to report that in the USA, before 2009-2010, in the National Health and Nutrition Examination Surveys (NHANES), periodontal examinations relied on partial mouth assessments. As periodontal disease is not evenly distributed in the mouth, estimates based on partial mouth oral health examinations might have underestimated actual prevalence rates of periodontal disease in the U.S. population by as much as 50% (Eke et al., 2015). The 2009-2010 NHANES study included for the first time a full-mouth periodontal examination to assess for mild, moderate, or severe periodontitis, making it the most comprehensive survey of periodontal health ever conducted in the U.S. The findings also indicate disparities among certain segments of the U.S. population (Eke et al., 2015).

In NHANES 2009-10, and the Australia Oral Health Survey of 2004-06, the prevalence of moderate and severe periodontitis was measured as defined by the US Centres for Disease Control and

Prevention (CDC) and the American Academy of Periodontology (AAP) for health surveys (Haisman et al., 2010, Eke et al., 2015). The CDC/AAP defined, severe periodontitis as having at least two sites between adjacent teeth where there was loss of attachment of 6 mm or more, and there was at least one pocket of 5mm or greater depth. Moderate periodontitis was defined as the presence of either two sites between adjacent teeth where there was loss of gingival attachment of 4 mm or more or at least two such sites that have pockets of 5 mm or more. Mild periodontitis was, defined as two or more interproximal sites with clinical loss of attachment of 3 mm or more and two or more interproximal sites with pocket depth of 4mm or more (not on the same tooth) or one site with pocket depth of 5mm or more (Slade et al., 2007, Page and Eke, 2007, Haisman et al., 2010, Eke et al., 2015).

It is difficult to make comparisons between the different countries and changes over time because of heterogeneity among studies and methodological variabilities in reporting and collection of periodontal health data (Frencken et al., 2017). This section will report comparisons of periodontal health data as probing depths 4mm or more, and attachment loss 4mm or more, among different countries. As a probing depth of up to 3.5mm is regarded as healthy then probing depths of 4mm or more provide an estimation of the prevalence of periodontal disease from the mildest level of periodontitis. It is useful for service planning to assess the normative need for periodontal care. In this section comparisons between different countries (where comparable data are available) by the proportion of adults with probing depths of 4mm or more, 6mm or more and with clinical attachment loss of 4mm or more, in adults 50 years and over are reported. Ireland and Canada are compared using the proportion of adults with max CPITN score of healthy, bleeding, calculus, shallow and deep pockets.

Figure 2-6 shows, the comparisons between Ireland from 1989-90 to 2000-02 and the UK, from 1998 to 2009, in relation to the proportion of adults with pocket depths of 6mm or more. The trends in Ireland and the UK show that in both countries there was an increase in the proportion of adults with pocket depths of 6mm and more with age, except in the UK there was decrease in proportion of adults with pocket depths of 6mm or more in 2009, in those aged 65-74 years and 75 years and over. It may be because of fewer retained teeth among adults aged 65 years and over (Note: Irish data of CPITN in 1989-90 should be used with caution because, in 1989-90, periodontal examinations were not done in a dental chair).



(O'Mullane and Whelton, 1992, Walker and Cooper, 2000, Whelton et al., 2007, Fuller et al., 2011)

Figure 2-6: Changes over time in the percentage of adults with any pockets of 6mm or more in UK and Ireland.

Table 2-41 shows comparisons between Ireland and Canada by the proportion of adults with highest CPITN score by age group. In both countries, a higher proportion of adults had calculus and shallow pockets. In Canada (2007-09) more adults had a highest score of bleeding compared to Ireland in 2000-02. Although the age groups were somewhat different, in both countries the percentage of adults with a highest score of healthy, bleeding, and calculus decreased with age and adults with shallow and deep pockets increased with age. In 2000-02, Ireland had more adults with a highest score of shallow and deep pockets than Canada in 2007-09. These findings suggest that in both countries periodontal treatment need was for simple treatments such as scaling, polishing and root planing. But with age, advanced periodontal treatments may become necessary because of the increase in the prevalence of deep pockets in both countries.

Table 2-41: Percentage of adults with highest CPITN score in Ireland (2000-02) and Canada (2007-09) by age group.

Years of survey	Age groups	Healthy	Bleeding	Calculus	Shallow pockets	Deep pockets	Unable to record
Ireland 2000-02	**35-44 years**	8.4%	4.9%	45.2%	33.9%	6.3%	1.3%
	65 years and over	6.9%	3.6%	29.5%	37.6%	12%	9.8%
Canada 2007-09	**40-59 years**	5.8%	24.0%	46.7%	18.1%	5.4%	N/A
	60-79 years	2.9%	22.5%	43.8%	23.6%	7.1%	N/A

(Whelton et al., 2007, Health Canada, 2010)

Table 2-42 shows that among all the reported countries, in 2009, the UK had the highest and Australia and Canada had the lowest proportion of adults with pocket depths of 4mm or more. New Zealand had a lower proportion of adults with pocket depths 4mm or more compared with the UK, although the both the UK and New Zealand surveys were done in 2009. The UK and Ireland had the highest and Australia and Canada had the lowest proportion of adults with pocket depths of 6mm or more. This may be because of the difference in the mean number of teeth among adults in both countries. Although the UK and New Zealand surveys were done in 2009, yet adults in New Zealand had a much lower prevalence of pocket depth of 6mm or more than the UK adults. Canada had the lowest prevalence of adults with attachment loss of 4mm or more in all the reported countries. However, among adults 55 years and over, the UK had a lower prevalence of attachment loss of 4mm or more when compared with New Zealand, Australia, USA and Ireland.

Although the prevalence of pocket depths of 4mm or more and 6mm or more and attachment loss of 4mm or more, varied among the different countries and in different age groups, in most countries the proportion of adults with pocket depths of 4mm or more and 6mm or more increased with age. The exceptions were in those aged 75 years and over, in the USA and the UK where there was a decrease in the proportion of adults with pocket depths of 4mm or over and 6mm and over. From those aged 55-64 years to 65-74 years, in Australia and in New Zealand there was also a decrease in adults with pocket depths of 4mm or more (Table 4-42).

Table 2-42: Percentage of dentate adults with 4mm or more and 6mm or more pocket depths and 6mm or more clinical attachment loss by age group and country (pocket depth was 4-5 mm not more than it).*

Country	Year of Examination	Age group	Any pocket depth of 4mm/more	Any pocket depth of 6mm/more	Any CAL 4mm/ more
Ireland	**2000-02**	**35-44 years**	33.9%*	6.3%	32.1%
		65 years and over	37.6%*	12%	75.8%
UK	**2009**	**35-44 year**	43%	7%	N/A
		45-54 years	52%	10%	N/A
		55-64years	61%	16%	61%
		65-74 years	60%	14%	67%
		75-84 years	61%	14%	76%
		85 years and over	47%	14%	72%
New Zealand	**2009**	**35-44 year**	36.3%	4.3%	44%
		45-54 years	35.5%	5.5%	62.6%
		55-64 years	39.5%	5.5%	68.9%
		65-74 years	30.0%	5.5%	73.2%
		75 years and over	32.6%	5.1%	86.7%
Australia	**2004-06**	**35-44 year**	22.6%	N/A	38.5%
		45-54 years	25.5%		60.5%
		55-64 years	25.4%	N/A	71.8%
		65-74 years	20.6%		75.5%
		75 years and over	25.8%	N/A	79.9%
Canada	**CHMS 2007-09**	**40-59 years**	23.7%	5.4%	26.1%
		60-79 years	31.0%	7.2%	47.1%
USA	**NHANES 2009-12**	**35-49 years**	39.2%	9.4%	51.8%
		50-64 years	46.1%	12.0%	71.4%
		65-74 years	50.5%	12.8%	81.5%
		75 years and over	44.7%	10.4%	

(Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Sullivan et al., 2011, Eke et al., 2015)

2.4.4.3 Factors associated with pocket depths and clinical attachment loss

Table 4-42 shows, age was an important factor affecting periodontal health. There was an increase in attachment loss of 4mm and over with age among different countries except in UK, where those aged 85 years and over had a lower proportion of adults with attachment loss of 4mm and over, which again might have been due to reduced numbers of natural teeth in this age group. This increase in clinical attachment loss of 4mm or more with age, varied among different countries and in different age groups. For example, in relation to prevalence of pockets of 4mm or more, in the UK the highest increase occurred between those aged 55-64 years (52%) and 65-74 years (61%), in the USA from those aged 35-49 years (39.2%) to 50-64 years (46.1%), in Australia from those aged 65-74 years (20.6%) to 75 years (25.8%) and over and in New Zealand from those aged 45-54 years (35.5%) to 55-64 years (39.5%) (Table 2-42).

Data on the Community Periodontal Index from the WHO global data bank reported that among 65-74 years old, calculus was highly prevalent in China and Tanzania as compared to the USA and Denmark. Shallow and deep pockets were more common in the USA and Denmark than in China and Tanzania. With age the prevalence of calculus and bleeding decreased while deep pockets and excluded sextants increased throughout all countries (Petersen and Ogawa, 2005, Petersen, 2008). A large cross-sectional study of a random sample of 1,115 people aged 35-44 years and 65-74 years in Denmark, also reported that periodontal disease increased with age, more than 82% of older participants had pockets of 4-5mm or deeper as compared with 42% in younger adults. A high proportion of the elderly had scores of severe periodontal disease (more than 5 mm) (Siukosaari et al., 2012). In 2014, Kassebaum and colleagues also reported that the prevalence of severe periodontitis slowly increased with age, showing a steep increase between 30-40 years of life with a peak at around 38 years of age (Kassebaum et al., 2014, Frencken et al., 2017). There were also considerable variations in the incidence and prevalence of severe periodontitis between different regions and countries of the world (Kassebaum et al., 2014).

Table 2-43 shows, that in the reported countries, gender difference was present in relation to pocket depths of 4mm or more and attachment loss of 4mm or more. In all countries, higher proportions of males had pocket depths of 4mm or more and clinical attachment loss of 4mm and more, although this gender difference varied between different countries. For example, in relation to pockets of 4mm or more depth, the highest difference was present in the proportion of males (50.6%) and females (34.0%) in the USA and least difference was present in the proportion of males (47%) and females (43%) in the UK. In relation to clinical attachment loss of 4mm or more, in 2009 in the UK, in adults aged 55 years and over, the gender difference was (72% vs 60%) which was very similar to that in adults aged 55-74 years in Australia in 2004-06 (79.1% vs 66.9%). Among all reported countries, in relation to clinical attachment loss of 4mm or more, the highest gender difference was in the USA (M= 68.4% vs F=53.6%) and least was in Canada (M= 22.7% vs F=19.4%). Some countries such as Australia and UK, reported this gender difference in the whole sample and a few in age groups, but the gender difference was present in each age group (the UK recorded clinical attachment loss of 4mm or more among adults aged 55 years and over only). However, Frencken and colleagues from a systematic review of 72 studies reported that age-standardised incidence and prevalence of periodontal disease were similar for males and females (Frencken et al., 2017).

Table 2-43: Percentage of dentate adults with 4mm or more pocket depths and 4mm or more clinical attachment loss by gender and country.

Country	Year of Examination	Age group	Any pocket depths of 4mm or more		Any CAL 4mm or more	
			Male	Female	Male	Female
UK	**2009**	**All**	47%	43%		
		55 years and over			72%	60%
New Zealand	**2009**	**All**	38.9%	28.5%	55.2%	45.1%
Australia	**2004-06**	**All**	22.8%	16.7%	46.6%	38.3%
		35-54 years	28.6%	19.2%	52.9%	44.6%
		55-74 years	25.5%	21.9%	79.1%	66.9%
		75 years and over	23.2%	28.0%	86.7%	76.1%
Canada	**CHMS 2007-09**	**All**	23.5%	16.9%	22.7%	19.4%
USA	**NHANES 2009-12**	**All**	50.6%	34.0%	68.4%	53.6%

(Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Sullivan et al., 2011, Eke et al., 2015)

Table 2-44 shows that the prevalence of pocket depths of 4mm or more and clinical attachment loss of 4mm or more, varied among different countries of the UK. Wales had the highest prevalence of pocket depths of 4mm or more (50%) and clinical attachment loss of 4mm or more (77%) and Northern Ireland had the lowest prevalence of pocket depth of 4mm or more (38%) and clinical attachment loss of 4mm or more (61%). Prevalence of pocket depth of 4mm or more and clinical attachment loss of 4mm or more also varied in different areas of other countries. For example, in Australia, adults aged 55-74 years living in a capital city had a higher prevalence of pocket depth of 4mm or more (25.1% vs 21.5%) and a lower prevalence of clinical attachment loss of 4mm or more (71.9% vs 74.9%) than adults living in other areas and the same trend was in those aged 75 years and over.

Table 2-44 also shows that adults with lower education levels had a higher prevalence of pocket depth of 4mm or more and clinical attachment loss of 4mm or more than adults with higher levels of education. Except in Australia, adults aged 55-74 years with Year 9 or less education had a slightly lower prevalence of pocket depth of 4mm or more, compared with adults of same age group with Year 10 or more education (23.4% vs 24%), which may be because of difference in tooth retention among the two groups.

Table 2-44: Percentage of dentate adults with pocket depths of 4mm or more and clinical attachment loss (CAL) of 4mm or more by education level, socioeconomic status, area of residence and population group in different countries.

Country & examination years	Socioeconomic Variables	Categories of Socioeconomic Variables	Age groups	Any pocket depths of 4mm/more	Any CAL 4mm/ more
UK 2009	Countries	England Wales Northern Ireland	All	40% 50% 38%	N/A
		England Wales Northern Ireland	55 years and over		65% 77% 61%
Canada CHMS 2007-09	Highest household Education	Less than degree/diploma Equal to degree/diploma	All	25.5% 16.8%	25.9% 18.5%
	Origin	Aboriginal Non-aboriginal	All	N/A 19.2 %	N/A 21.2 %
	Insurance	Public insurance Private insurance	All	19.5 % 16.0 %	16.4 % 17.7 %
USA 2009-12	Racial group	Hispanic Non-Hispanic Asian American Non-Hispanic white Non-Hispanic black		62.7 % 45.4 % 36.9 % 56.8 %	71.6 % 65.0 % 52.2 % 69.7 %
	Education	Less than high school High school More than high school	All	59.4 % 50.1 % 34.9 %	77.0 % 62.2 % 54.1 %
New Zealand 2009	Ethnic groups	Maori Pacific Asian European /others	All	46.2% 46.0% 44.2% 30.5%	53.9% 51.9% 46.6% 49.1%
Australia 2004-06	Level of schooling	Year 9/less	All 35-54 years 55-74 years 75 years and over	23.3 % 27.5 % 23.4 % 32.4 %	55.3 % 55.9 % 73.8 % 81.3 %
		Year 10/more	All 35-54 years 55-74 years 75 years and over	19.4 % 23.7 % 24.0 % 23.0 %	40.9 % 48.3 % 72.7 % 80.1 %
	Eligibility for public dental care	Eligible	All 35-54 years 55-74 years 75 years and over	21.8 % 25.9 % 21.4 % 33.0 %	52.1 % 53.2 % 76.6 % 89.4 %
		Ineligible	All 35-54 years 55-74 years 75 years and over	19.1 % 23.6 % 25.4 % 14.5 %	39.4 % 48.0 % 70.5 % 65.8 %
	Indigenous Identity	Indigenous	All 35-54 years 55-74 years 75 years and over	21.4 % 27.3 % 17.0 % N/A	52.0 % 66.4 % 59.4 % N/A
		Non-indigenous	All 35-54 years 55-74 years 75 years and over	19.7 % 23.9 % 23.8 % 26.3 %	42.3 % 48.5 % 73.2 % 80.3 %
	Residential location	Capital city	All 35-54 years 55-74 years 75 years and over	20.6 % 26.1 % 25.1 % 23.3 %	41.1 % 48.5 % 71.9 % 78.1 %
		Other areas	All 35-54 years 55-74 years 75 years and over	18.2 % 20.1 % 21.5 % 30.3%	45.1 % 49.3 % 74.9 % 84.3 %

(Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Sullivan et al., 2011, Eke et al., 2015)

Table 2-44 also shows adults with poor economic status had a higher prevalence of pocket depth of 4mm or more and clinical attachment loss of 4mm or more, than adults with better economic status. Except in Australia, the adults aged 55-74 years those were eligible for public dental care had less prevalence of pocket depths of 4mm or more than adults those were not eligible for public dental care (21.4% vs 25.4%).

Table 2-44 shows the prevalence of pocket depths of 4mm or more and clinical attachment loss of 4mm or more, also varied among different population groups in a country. For example, in USA and Australia, Hispanic adults and indigenous adults had the highest prevalence of pocket depths of 4mm or more and clinical attachment loss of 4mm or more compared to Non-Hispanic black, Non-Hispanic white and Non-Hispanic Asian Americans and non-indigenous in Australia. Except in those aged 55-74 years where the non-indigenous had a higher prevalence of pocket depths of 4mm or more (23.8% vs 17.0%) and clinical attachment loss of 4mm or more (73.2% vs 59.4%) than indigenous adults.

Other studies have reported that the distribution of periodontal disease prevalence and severity, within countries also differs according to race or ethnic group (Borrell et al., 2002, Borrell et al., 2004, Kassebaum et al., 2014). Beck and colleagues reported that groups of African-Americans had a risk of periodontal destruction three times higher than that of white Americans of the same age cohort (Beck et al., 1990) and studies by Borrell and colleagues reported that African-Americans were twice as likely to have periodontal disease as were white Americans (Borrell et al., 2002). The effect of ethnicity on periodontal health status was also documented in adults of developing countries (Petersen and Razanamihaja, 1996, Nishida et al., 2000).

In 1999, Drury and colleagues reported that in the USA periodontal disease prevalence and severity varied 10-20% between people of low and high socioeconomic status (Drury et al., 1999). Considerable difference in periodontal disease status was present because of urbanization and socio-environmental factors in different countries (Petersen and Ogawa, 2005). In Denmark, a large cross-sectional study also reported that poor periodontal health was related to lower levels of education. It was calculated that among adults of aged 35-44 years and 65-74 years, the mean number of teeth with periodontal pockets deeper than 4-5 mm, was higher in individuals with low levels of education (Siukosaari et al., 2012).

The WHO also reported that adults in poor countries (Africa, Madagascar) of the world had worse periodontal health than in the developed countries (USA, UK, Canada) and older adults despite having fewer teeth had worse periodontal health than younger adults. The proportion of adults with calculus and shallow pockets (CPI score 3) was less among the age group 65-74 years in different countries of the world. Deep pockets were less common, but Chilli, Gambia and Turkmenistan had more than 70% of adults with deep pockets (CPI= 4). In European countries, Hungary had the highest proportion of adults with healthy periodontium (CPI score 0) (Petersen, 2008).

2.4.5 Tooth wear

Tooth wear describes the progressive loss of tooth substance due to the effects of erosion, abrasion, attrition, or combinations of these, but not due to caries or trauma (Bishop et al., 1997, Suchetha et al., 2014). Tooth wear can be on occlusal surfaces, and incisal edges or cervical wear. Some tooth wear occurs naturally with age and therefore it is more relevant to older adults, though excessive wear can be seen in all age groups. As there is an increasing trend of retaining teeth among older people compared with previous decades, then tooth wear is likely to be more prevalent among older adults than before (Bishop et al., 1997, Steele and Walls, 2000).

Erosion is the dissolution of tooth substance by acidic chemicals in foods and drinks. Petersen and colleagues stated “Erosion appears to be a growing problem in several countries, affecting 8–13% of adults, and the increasing levels are thought to be due to higher consumption of acidic beverages (sugary, carbonated drinks and fruit juices)” (Gate and Imfeld, 1996, Petersen, 2003). Abrasion is wear of tooth surfaces in contact with items such as hard toothbrushes and abrasive toothpaste whereas attrition is caused by grinding between the upper and lower teeth (Nunn, 2000). Any of these processes may result in loss of tooth form and shape and in some cases, severe destruction of tooth substance may occur. Although tooth wear can be a natural process, its severity increases with age but if not within the normal range it can be rapidly destructive and so requires treatment (Litonjua et al., 2003). As tooth wear is a normal physiological process but because of an increase in the retention of teeth among older adults, the prevalence of tooth wear among older adults is also likely to increase (Slade et al., 2007).

2.4.5.1 Prevalence of tooth wear

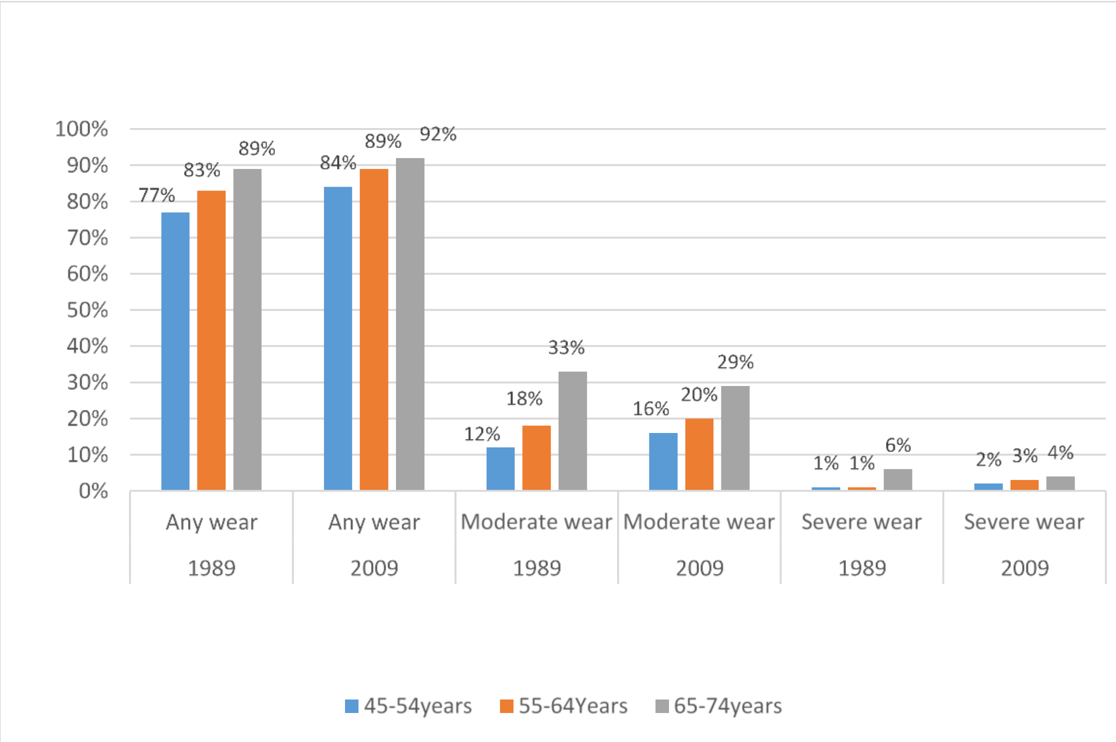
Different countries and authors used different methods to record tooth wear in their studies among their populations. For example, the UK in 2009 and 1998 and Sudan in 2009-10, used the same Tooth Wear Index (TWI) in their national surveys (Kelly et al., 2000, Fuller et al., 2011, Khalifa et al., 2012). Tooth wear was recorded on the three surfaces of the six upper anterior teeth, buccal, palatal and incisal along with the worst affected surface of each of the six lower anterior teeth (Smith, 1984, Kelly et al., 2000, Fuller et al., 2011, Khalifa et al., 2012). In the UK, as reported by Steele and colleagues “Recording using six or 12 anterior teeth is appropriate for measuring and reporting tooth wear data in large population surveys” (Steele and Walls, 2000). For the three surfaces mentioned above, wear was assessed as, no obvious wear or wear restricted only to the enamel of the tooth, loss of enamel just exposing dentine somewhere on the surface, more extensive exposure of dentine (more than one third of the buccal or palatal surface) or substantial loss of dentine (incisal surface), and complete enamel loss with exposure of dental pulp or secondary dentine. Wear was reported at three levels; any wear, wear that has exposed a large area of dentine on any surface (moderate wear) and wear that has exposed the pulp or secondary dentine (severe wear) (Nunn, 2000).

The Australian Oral Health Survey of 2004-06, recorded enamel wear on four lower incisors by assessing the complete loss of tooth enamel on the incisal edges of teeth. Severe tooth wear was assessed as the complete loss of enamel from incisal edges and the remaining height of tooth crown was in the lowest 5% of all crown heights for lower incisors. Height of the crown of a tooth was recorded at the mid-point of the incisal edge of the tooth. Teeth having fillings on the occlusal surfaces were excluded from the assessment (Slade et al., 2007). A few studies used the modified Smith and Knight index and the occlusal tooth wear index for tooth wear assessment such as a study in China (Zhang et al., 2014).

Not only were the recording methods for tooth wear different, the methods of reporting tooth wear were also different. For example, in the 2009 UK oral health survey, tooth wear was reported as moderate wear and severe wear, but the Australian survey reported wear as enamel wear and severe wear (exposed dentine). Furthermore, it is difficult to make comparisons, because some studies evaluated and reported data on tooth wear per person and others on wear at tooth level (Spijker et al., 2009). For example, in 2009, a systematic review (13 studies of adults aged 18 and over from 1980 to 2007) by Spijker and colleagues evaluated tooth wear (attrition, abrasion, erosion) prevalence and general trends among adult populations and its relationship with different variables such as age and gender. They reported that the sample selection, the clinical appearance and interpretation of the types of tooth wear varied among clinicians and whether tooth wear was recorded at surface or tooth level also varied. These variations need to be considered when calculating the prevalence of any type of occlusal or cervical wear (Spijker et al., 2009).

It is difficult to make a comparisons of tooth wear between different countries because of methodological variations in the recording of tooth wear and heterogeneity about the cause of tooth wear (Ganss et al., 2011). This section will review studies of occlusal and cervical tooth wear (both mechanical and chemical) among older adults in different countries and the socioeconomic factors associated with tooth wear, although there is limited data on tooth wear in large population-based studies as compared to edentulism and number of teeth. Ireland does not have any previous national-level data of tooth wear of older adults. So, in this section countries other than Ireland are compared in relation to tooth wear among older adults. As the methods used for the recording of tooth wear are also different among different countries and studies, comparisons are made only where comparable data are available.

Figure 2-7 shows, in UK, there has been an increase in tooth wear among older adults, at least in part, because of increased retention of teeth. For all groups aged 45 years and over, there was an increase in all levels of tooth wear from 1998 to 2009, except for those aged 65-74 years, where there was decrease in moderate (33% to 29%) and severe wear (6% to 4%) from 1998 to 2009. From 1998 to 2009, in the UK, among adults aged 45 years and over, this overall increase in tooth wear reflects improved tooth retention with age from 1998-2009 (Figure 2-6), as reported in section 2.4.2. Data reported by Kelly and colleagues and O'Sullivan and colleagues also showed that in the UK, tooth wear prevalence among adults increased from 1998 to 2009, and any wear increased 66% to 77%, moderate wear increased 11% to 15% and severe wear doubled from 1% to 2%, from 1998 to 2009 (Kelly et al., 2000, O'Sullivan et al., 2011).



(Kelly et al., 2000, O'Sullivan et al., 2011)

Figure 2-7: Percentage of adults in different age groups with any wear, moderate wear and severe wear in the UK from 1989 to 2009.

The trends among the different countries of the UK also showed that the percentage of adults with any level of tooth wear increased in all three countries (Scotland was not included in the

2009 survey). Northern Ireland showed the highest increase of 25% for any wear and 6% for moderate wear and Wales reported the highest increase in severe wear, which increased from 0% to 2% from 1998 to 2009 (Kelly et al., 2000, O'Sullivan et al., 2011). A Dutch study also reported that there was an increase over time in mean tooth wear from 2007 to 2013 for all types of teeth and in all age groups (Wetselaar et al., 2015).

2.4.5.2 Factors associated with tooth wear

Many of the suggested factors related to tooth wear include socioeconomic status, dietary factors, medications, and health conditions (Lussi and Carvalho, 2014). Dietary factors related to tooth wear either occlusal or cervical wear, were the intake of acidic food, drinks and raw foods (Lussi et al., 1991). However, the different factors were related to different types of tooth wear, for example, higher intake of acidic foods and drinks caused more erosive wear while the main factor related to attrition is bruxism. Medical conditions affecting tooth wear were gastric reflux, chronic vomiting, anorexia and bulimia (Lussi and Schaffner, 2000). It has also been reported that excessive lingual erosion was also related to chronic vomiting, anorexia and bulimia (Eccles, 1979, Lussi and Schaffner, 2000).

Technique and habits of tooth brushing were related to abrasive tooth wear, mostly cervical (Addy and Hunter, 2003). The relationship of shortened dental arches or loss of posterior teeth with more wear in anterior teeth was reported by some studies but some did not find any increased anterior tooth wear associated with loss of posterior teeth (Smith and Robb, 1996, Witter et al., 2001). For example, a study in Tanzania reported that without posterior teeth support there was a 10% increase in severe anterior wear, but a study in China reported that there was no association between shortened dental arch (SDA) and complete dental arch (CDA) sample, in relation to severe occlusal wear score of 3 and 4. However, adults with SDA had higher mean occlusal wear in premolars than adults with CDA (Smith and Robb, 1996, Witter et al., 2001, Zhang et al., 2014). Similarly, a study in England also reported no relationship between increased wear in anterior teeth with loss of posterior teeth (Smith and Robb, 1996). This variation in results between studies may be because of different sample size, different cultural habits of eating and other factors associated with anterior wear apart from the loss of posterior teeth. Tooth wear has been associated with periodontal bone loss which may lead to gingival recession and increased cervical wear. For example, a study in the USA reported that adults who had any periodontal bone loss also had a 20% higher prevalence of wear than adults without periodontal disease (PR=1.2, 95% CI=1.0-1.4). The authors pointed out "The causative mechanisms contributing to the observed association of tooth wear and periodontal disease cannot be further elucidated in this cross-sectional study" (Cunha-Cruz et al., 2010).

Differences in prevalence of wear between anterior and posterior teeth have also been reported with a higher prevalence of anterior wear than posterior wear (Hugoson et al., 1988, Pigno et al., 2001). For example, Schierz and colleagues reported that mean anterior tooth wear was higher than posterior 3.2 vs 2.6 and exposed dentine was about five times higher in anterior teeth (40.9%) than in posterior teeth (8.7%). The difference between anterior and posterior teeth, in mean tooth wear and exposed dentine prevalence was constant between all age groups and genders (Schierz et al., 2014). In 2009, Spijker and colleagues also reported that the most commonly affected teeth were incisors and most severely affected teeth were molars (Spijker et al., 2009).

It appears that many dietary, medical and behavioural factors have been associated with tooth wear (occlusal, erosive, cervical) but in this section, the factors associated with tooth wear, such as age, gender and socioeconomic variables will be reviewed. Age has been reported as an important factor in relation to tooth wear, with an increase in occlusal tooth wear scores and dentine exposure (Hugoson et al., 1988, Donachie and Walls, 1995). Table 2-45 compares three countries in relation to the proportion of adults with the type of wear by age group and gender, although the methods for recording the tooth wear were somewhat different between countries.

Table 2-45: Percentage of adults with any wear in different countries by age group and gender.

Characteristic	**UK 2009**			**Sudan 2009-10**	**Australia 2004-06**		
Wear	**Any wear**	**Moderate wear**	**Severe wear**	**Any wear**		**Enamel wear**	**Severe wear**
Male	82%	19%	3%	15%		31.7%	4.7%
Female	73%	11%	1%	18.2%		20.0%	1.8%
All	77%	15%	2%	N/A		25.9 %	3.3%
35-45 years	77%	10%	0%	36.9%	**35-55 years**	28.8 %	2.3%
45-54 years	84%	16%	2%	38.7%			
55-64 years	89%	20%	3%	43.6%	**55-74 years**	44.1 %	7.8%
65-74 years	92%	29%	4%	49.4%			
75-84 years	95%	44%	6%	45.5%	**75 years and over**	50.5%	12.0%
85 years and over	94%	34%	6%				

(Slade et al., 2007, O'Sullivan et al., 2011, Khalifa et al., 2012)

Table 2-45 shows that there was an increase in any type of wear with age in the three reported countries. In the UK, any wear and moderate wear increased with age except from 75-84 years to 85 years and over, this decreased tooth wear possibly related to fewer teeth present among very old adults aged above 85 years. Although in the UK, moderate and severe wear also increased with age, the difference between moderate and severe wear was high for all age groups. For example, for in those aged 45-55 years, moderate and severe wear were 16% and 2% respectively and for those aged 75-84 years, it was 44% and 6% respectively. So moderate wear was more common than severe wear among adults in the UK. In 2004-06, in Australia, the proportion of adults with enamel wear almost doubled between those aged 35-55 years (25.9%) to those aged 75 years and over (50.5%) and the proportion of adults with severe wear increased more than three times from those aged 35-55 years (3.3%) to 75 years and over (12.0%). In Sudan, the prevalence of tooth wear also increased with age and it was reported that there was a statistically significant relationship between tooth wear and age (P<0.0001) (Khalifa et al., 2012).

If the three countries are compared in relation to tooth wear, for adults aged 45 years and over, Table 2-45 shows, that the UK had higher any tooth wear prevalence than enamel wear prevalence in Australia and any tooth wear in Sudan. However, in the reported age groups the proportion of adults with severe wear was less in the UK than Australia (though the methods of recording severe wear were different). The severe wear increase was higher in the UK from those aged 35-45 years to those aged 74-35 years (0% to 6%) compared with Australia, from the age group 35-55 years to 75 years and over (3.3% to 12.0%).

Table 2-45 also shows that gender difference was present in the different types of tooth wear in these countries. For example, higher proportions of males had any wear, moderate wear and severe wear in the UK. Similarly, in Australia, higher proportions of males had enamel and severe wear than females. However, in Sudan tooth wear was more common in females than males. A Chinese study also reported that women had higher mean tooth wear among anterior teeth than males (Zhang et al., 2014). However, some studies also did not find any gender difference in relation to tooth wear (Milosevic and Lo, 1996, Rafeek et al., 2006). These studies provide conflicting data on the relationship of tooth wear with gender and this may be a reflection of the different methods of recording tooth wear and variations of behavioural factors between different population groups.

Apart from the comparisons in Table 2-45, other studies have also reported that age was an important factor in relation to tooth wear. For example, in 2009, a systematic review of studies that used the Smith and Knight index of basic tooth wear (Smith, 1984), reported that the percentages of extensive wear (scores 3 and 4) at tooth level varied from 1.4% to 5.7% for occlusal and 3.9% to 24% for cervical wear. The tendency to develop severe wear increased with age, for example, the predicted proportion of adults with severe tooth wear increased from 3% at the age of 20 years to 17% at age of 70 years. Six studies reported that tooth wear prevalence was higher among males than females (Spijker et al., 2009). The trends in tooth wear reported by this systematic review, resemble the findings of different countries reported in Table 2-45, although the methods of recording wear and type of tooth wear again varied between the different studies.

Nonetheless, any type of tooth wear increased with age and males had more severe wear than females. In support of these findings, a study of 1007 adults who attended a dentist and were aged between 26 years to 65 years in South East England, also reported that tooth wear progressed with age and men had more wear than women. Also, they did not find any increased anterior tooth wear with loss of posterior teeth (Smith and Robb, 1996). In 2015, Wetselaar and colleagues in a cross-sectional survey of oral health and preventive behaviour also reported that tooth wear increased with age and males had more wear than females. They reported that mean tooth wear increased with age, as it was 1.79 in those aged 35-44 years and 2.07 in those aged 65-74 years and the trend was the same for all teeth (molar, premolars, canines and incisors). Mean tooth wear was higher among males than females (2.00 vs 1.81) and this difference was constant among all age groups except 45-54 years where both men and women had same mean tooth wear (1.96 vs 1.97) (Wetselaar et al., 2015).

Other studies have reported a greater increase in anterior tooth wear than the posterior tooth wear with age. For example, in Germany, a study estimated the prevalence of dentine exposure, both in anterior and posterior teeth and evaluated the effect of age, sex and location of teeth on tooth wear among a randomised sample of the general population (836 individuals aged 20-59 years) and reported that both anterior and posterior mean tooth wear increased with age. Tooth wear was measured in casts of both jaws of 836 persons and each tooth was scored by 6-point (0-5) ordinal rating scale of modified severity index described by John and colleagues (John et al., 2002). The scores 4 and 5 represented exposed dentine (Schierz et al., 2014). Overall, mean tooth wear increased from 3.0 to 3.3 from those aged 40-49 years to those aged 50-59 years. Whereas a much larger increase was observed in exposed dentine of 24.8% for those aged 40-49 years and 40.4% in those aged 50-59 years. Tooth wear was higher among men than women and the difference between genders was nearly the same in all age groups. Exposed dentine was also higher among males than females. Although this study did not differentiate between attrition, abrasion and erosion, the large sample size gave a good insight into tooth wear among a random sample of the general German population and shows that trends were similar to those reported in Australia and UK, where tooth wear was also increased with age and was more in males than females (Slade et al., 2007, O'Sullivan et al., 2011, Schierz et al., 2014).

The association of age and gender with non-carious cervical wear has also been reported. For example, a cross-sectional study of 768 adults aged 35-44 years and 991 adults aged 65-74 years from urban and suburban districts of Guangzhou, Southern China, reported an increase in the prevalence of non-carious cervical lesion (abrasion and erosion) with age. In this study, the prevalence of non-carious cervical lesions was 76.8% in adults aged 35-44 years and was 81.3% in adults aged 65-74 years. Furthermore, it was reported that non-carious cervical lesions were more prevalent among men aged 65-74 years who lived in suburban districts, used toothpicks, ate hard food, drank vinegar containing beverages and had not visited the dentist in the previous year (Lai et al., 2015). A study in the West Indies also reported that there was a strong association of non-carious cervical wear with old age, vegetarian diet, with high intake of citrus fruit, brushing more than once with medium or hard brushing technique, gastric reflux, bruxism, headaches and broken restorations (Smith et al., 2008). Apart from old age, the possible reason of an increase in non-carious cervical wear with age is that it is due to more recession and periodontal disease with age, that leads to increased cervical wear on exposed tooth surfaces.

Along with occlusal and cervical tooth wear, erosive tooth wear has also been reported to have an association with age, as well as other dietary and oral health habits and medical conditions. For example, a Swedish study reported that facial surface erosion involving the dentine (Grade 2) was much higher (13.2%) in older age groups when compared with younger groups (7.7%), lingual erosion was 6.1% among older groups and 3.6% in younger age groups and occlusal wear due to erosion affected 42.6% of older adults and 29.9% of younger adults. All types of erosive wear were higher in those aged 46-50 years compared with those aged 26-30 years. Erosion was also related to dietary intake habits such as high intake of citrus fruits and juices and occlusal erosion could be further increased by attrition, and abrasion with increasing age (Lussi et al., 1991). Another study in China also reported that age, acidic beverages, xerostomia and brushing habits were identified as risk factors for tooth wear ($p<0.05$) (Sun et al., 2017).

Table 2-46: Percentage of adults with different types of tooth wear in different countries by socioeconomic status, population group and area of residence.

Country & examination years	Socioeconomic Variables	Categories of socioeconomic Variables	Type of tooth wear	% of adults with tooth wear
UK 2009	Occupational Status	Managerial and professional occupations	Any wear Moderate wear Severe wear	77% 15% 1%
		Intermediate occupations	Any wear Moderate wear Severe wear	80% 14% 1%
		Routine and manual occupations	Any wear Moderate wear Severe wear	77% 16% 2%
	Countries in UK	England	Any wear Moderate wear Severe wear	77% 15% 2%
		Wales	Any wear Moderate wear Severe wear	87% 18% 2%
		Northern Ireland	Any wear Moderate wear Severe wear	88% 15% 2%
Australia 2004-06	Level of schooling	Year 9/less	Enamel wear Severe wear	35.3% 6.6%
		Year 10/more	Enamel wear Severe wear	24.6% 2.9%
	Indigenous Identity	Indigenous	Enamel wear Severe wear	37.1% 10.9%
		Non-indigenous	Enamel wear Severe wear	25.7% 3.2%
	Residential location	Capital city	Enamel wear Severe wear	22.7% 2.4%
		Other areas	Enamel wear Severe wear	31.8% 5.0%
	Eligibility for public dental care	Eligible	Enamel wear Severe wear	31.0% 5.4%
		Ineligible	Enamel wear Severe wear	24.1% 2.5%
Sudan 2009-10	Education	No formal schooling Primary Secondary Higher	Tooth wear P>0.0001	10.5% 17.1% 18.4% 21.4%
	Income	Low Moderate High	Tooth wear P=0.05	17.1% 13.1% 20.8%
	Profession	Semiskilled IV & unskilled V Skilled Manual & Non-Manual III Intermediate II Professional I	Tooth wear P=0.012	18.3% 14.4% 7.2% 21.1%

(Slade et al., 2007, O'Sullivan et al., 2011, Khalifa et al., 2012)

Table 2-46 indicates, that apart from behavioural, dental and medical factors, the proportion of adults with wear also varied by education level, type of profession, area of residence and among population groups. Less education and poor economic status had negative effect on tooth wear.

Except in Sudan, where adults with a higher level of education had more tooth wear (21.4%) than adults with no formal schooling (10.5%), and adults with a high income had highest tooth wear (20.8%), followed by adults with low income (17.1%) and moderate income (13.1%). In Sudan, tooth wear prevalence was also highest (21.1%) among adults with professional occupation and lowest among adults with intermediate occupation (7.2%) (Table 2-46).

Tooth wear also varied in the different countries of the UK in 2009, for example England had lowest prevalence of any wear, moderate and severe wear and Wales had the highest prevalence of moderate (18%) and severe wear (2%) and Northern Ireland had the highest prevalence of any wear (88%). Tooth wear not only varied among different countries, but it also varied among different areas and ethnic groups in a country. For example, in Australia, enamel and severe wear prevalence was lower in indigenous adults and adults living in a capital city compared with non-indigenous and adults living in other areas (Table 2-46).

Apart from the comparisons in Table 2-46, a study in China also reported that severe tooth wear was closely related to age and rural adults had more severe wear than urban adults and the mean tooth wear score was also higher for rural adults in posterior teeth than in anterior teeth (Zhang et al., 2014). The association of more wear with low socioeconomic status was also reported by a Dutch study. It found that adults with low socioeconomic status had more wear than adults with high socioeconomic status and this difference was more prominent in those aged 55-64 years and 65-74 years. This difference by socioeconomic status was statistically significant for all type of teeth except premolars (Wetselaar et al., 2015).

2.5 Self-reported versus objectively measured oral health

2.5.1 Introduction

Estimation of oral health status at a national level provides an evidence-base for the formulation of oral health policies aimed at improving oral health and reducing inequalities among different population groups. The clinical assessment of oral health is a detailed process which includes identifying the existing natural teeth, detecting dental caries, assessing periodontal health and documenting oral lesions, as well as evaluating the need for replacement of missing teeth and the placement of restorations. Each of the 32 teeth needs to be evaluated in all these dimensions, both the crown and root of each tooth are examined for dental caries, which may be recorded at tooth or surface level. The extent of periodontal disease and the need for treatment may be evaluated by measuring the plaque score, gingival health, presence of calculus, and periodontal attachment level at each tooth surface (Liu et al., 2010). A simple oral examination of counting number of teeth and the presence of dental caries may be considered invasive by some respondents. A periodontal examination is more invasive than tooth status examination in epidemiological studies and probing the gingivae is often uncomfortable for respondents. In a population-based study, respondents are mostly willing to complete a questionnaire on oral health, but a proportion will not agree to undergo a clinical examination, which may introduce bias in oral health evaluation at a population level. Indices such as the Community Periodontal Index of Treatment Need (CPITN) have been developed to make epidemiological studies more practicable and to overcome the difficulties associated with very detailed periodontal assessment. Nonetheless, it is difficult to calibrate examiners in periodontal indices. The methods of clinical assessment of the two common oral health pathologies, dental caries and periodontal health are expensive, invasive and somewhat uncomfortable procedures (Barmes, 1999). Hence the self-reported assessment of these conditions has become an alternative way to obtain relevant data (Robinson et al., 1998, Gilbert and Nuttall, 1999).

Most periodic social science studies evaluate oral health status through self-reported data either by a questionnaire or an interview (Barry et al., 2009). These are relatively cheap, convenient, quick and replicable ways to collect quantitative and qualitative data in the form of closed questions or open-ended questions, from a large sample or population, which can be easily quantified for analysis (Jupp, 2006). Validation of self-reported behavioural factors, such as diet and physical activity, has been reported and used in the medical literature (Rimm et al., 1992, Wright et al., 1994).

Being a subjective approach, self-reported oral health status (by questionnaire or interview) provides good validity about personal beliefs and attitudes to oral health but may be less valid as an assessment of clinical oral health or as an objective measure of need for treatment. Closed questions are less flexible and force respondents towards limited answers whereas self-reported open-ended questions provide qualitative data that may be difficult to analyse, as both of these are affected by the ideas, thinking and decision-making of each person (Northrup, 1997). The self-reported method of measuring oral health status is also less reliable because questions may be misunderstood and there may be a social desirability bias, including educational, environmental and cultural background factors (Northrup, 1997). However, if self-reported oral health status can be validated for certain aspects of oral health it would be extremely valuable in monitoring oral health in populations.

For the evaluation of oral health conditions at a population level, oral health studies have used one of three modes: self-reported, clinically measured and a combination of self-reported and clinically assessed oral health. For accuracy in self-reported evaluation of oral health conditions and treatment needs, it is important to check the validity and reliability of self-reported oral health conditions and treatment need by comparing them with the equivalent clinical assessments. This can be achieved by applying statistical tools (Kappa coefficient, Chi-square analysis, positive and negative predictive values) or by checking the sensitivity and specificity of self-reported oral health conditions and treatment need.

2.5.2 Self-reported status of teeth

Most of the studies reviewed have reported good validity for the self-reported number of teeth (Douglass et al., 1991, Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003, Liu et al., 2010). For example, in New England (US) a study of community-dwelling adults aged 70 years and over, reported no significant difference in self-reported and clinically measured numbers of teeth (Douglass et al., 1991). A recent study in Japan reported good validity of the self-reported number of teeth against the clinically examined number of teeth by significant Spearman correlation value ($\rho = 0.69$). Although there was a slight underestimation of self-reported mean number of teeth both in males (clinically examined mean number of teeth 26.5 vs self-reported mean number of teeth 24.8) and females (clinically examined mean number of teeth 26.4 and vs self-reported mean number of teeth 25.5) compared to clinically assessed number of teeth was also reported with this significant correlation (Matsui et al., 2016). However, some previous studies in Scandinavia reported an overestimation of self-reported numbers of teeth (Könönen et al., 1986, Palmqvist et al., 1991).

In 2010, Liu and colleagues analysed the data comparing self-reported oral health with clinically examined oral health from two waves (1999-2000 and 2001-2002) of the US National Health and Nutrition Examination Survey (NHANES) (Liu et al., 2010). They reported that adults were able to accurately assess the presence of restorations and prostheses. Pitiphat and colleagues (2002) also reported that the validity of the self-reported presence of dentures, crowns and fixed restorations was good, with high sensitivity (90-100%) and good Spearman correlation ($r = 0.74$-1). These results differ slightly from a study in Scandinavia, which reported that 30% of their sample was not able to self-report the presence of their fixed partial dentures. However, in this Scandinavian study, agreement between self-reported and clinically present, removable dentures was very good. Agreement between the number of missing and replaced teeth was also good at 65%, with a Kappa coefficient of 0.52 (Palmqvist et al., 1991). One of the reasons for this difference between Liu and colleagues and Palmqvist and colleagues studies could be the variability of self-assessment for the fixed-restorations between the samples of two studies (Palmqvist et al., 1991, Liu et al., 2010). A literature review of 19 studies by Ramos and colleagues also reported good the validity (both sensitivity and specificity) of number of remaining teeth and use and need of prosthesis, despite the variations of the self-reported questions used to measure number of teeth and use and need of dental prosthesis among studies reviewed (Ramos et al., 2013).

Studies have reported moderate sensitivity of self-reported dental caries against clinically assessed caries. For example, in relation to the self-reported evaluation of dental caries, Robinson and colleagues reported a sensitivity of 58% and specificity of 71%, when self-reported dental caries was compared with clinically assessed dental caries (Robinson et al., 1998). Pitiphat and colleagues 2002 also reported that counts of self-reported decayed teeth had moderate sensitivity (59.5%) and Spearman correlation (r=0.47) when compared with the clinical assessment.

2.5.3 Self-reported periodontal status

Given the generally asymptomatic nature of periodontal disease, it is not surprising that studies on self-reporting of periodontal status report low validity. Most of the studies have focussed on symptoms such as bleeding, deposits, gingival recession or mobility, of which people are more likely to be aware.

In 1999, Gilbert and Nuttall did a study to develop a questionnaire for use in self-reported epidemiological studies of periodontal disease. Their self-reported questionnaire included questions about deposits, bleeding gums, tooth migration and the factors (smoking and dental attendance) related to these conditions. Clinical examination included the recording of plaque score, bleeding gums, tooth mobility for each tooth present and CPITN for the worst tooth in each sextant in the mouth (Gilbert and Nuttall, 1999). The sensitivity for most of the self-reported questions was more than 0.50 and specificity was 0.95-1, which indicates that half of those people who had periodontal disease were unaware of it but on the other hand, a high proportion was correct in reporting that they did not have periodontal disease (Gilbert and Nuttall, 1999). Furthermore, the sensitivity for bleeding gums after tooth brushing was 0.75-0.88 and specificity was 0.18-0.25 but these figures were reversed when asked about current bleeding gums when sensitivity was 0.19 -0.35 and specificity was 0.86-0.88.

Different studies have reported overall poor sensitivity of self-reported gingival and periodontal health, using different questions for self-reported periodontal health although few questions, such as bleeding after brushing had good sensitivity. For example, Tervonen and Knuuttila (1988) compared CPITN scores with the self-reported bleeding and inflammation of the gingivae and whether the respondent felt that he/she had periodontal disease. In this study, bleeding after tooth brushing had good sensitivity (0.75-0.88) and low specificity. But the question about the current self-reported experience of gingival bleeding showed the opposite trend. It had high specificity (0.86 - 0.88) but low sensitivity (0.19-0.35). Overall, self-reported periodontal disease had low sensitivity (less than 0.5) except for bleeding after brushing (Tervonen and Knuuttila, 1988).

Similarly, in 1994, Kallio and colleagues related self-reported gingivitis and gingival bleeding with CPITN score in adolescents. Their study reported poor validity of self-reported gingival health, as compared to clinically determined status and that supported the results of the study by Heloe, which noted that gingival disease was under-reported by self-assessment (Heloe, 1972, Kallio et al., 1990). However, the Tervonen and Knuuttila and Gilbert and Nuttall studies reported that self-reported bleeding gums after brushing had good validity. A literature review (of 19 studies out of which 13 included the validity of self-reported periodontal health) by Ramos and colleagues reported that self-reported bleeding gums had the highest sensitivity (100%) and specificity (83%) among all self-reported questions of periodontal health in the studies reviewed. However, the sensitivity of self-reported periodontal health varied with different types of self-reported questions (Ramos et al., 2013). These studies concluded that an easy method of self-reported evaluation and its association with clinically assessed periodontal health were important factors to improve the validity of self-reported periodontal health.

Although the Tervonen and Knuuttila and Gilbert and Nuttall studies that had noted self-reported bleeding gums after brushing had good validity, this was disagreed with by the Nagarajan and Pushpanjali study in India (Tervonen and Knuuttila, 1988, Gilbert and Nuttall, 1999, Nagarajan and Pushpanjali, 2008). In 2008, they did a cross-sectional study of 216 patients, aged 20-44 years (selected from outpatients' department of Ramaiah Dental College, Bangalore, India) to evaluate the agreement between clinically assessed and self-reported periodontal health. The study used self-reported questions regarding deposits on teeth, bleeding and receding gums, swelling of gums and tooth mobility and was followed by a periodontal examination, including the recording of a gingival index (Loe and Silness), CPITN (WHO) and tooth mobility (arbitrary no/yes) (Nagarajan and Pushpanjali, 2008). Self-reported versus clinically examined the sensitivity and specificity of different periodontal conditions calculated from this study are shown in Table 2-47.

The Nagarajan and Pushpanjali study reported very low sensitivity for current bleeding gums, which supported the findings of Tervonen and Knuuttila (Tervonen and Knuuttila, 1988, Gilbert and Nuttall, 1999, Nagarajan and Pushpanjali, 2008). The possible reason for the lower sensitivity of bleeding gums may be the small sample size or other questions asked along with bleeding gums, such as tooth mobility and calculus, were easier to self-evaluate than swelling and bleeding. Furthermore, in those aged 20-44 years, bleeding on brushing may not have been as evident as bleeding on probing. The Nagarajan and Pushpanjali study also reported the highest sensitivity for self-reported tooth mobility, which supports the study of Gilbert and Nuttall, who also reported good validity for self-reported tooth mobility. The probable reason for higher validly of self-reported tooth mobility is the symptomatic nature of the tooth mobility as compared to gums swelling and bleeding.

Table 2-47: Sensitivity and specificity of self-reported periodontal health in Indian adults of 20-44 years.

Periodontal Condition	**Sensitivity**	**Specificity**
Gingival bleeding	18%	75.8%
Deposits on teeth	22.7%	87.5%
Gingival swelling	1.6%	65.7%
Gingival recession	0%	100%
Tooth mobility	35.2%	98%

(Nagarajan and Pushpanjali, 2008)

The above-reported studies show that it is difficult to compare different studies in the context of the validity of self-reported periodontal health because of differences in the self-reported questions, sample selection and factors associated with it. Nonetheless, the broad conclusion from above-reported studies is that self-reported periodontal health had overall poor sensitivity. Apart from periodontal disease being less symptomatic, the possible reasons for this poor sensitivity need further investigations.

2.5.4 Self-reported treatment need

There is much less data available specific to the relationship between self-reported dental treatment needs and objectively measured dental treatment needs. Recently, in 2016, Farmer and colleagues checked the reliability of self-reported versus clinically assessed dental treatment needs among a Canadian population. They drew a sample of adults from the Canadian Health Measures Survey (CHMS), Cycle 1, household and clinical questionnaire, who self-reported their unmet dental treatment need. They found that 32.8% of the Canadian population had at least one unmet dental treatment need. This study found that there was moderate agreement for orthodontic, endodontic and surgical treatment need (Kappa coefficient 0.41-0.60), fair agreement for preventive and restorative treatment need (Kappa coefficient 0.21-0.40) and poor agreement (Kappa coefficient <0.20) between clinical and self-reported periodontal treatment need.

This study concluded that self-reported unmet dental treatment need evaluation in a population is not reliable at the clinically determined standards. Self-reported periodontal, diagnostic and preventive treatment needs had poor diagnostic accuracy, whereas self-reported endodontic and orthodontic treatment needs had reasonable diagnostic accuracy in this epidemiological study (Farmer et al., 2017).

Despite the lack of literature specific to the comparison of self-reported dental treatment needs against the clinically assessed dental treatment needs. If the self-reported oral health is used as a proxy for self-reported dental treatment needs and is compared with clinically measured oral health as the proxy for clinically assessed treatment needs as reported in section 2.5.2 and section 2.5.3. The self-reported missing teeth and self-reported dental decay as a proxy of self-reported restorative treatment needs had better validity than self-reported periodontal health as a proxy of self-reported periodontal need and these findings were similar to study of Farmer and colleagues in 2017 (Farmer et al., 2017).

2.5.5 Factors affecting the accuracy of self-reported oral health status

It is also noticeable from the above-mentioned studies that self-reported sensitivity of oral health apart from bias of self-believes, ideas, and personal preferences, is also affected by a range of factors, such as the question design, demographic covariates, the participants' use of a mirror when answering the questionnaire and the clinical methods used for the assessment (Douglass et al., 1991, Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003, Liu et al., 2010, Firmino et al., 2018). The effects of question design on the validity of self-reported oral health data compared with clinically examined oral health data were best described by studies of Vered and Cohen and Robinson and colleagues (Robinson et al., 1998, Vered and Sgan-Cohen, 2003). In 2003, a study in Israel by Vered and Cohen, calculated the validity of self-reported dental health and periodontal health by asking the question, "How do you report the health of your teeth and gum health?" Later they compared it with clinically measured periodontal health and dental health. The results reported that sensitivity for self-reported dental health was 0.34 (95% CI= 0.32-0.36) and for self-reported gum health was 0.28 (95% CI= 0.21-0.35). The specificity for both self-reported dental health and gum health was 0.83 (95% CI= 0.81-0.83). However, an explanation for these poor sensitivity figures may have been the openness and pattern of the questions asked. Whereas, Robinson and colleagues validated self-reported dental caries with clinically assessed dental caries and found that the number of respondents with clinically assessed dental caries was the same compared with their own self-report of dental caries. This was probably because they asked the question differently, "Do you think some of your teeth are decayed". It improved the validity of self-reported dental decay against objectively measured dental caries. In order to improve self-reported validity, they recommended to first evaluate the questionnaire among the adult population being investigated (Robinson et al., 1998). These two studies show that a well-structured question can improve the validity of self-reported data on oral health (Robinson et al., 1998, Vered and Sgan-Cohen, 2003).

Furthermore, Pitiphat and colleagues improved the validity of self-reported data by facilitating the participants with the handheld mirrors which helped them in their self-reporting of oral health and improved the validity of self-reporting of teeth and prosthesis. Another important issue noted in this study was the elimination of the time gap between self-reporting and clinically examined dental health because they carried out the clinical examination later on the same day of the self-reporting data collection, which might have improved the validity of self-reported oral health (Pitiphat et al., 2002).

In relation to socioeconomic factors, Liu and colleagues reported that age, gender, education, ethnicity and income were important covariates in the discrepancy between self-reported and clinically determined oral health. For example, generally, older adults had poorer oral health status and were also unaware of it, which suggests that older adults may overestimate their oral health status compared with young adults. These authors suggested the need for a model with covariates that can calibrate the self-reported oral health score to clinically determined oral health status, in order to improve the specificity and sensitivity of self-reported against clinically measured oral health (Liu et al., 2010).

Along with the above-reported factors affecting the validity of self-reported oral health status against clinically measured oral health status, Firmino and colleagues reported that oral health literacy was also an important factor affecting the validity of self-reported oral health (Firmino et al., 2018). Matsui and colleagues reported that improvements in the question about remaining teeth can further improve the validity of self-reported data on the number of teeth (Matsui et al., 2016)

In short, apart from personal believes and ideas, the age, gender, education, ethnicity, socioeconomic status, physical health, mental health, the structure of self-reported questions, the time gap between self-reported and clinically examined oral health and oral health literacy level were important factors affecting the validity of self-reported data (Douglass et al., 1991, Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003, Liu et al., 2010, Firmino et al., 2018). Among all of the reported factors affecting the validity of self-reported oral health data, the structure of the self-reported question, improvements in oral health literacy level and reduction of time gap between self-reported and clinically measured oral health evaluation can be improved.

2.5.6 Conclusions

It is difficult to compare and draw conclusions from the results of the studies discussed above as each study used different questions for different oral health conditions, although their methods of clinical examination were quite similar. The validity of the self-reported oral health tends to be poor and most of the studies reviewed have reported higher sensitivity of self-reported assessment of the number of teeth and dentures (Douglass et al., 1991, Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003, Liu et al., 2010, Ramos et al., 2013, Matsui et al., 2016). Poor sensitivity was reported for different dental treatment needs and periodontal health (Heloe, 1972, Könönen et al., 1986, Gilbert and Nuttall, 1999, Vered and Sgan-Cohen, 2003). Whereas the sensitivity of self-reported dental caries status was better than that for periodontal health, this may depend upon having well-structured and understandable questions about tooth decay (Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003). A possible reason for periodontal conditions having lower self-report sensitivity might be because these disease processes are less symptomatic, less visible and do not interfere with oral functions until very far advanced. It may be necessary to create an awareness of the symptoms of periodontal disease in order to improve the sensitivity of self-assessed periodontal disease. However, decayed and missing teeth often cause discomfort and pain and, on anterior teeth, nearly always have aesthetic concerns, these are more easily noticed by a person and therefore have better self-report sensitivity.

Although the self-reported oral health assessment provides an easy, cheap and quick method of evaluation of oral health, its validity is questionable as it often gives different results as compared to clinically assessed oral health. It is affected by socioeconomic, general and mental health as well as self-perceptions and beliefs (Liu et al., 2010). Different scales have been developed for self-report measures, for example, the Oral Health Impact Profile (OHIP) is a widely used measure and reflects the negative effects of a person's oral health (Marcus et al., 1983, Spolsky et al., 2000).

There is a need to design a simple, easily understandable and valid questionnaire to target each oral health condition, which should be minimally affected by the personal perception of the questions. These questions should be piloted in different population groups within and between countries, to determine the best achievable sensitivity for various oral health conditions and treatment needs. There is also a need to fill the gap between structured questions and clinical assessment of oral health. For example, "How is the health of your teeth?" compared to asking, "Can you count your decayed teeth in front of the mirror?". The latter question is likely to provide much better data in relation to decayed teeth. In addition to the structure of self-reported questions, improvements in oral health literacy level and reduction of time gap between self-reported and clinically measured oral health evaluation will further improve the validity of self-reported oral health assessments against clinically examined oral health.

2.6 Oral health and its relationship with systemic diseases

2.6.1 Introduction

The relationship between oral health and systemic health conditions has been investigated for many years and the importance of oral health for prevention of chronic general health conditions has been endorsed by the World Health Organisation (WHO) (Petersen and Yamamoto, 2005). Some oral health and systemic health conditions not only share common risk factors and risk indicators, but there are also physiological and pathophysiological connections between the oral cavity and the body systems in both healthy and disease situations (Sheiham and Watt, 2000, Chapple, 2009). It has been estimated that more than 100 systemic conditions have oral manifestations, among which are diabetes, blood disorders and HIV (Chapple, 2009).

The inter-relationship between oral health and systemic diseases is becoming better understood but still needs further research to establish the nature of these relationships; in particular, whether they are associations or causative (Seymour, 2007). This interrelation is more pronounced in old age, when for example, fewer natural teeth may affect nutritional intake. Being a cumulative effect of oral disease, edentulism is an independent risk factor for weight loss which may lead to poor health and diseases such as diabetes, osteoporosis and heart disease (Petersen and Yamamoto, 2005). Evidence suggests that the loss of all natural teeth has an impact on diet, nutrition and general wellbeing, and this impact might extend well beyond the mouth (Steele et al., 1998, Walls et al., 2000). For example, it was reported that on average, most edentulous people who wore dentures reported poorer subjective health, than people who had natural teeth (Slade and Spencer, 1994). On the other hand, systemic diseases and the medications to manage them often cause salivary hypofunction which can lead to poor oral health.

Because of increased life expectancy and lower birth rates, in most countries, the population is ageing rapidly. Many chronic diseases are part of ageing and oral health is significant in the ageing population because, along with decreased immunity, poor oral health may exacerbate systemic conditions and vice versa (Shlossman et al., 1990).

In this section of the literature review, the evidence for the relationship between oral health (mainly periodontal disease and tooth loss) and some systemic conditions such as diabetes, cardiovascular disease (CVD), osteoporosis and cognition are reviewed. Nonetheless, as alluded to previously, tooth loss may not be a good indicator of oral health (Haworth et al., 2018). Haworth and colleagues stated, "Tooth loss is a complex measurement of oral health and is related with many determinants (age, socioeconomic status, systemic, mental and physical health conditions) and one of them is dental status (periodontal health, caries, previous tooth loss) itself." So, they suggested that tooth loss as an indicator of poor oral health should be used with caution when the relationship between oral health and other conditions is evaluated. The authors also suggested that the tooth loss could be because of other oral health conditions instead of systemic health conditions and so it should be used with caution when evaluating the relationship between oral health and systemic health conditions (Haworth et al., 2018).

2.6.2 Oral health and diabetes

2.6.2.1 Introduction

Among all diseases, periodontal disease is one of the most important non-communicable diseases confronted globally and it is an essential component of oral health. The European Workshop on Periodontal Education stated, "Preservation of periodontal health is a key component of oral and overall health and as such is a fundamental human right" (Baehni and Tonetti, 2010). Worldwide, periodontitis affects 50% of adults of all ages, this figure rises to 60% in adults over 65 years, and severe periodontitis affects 10-15% of populations (Chapple and Genco, 2013). Periodontitis is a multifactorial, chronic inflammatory, destructive disease of the periodontium (the tooth supporting structures). It is initiated by microbial activity but an interplay between this activity and the host immune response can cause progressive destruction of the tooth-supporting structures and may lead to tooth loss. Periodontitis is one of the most common chronic diseases and is considered a major public health issue because it is a source of social inequity due to impaired aesthetics, inadequate chewing, increased dental costs, tooth loss and reduced oral functions (Chapple and Genco, 2013).

Globally, diabetes mellitus is an emerging epidemic whose complications lead to poor quality of life and reduced longevity. In 2014, the WHO reported that worldwide, 422 million people suffered from diabetes and this figure is projected to increase to 439 million (affecting 10% of adults) by 2030 (World Health Organisation, 2015, Updated 2017). Complications of diabetes include renal failure, heart attacks, stroke, loss of eyesight and lower limb amputation. The WHO has reported that diabetes is projected to be the seventh most likely cause of death by 2030 (World Health Organisation, 2015, Updated 2017).

Pathophysiologically, there are three types of diabetes; Type-1 (insulin-dependent, autoimmune destruction of pancreatic beta cells stops the insulin production), Type-2 (insulin-independent, altered body response to insulin or altered insulin production), Gestational diabetes (hyperglycaemia in the third trimester of pregnancy). Type-2 diabetes is the most common form of diabetes and it is related to overweight and inactivity (Mealey and Oates, 2006).

2.6.2.2 The effect of diabetes on periodontal disease

Both diabetes and periodontal disease are chronic inflammatory diseases and appear to be interrelated (Lalla and Papapanou, 2011). A review of the literature provides strong evidence that diabetes is a risk factor for both gingivitis and periodontitis and glycaemic control plays an important role in this relationship (Papapanou, 1996, Mealey and Oates, 2006). The mechanisms involved in diabetes as a risk factor for periodontal disease are; alteration in gingival crevicular fluid, alteration in collagen metabolism, microangiopathy, altered host response, changed subgingival microflora and heredity patterns (Taylor et al., 1998). Periodontitis is not only directly interrelated with diabetes but tooth loss because of periodontitis in diabetic adults may be more pronounced than in non-diabetic adults.

Studies have evaluated the relationship of both Type-1 diabetes and Type-2 diabetes with different aspects of periodontal disease such as gingivitis and periodontitis. It has been reported that among adults and children with Type-1 diabetes, gingivitis developed more rapidly and was more severe than in adults and children without Type-1 diabetes, even though plaque scores were the same among the two groups. In this association glycaemic level played some role because better glycaemic control improved gingivitis in Type-1 diabetic children (Karjalainen and

Knuuttila, 1996, Salvi et al., 2005). In contrast, Ervasti and colleagues reported that there was no difference between gingival inflammation in adults with the same plaque score, with and without Type-1 diabetes. However, gingival bleeding was directly related to glycaemic control, so adults with poorly controlled Type-1 diabetes had significantly more gingival bleeding than adults with well-controlled Type-1 diabetes and those without diabetes (Ervasti et al., 1985).

Type-2 diabetes has also been related to gingivitis. For example, in 1999, the study by Cutler and co-workers reported that adults with Type-2 diabetes had more gingivitis than adults without diabetes and the level of gingivitis was directly related to glycaemic control (Cutler et al., 1999). A few studies have not reported a significant association between diabetes and gingival inflammation (Sbordone et al., 1998). But there is ample evidence to state that diabetes (Type-1 and Type-2) is a risk factor for gingivitis, which is dependent on glycaemic control in diabetic adults and independent of plaque score. So poorly controlled diabetic adults are more prone to develop severe gingivitis than well-controlled diabetic adults. Gingivitis is a reversible condition, and improvements in gingivitis are related to glycaemic control (Karjalainen and Knuuttila, 1996, Sbordone et al., 1998, Cutler et al., 1999, Salvi et al., 2005).

Other studies have reported an association between diabetes (Type-1 and Type-2) and periodontitis. In 1996, Baelum and Papapanou provided evidence that any type of diabetes in any age group had a significant association with periodontitis (Baelum and Papapanou, 1996). Their conclusions were drawn from a meta-analysis of 10 cross-sectional adult studies, 6 longitudinal studies and 32 cross-sectional studies of children and adolescents (a total of 3500 diabetic adults) to evaluate the association between diabetes and periodontitis (Baelum and Papapanou, 1996).

Apart from the association between diabetes (Type-1) and periodontitis, some studies also reported that the severity of periodontitis was also related to glycaemic control among Type-1 diabetic adults. For example, in 1992 and in 1994, Safkan-Seppala and Ainamo reported that adults with poorly controlled Type-1 diabetes had more the interproximal clinical attachment loss and alveolar bone loss (by radiographic evaluation and by site by site evaluation of attachment loss and alveolar bone loss) than adults with well-controlled Type-1 diabetes (Safkan-Seppala and Ainamo, 1992, Seppala and Ainamo, 1994).

In contrast to the above studies, a few studies did not find any association between Type-1 diabetes and periodontitis (Sbordone et al., 1998). In one example, a 3-year follow up study of 16 Type-1 diabetes (insulin-dependent) patients and their 16 siblings without diabetes reported no difference between periodontal health of diabetic and non-diabetic siblings (Sbordone et al., 1998). Although the sample in the study was very small and results may not be reliable but the study is important to report because it involved siblings and so the participants had similar lifestyles (Sbordone et al., 1998).

There is sufficient evidence to support the association between Type-2 diabetes and the prevalence and severity of periodontitis although the methods of measurement for periodontitis were different in different studies. As most of these studies used clinical examination to record pocket depth or attachment loss and some used radiographs to measure attachment loss and alveolar bone loss to diagnose periodontitis (Nelson et al., 1990, Taylor et al., 1998). For example, an epidemiological study in a population with the highest occurrence of Type-2 diabetes (the Pima Indians of Arizona) reported that among a dentate sample of all age groups, the prevalence and extent of attachment loss and alveolar bone loss was greater among adults with Type-2 diabetes when compared with nondiabetic adults (Emrich et al., 1991). In 1990, Nelson et al, also reported that among 2273 Pima Indians aged 15 years and over, periodontitis prevalence was 60% among adults with Type-2 diabetes and 36% in non-diabetic adults (Nelson et al., 1990).

Apart from a higher prevalence of periodontitis among Type-2 diabetic adults, some studies have also reported that the incidence and progression of periodontitis were greater among adults with Type-2 diabetes than in adults without Type-2 diabetes (Nelson et al., 1990, Taylor et al., 1998). For example, in 1990, Nelson and colleagues reported that the periodontitis incidence was 2.6 times greater among adults with diabetes with no baseline periodontitis compared to the non-diabetic adults with no baseline periodontitis, in an average of 2.5 years follow up (Nelson et al., 1990). In 1998, Taylor and colleagues also reported that the prevalence of alveolar bone loss was higher among Type-2 diabetic adults than non-diabetic adults (Taylor et al., 1998).

Other studies have also evaluated whether Type-2 diabetes is as a risk factor for periodontal disease (Taylor et al., 1998, Tsai et al., 2002, David and Famili 2017). For example, in 1998, Taylor and colleagues carried out a study of 362 subjects aged 15-57 years, among them 24 adults had Type-2 diabetes and 338 subjects were without diabetes at baseline. Alveolar bone loss in both groups of subjects was recorded at baseline and at 2-year follow up by panoramic radiographic measures. The results revealed that adults with Type-2 diabetes were at 4 times higher risk of alveolar bone loss compared with adults without diabetes. So, this longitudinal study suggested that Type-2 diabetes is a risk factor for periodontal disease (Taylor et al., 1998).

In 2002, a study by Tsai and colleagues reported that poorly controlled diabetes was more related to periodontitis than well-controlled diabetes. They also reported that poorly controlled Type-2 diabetes significantly increased (OR= 2.90, 95% CI=1.40- 6.03) the risk of periodontitis, after controlling for age, calculus, education and smoking. However, well-controlled diabetes, less significantly increase the risk of periodontitis (OR= 1.56; 95% CI=0.90- 2.68) (Tsai et al., 2002).

In 2017, David and Familli supported the findings of Tsai and colleagues in 2002 and evaluated the association of periodontal disease with diabetes along with covariates of age, gender, education, and smoking. Their study concluded that the adults with diabetes, who were aware of it and tried to control glycaemic levels had less chance of developing periodontal disease and that diabetes was a major risk factor for periodontal disease in the presence of other covariates such as age, gender, education, and smoking. This finding suggests that a well-controlled glycaemic level was not related to periodontal disease (David and Famili 2017). A German study of 4288 adults (145 Type-1 diabetics, 182 Type-2 diabetics, 2647 non-diabetic aged 20-59 years, and 1314 non-diabetic aged 50-81 years) also reported that the Type-1 diabetes ($p<0.01$) and Type-2 diabetes ($p<0.01$) had significant associations with mean attachment loss in a fully adjusted model. After adjustment for age, a significant association between Type-2 diabetes and mean attachment loss was only present in 60-69 years old adults (Kaur et al., 2009). The probable reason for this was that in the study, the adults in the sample with Type-1 diabetes were younger than adults with Type-2 diabetes.

Most of the studies reviewed here have reported that glycaemic control in Type-1 and Type-2 diabetes was a reason for diabetes being a risk factor for periodontal disease (Safkan-Seppala and Ainamo, 1992, Seppala and Ainamo, 1994, Taylor et al., 1998, Tsai et al., 2002, Al-Emadi et al., 2006, Kaur et al., 2009, Chapple and Genco, 2013, David and Famili 2017). However, a few studies did not report an effect of glycaemic control on periodontal health. For example, a study of 118 diabetic and 115 non-diabetic reported that the duration of diabetes and glycaemic control (Glycaemic control as assessed by fasting plasma glucose and glycosylated haemoglobin values) were not significantly related to periodontal health status, though all the periodontal measurements were significantly worse among diabetic adults than in non-diabetic adults (Bridges et al., 1996). This study was a cross sectional study, limited to men only and included co-factors of smoking, dental attendance and socioeconomic status. It may be that poor periodontal health among the diabetic group was because of other cofactors, for example, smoking and poor socioeconomic status instead of diabetes. This may be why periodontal health was not significantly related to glycaemic control.

The above-mentioned evidence supports the association of diabetes (Type-1 and Type-2) with gingivitis and periodontitis. Poorly controlled diabetes (poor glycaemic control) is a well-evaluated risk factor for severity and incidence of periodontitis while age, smoking and poor socioeconomic status are important covariates affecting this relationship.

2.6.2.3 The effect of periodontal disease on diabetes

For the last 20 years, the association between periodontal inflammation and hyperglycaemia and diabetes has been reported. It has also been suggested that poor periodontal health worsens diabetic complications caused by inadequate glycaemic control. The possible reason is that periodontitis causes bacteraemia by the entry of oral microbial agents and their virulence factors into the circulation. It is evident by increased serum C-reactive proteins and oxidative stress biomarkers leading to reduced glycaemic control, more complications, insulin resistance, decreased beta cell activity and Type-2 diabetes (Chapple and Genco, 2013).

Studies have indicated that periodontal health affects glycaemic control in diabetes (Type-1 and Type -2) which in turn increases complications (Thorstensson et al., 1996, Taylor and Borgnakke, 2008, Demmer et al., 2008). For example, in 2008, Taylor and colleagues did a systematic review of 17 reports to explore the effect of periodontal health on glycaemic control in diabetes. They found that improved periodontal health helped glycaemic control and complications of diabetes (Taylor and Borgnakke, 2008). In 1996, Thorstensson and colleagues (longitudinal case-control study of 39 diabetic and 39 non-diabetic adults, aged 36-70 years) also reported that 82% of Type-1 diabetic patients with severe periodontitis suffered complications of diabetes (cardiovascular disease, cerebrovascular, peripheral vascular) as compared to 21% of patients with diabetes and without periodontitis (Thorstensson et al., 1996).

In 1996, Taylor and colleagues (from a 2-year longitudinal study of adults aged 18-67 years), also supported the evidence by Thorstensson et al in 1996 and reported that adults with Type-2 diabetes and severe periodontitis had a six-times increased risk of poor glycaemic control compared to adults without periodontitis (Taylor et al., 1996). However, some studies did not find any effect of improved periodontal health on glycaemic control, such as the study by Promsudthi and colleagues in 2005 (Promsudthi et al., 2005).

The effect of periodontal health on diabetes (Type-1 and Type-2) was further investigated by examining the effect of periodontal treatment on glycaemic control among diabetic adults. Different studies used different periodontal treatments with and without antibiotic use, to see the effect of periodontal treatment on Type-1 and Type-2 diabetes. For example, in 1996, Grossi and colleagues reported an association between periodontal treatment by scaling, root planing and systemic doxycycline with a reduction of glycosylated haemoglobin (HbA1c) which reflects serum glucose level in adults with Type-1 and Type-2 diabetes (Grossi et al., 1996). In 1960, Williams and Mahan reported that a reduction in insulin dose was required among Type-1 diabetic patients with periodontitis who were treated by scaling, root planing, gingivectomy, and extraction of hopeless teeth, along with systemic penicillin G, streptomycin and procaine (Williams and Mahan, 1960).

A few studies reported improved glycaemic control only after scaling and root planing without systemic antibiotics (doxycycline or amoxicillin) (Stewart et al., 2001, Kıran et al., 2005). A study of adults aged 55-80 years with poorly controlled Type-2 diabetes also reported that the treatment group showed improvements in periodontal health and HbA1c (glycosylated haemoglobin) levels were lower than in the control group. But there were no statistically significant improvements in HbA1c levels with periodontal therapy of scaling, root planing and systemic doxycycline in 3 months. It may be that the effects of periodontal treatment were not statistically significant because the sample had poorly controlled diabetes (Promsudthi et al., 2005).

To evaluate the effect of type of periodontal therapy on glycaemic control in the diabetic patient, the studies have also reported that any type of periodontal treatment can affect glycaemic control in diabetes. For example, in 1997, Grossi and colleagues randomized 113 Native Americans with periodontal disease and Type-2 diabetes into five treatment groups. Each group received a slightly different type of periodontal treatment. They found a 10% reduction in HbA1c (glycosylated haemoglobin) from baseline to 3-months after any type of periodontal treatment (Grossi et al., 1997).

Although some of the above studies, reported a positive effect of periodontal treatment on glycaemic control, to exclude the effect of other cofactors, some studies reported the same effect when cofactors were controlled. For example, in 2013, a study of 50 Type-2 diabetes adults aged 35-70 years by Modi and Desai, excluded any adults with cardiovascular disease (CVD), other diseases, those on antibiotic or anti-inflammatory therapy and those who received periodontal therapy in the previous 4 months, to exclude an effect of other treatments on glycaemic control apart from full-mouth scaling and root planing. They reported that improved periodontal health by full-mouth scaling and root planing was associated with decreased levels of HbA1c. This study randomly divided the sample into two equal groups of case and controls. The cases received full-mouth scaling and root planing. After 3 months of periodontal therapy, the cases showed improved clinically measured periodontal health and a significant decrease in HbA1c level as compared to baseline measurements and with a control group. So this study concluded that the metabolic and clinical improvements after periodontal therapy (full mouth scaling and root planing) showed that there was a significant correlation between Type-2 diabetes and treatment of periodontitis (Modi and Desai, 2013).

In 2013, a consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases supported the results of a systematic review and meta-analysis of 9-studies by Engebretson and Kocher. This review reported that randomised controlled trials (RCTs) showed that periodontal treatment was associated with a decrease in HbA1c level in patients with Type-2 diabetes. The mean reduction in HbA1c was 0.36% in three months, which is equal to adding a second drug in the pharmacological regime of diabetes (Chapple and Genco, 2013, Engebretson and Kocher, 2013). They recommended periodontal treatment should be added to the management of Type-2 diabetes (Chapple and Genco, 2013).

In contrast to the above reported studies, in 2005, Janket and colleagues, did not find a statistically significant decrease in HbA1c level after periodontal therapy. They did a meta-analysis of 10 intervention studies (including 5 studies of Type 1 and 5 studies of Type 2 diabetes with a total 456 patients) to evaluate the effects of periodontal therapy on diabetes (Type-1 and Type-2) by measuring HbA1c level. The study reported a 0.4% weighted average decrease in absolute HbA1c level. Systemic antibiotic therapy led to 0.7% of average absolute reduction in HbA1c. However, both of these results did not show a statistically significant decrease in HbA1c level after periodontal therapy (Janket et al., 2005). The limitations to this meta-analysis were that the sample was from 10 studies (having 456 adults) and there was mixing of the sample with both types of diabetes and presence of important covariates such as smoking, BMI and other conditions among the sample. As reported above, Promsudthi and colleagues also found that the poorly controlled Type-2 diabetes showed no statistically significant improvements in HbA1c (glycosylated haemoglobin) levels by periodontal therapy of scaling, root planing and systemic doxycycline for 3 months (Promsudthi et al., 2005).

In addition to the effect of periodontal health on glycaemic control in diabetic adults (Type-1 and Type-2), periodontal health has also been reported as a risk factor for the incidence of diabetes in non-diabetic adults with periodontitis. For example, Demmer and colleagues evaluated the data from NHANES I (with mean follow up of 17 years), to see if there was a relationship between periodontitis and tooth loss in people with diabetes mellitus. They reported that the three worst periodontal disease quantiles were related to a risk of diabetes mellitus. Adults with periodontal disease and without diabetes were at higher risk of developing Type-2 diabetes than adults without periodontal disease and diabetes (Demmer et al., 2008).

Chapple and Genco also supported the finding of Demmer and colleagues and reported that the severe periodontitis was not only associated with increased HbA1c in Type-2 diabetes but was also in non-diabetic adults. In non-diabetic individuals, the progression of periodontitis for 5-10 years caused increased HbA1c and glucose intolerance. The non-diabetic adults with periodontitis had higher increases in HbA1c than non-diabetic adults without periodontitis (0.143% vs 0.005%). Therefore, adults with severe periodontitis were at higher risk of developing diabetes than adults with mild to moderate periodontitis. Gingivitis was not related to increased levels of HbA1c so periodontitis should be differentiated from gingivitis to evaluate the effect on diabetic and non-diabetic individuals (Chapple and Genco, 2013).

Although the sample sizes, age groups, methods of measurement and periodontal therapy were different, the above-mentioned studies concluded that periodontal disease and diabetes mellitus (Type-1, Type-2) are interrelated by sharing a common pathophysiology. Inflammation and glycaemia play a critical role in this relationship. However, the mechanism of the effect of periodontal disease on glycaemic control in diabetes is not as clear as the effect of diabetes on periodontal health. Secondly, cofactors need to be evaluated in detail, for example in diabetes and obesity as both are relevant in poor glycaemic control.

A systematic review in 2013, by Taylor and colleagues, to evaluate the relationship between periodontitis and diabetes at cellular and molecular level, reported that there was enough evidence to support the diabetes effects on periodontitis but the effect of increased inflammatory factors from periodontitis on diabetes was still speculative as samples were small and most of the studies included in their systematic review which evaluated the effect of periodontitis on diabetes at molecular level, were cross-sectional studies. They suggested that longitudinal clinical studies are required to answer this question conclusively (Taylor et al., 2013).

2.6.2.4 Diabetes and tooth loss

Along with periodontal health, studies have also reported a relationship between tooth loss and diabetes. For example, a cross-sectional study in the USA, that examined national data from 2002-2004, (from Behavioural Risk Factor Surveillance System (BRFSS), of 155,280 dentate adults, aged 18 years or more) reported that tooth loss (self-reported) was higher in diabetic adults than those without diabetes. Diabetic adults were 1.46 times more likely (95% CI= 1.30-1.64) to have at least one tooth removed than non-diabetic adults after adjusting for covariates. However, this association between diabetes and tooth loss was stronger among younger adults than older adults (Kapp et al., 2007). A possible reason may be that among older adults, tooth loss can be due to reasons other than periodontitis.

A German study of 4288 adults (145 Type-1 diabetics, 182 Type-2 diabetics, 2647 non-diabetic aged 20-59 years, and 1314 non-diabetic aged 50-81 years) reported that the number of missing teeth was significantly higher among adults with Type-1 diabetes, independent of other covariates. A significant association was present between Type-2 diabetes and the number of missing teeth in the presence of other covariates but in a fully adjusted model, a significant association was found only in females. Type-1 diabetes ($p<0.01$) and Type-2 diabetes ($p<0.01$) had significant associations with mean attachment loss in the fully adjusted model. After adjustment for age, a significant association between Type-2 diabetes and mean attachment loss was only present in 60-69-year-old adults (Kaur et al., 2009). The probable reason for this was, in the study the adults in the sample with Type-1 diabetes were younger than adults with Type-2 diabetes. In this study, tooth loss and attachment loss were reported to independently associated with to Type-1 diabetes and Type-2 diabetes.

In contrast to the study of Kaur and colleagues in 2009, Patino Marin and colleagues in 2008, did a study on 175 subjects (70-Type-1 diabetic, 35 without Type-1 diabetes, 35 with Type-2 diabetes and 35 without Type-2 diabetes) who were clinically assessed for caries, filled teeth, missing teeth, prosthetic restoration, plaque score, calculus index, probing depth and attachment loss. They reported that there was no difference in any of these oral health conditions between Type-1 diabetic patients and the control group. However, a statistically significant difference was found for missing teeth ($p=0.0134$), calculus ($p=0.0001$), probing depth ($p=0.0009$) and attachment loss ($p=0.0093$) between Type-2 diabetic adults and control group (Patino Marin et al., 2008).

The possible reason for differences in the significance of the association between Type-1 diabetic adults and missing teeth in Kaur et al and between Type-2 diabetic adults and missing teeth in Patino Marin et al study may be a difference in the sample size and covariates in both studies. In addition, glycaemic control may have been different among Type-1 and Type-2 diabetic adults In both studies. In 2008, Demmer et al, also reported that in dentate adults, 28-31 missing teeth were associated with incident diabetes (new diagnoses of diabetes) (Demmer et al., 2008). This raises the question as to whether tooth loss was a cause of becoming diabetic which could be because of change in eating habits due to tooth loss.

In 2004, Taylor and colleagues reviewed the literature (from 1960) on the relationship between Type-2 diabetes and tooth loss, periodontal disease and dental caries and reported that sufficient literature was present to support an interrelation between Type-2 diabetes and periodontal disease but a limited evidence-base in the literature provided information about Type-2 diabetes and tooth loss. The literature did not provide sufficient evidence for Type-2 diabetes as a risk factor for coronal and root caries because the studies reported a slight but not significant increase or decrease in caries prevalence in Type-2 diabetes. It was found that caries prevalence was the same among diabetic and non-diabetic adults (Taylor et al., 2004).

The above evidence suggests that tooth loss is related to diabetes and there are three possible mechanisms behind it; (i) The interrelationship between periodontitis and diabetes by systemic inflammation and glycaemic control leads to increase tooth loss, (ii) Eating habits in a person with less teeth can lead them to develop diabetes (iii) Common risk factors for diabetes, periodontitis and tooth loss. Further well control longitudinal studies are required in this context after exclusion of other causes of tooth loss.

2.6.2.5 Summary

In this section, although the sample size, age groups, methods of measurement of periodontal health (some did radiographic evaluation of alveolar bone loss and some clinically examined attachment loss), tooth loss and methods of periodontal therapy were different, that among oral health indicators, periodontal disease and diabetes mellitus (Type-1, Type-2) were interrelated by sharing a common pathophysiology. Inflammation and glycaemic control play a critical role in this relationship. However, the effect of periodontal disease on glycaemic control in diabetes is not as clear as the effect of diabetes in on periodontal health, which suggests the need for further investigation. Secondly, cofactors need to be evaluated in detail as periodontitis, diabetes and obesity often occur together, while obesity and periodontal disease both are important in respect of poor glycaemic control. Furthermore, studies also reported that periodontal treatment with or without antibiotics was helpful in glycaemic control of diabetic adults. However, it is not clear how the other cofactors and well-controlled diabetes were associated with the effect of periodontal treatment on glycaemic control.

There is limited evidence that diabetes is related to tooth loss and the effect of diabetes on coronal and root caries is questionable. Further studies are required to investigate the detailed relationship of diabetes with tooth loss and dental caries. A direct relationship between diabetes and tooth loss and dental caries is still questionable in older adults as the causes of tooth loss and dental caries may be other than periodontitis associated with diabetes.

2.6.3 Oral health and cardiovascular disease

2.6.3.1 Introduction

The term cardiovascular disease (CVD) covers a range of diseases of heart and vascular system, which includes coronary artery diseases (angina and myocardial infarction), heart failure, hypertensive heart disease, thromboembolic diseases, stroke, rheumatic heart disease, cardiomyopathy, heart arrhythmia, congenital heart disease, valvular heart disease, carditis, aortic aneurysms, peripheral artery disease and venous thrombosis. Among these, coronary artery or coronary heart disease (CAD/CHD), stroke, thromboembolic diseases and peripheral artery disease involve atherosclerosis (Mendis et al., 2011, Abubakar et al., 2015). This literature review covers the association of both periodontitis and tooth loss with atherosclerotic cardiovascular disease (ACD) and CVD-related mortality.

Three biological mechanisms have been proposed to explain the association of the number of missing teeth and atherosclerotic cardiovascular disease. These include (1) inflammation, (2) infection, and (3) diet and nutrition (Iwai, 2009, Kebschull et al., 2010).

The inflammation hypothesis suggests that chronic oral infection (as in periodontal disease) contributes to systemic inflammation and increases in the plasma concentration of acute-phase proteins (such as C-reactive protein), inflammatory cytokines, (such as interleukin-6), and coagulation factors (such as fibrinogen) (Kebschull et al., 2010). These inflammatory proteins activate the host inflammatory response by multiple mechanisms and in turn, the host immune response favours the formation, maturation and exacerbation of atheroma. In addition to periodontitis, other chronic inflammatory diseases such as uncontrolled diabetes and rheumatoid arthritis also increase the incidence of atherosclerotic CVD (Friedewald et al., 2009). The chronic exposure in periodontal disease is thought to result in cardiovascular changes that persist after tooth extraction, as tooth loss and edentulism may reflect past inflammatory conditions which may have led to irreversible systemic damage sufficient to cause ACD (Hujoel et al., 2001).

In support of the oral infection hypothesis, it is known that oral bacteria, bacterial components, or bacterial end products enter the bloodstream and result in transient bacteraemia (Kebschull et al., 2010). The pathogens may initiate this mechanism either by direct invasion from the blood or the endotoxins produced may initiate the process, though the exact mechanism it is not clear (Tonetti and Dyke, 2013). Some authors have provided a detailed summary of the possible mechanisms (Kebschull et al., 2010, Tonetti and Dyke, 2013). Oral bacterial DNA has been detected in endarterectomy samples by polymerase chain reactions (PCR) (Kebschull et al., 2010).

Desvarieux and colleagues reported that after adjusting for other traditional risk factors, carotid atherosclerosis as measured by intima-media thickness increased with increased levels of periodontal bacteria (Desvarieux et al., 2005).

The third hypothesis, diet and nutrition, is based on the dysfunctional masticatory system and on the inability to obtain proper nutrition from the diet because of fewer teeth (Joshipura et al., 1996, Gilbert et al., 2004). One of the possible mechanisms by which tooth loss may affect diet is that masticatory difficulty causes dietary restrictions which lead to less intake of fibrous food and more intake of sugary and high-calorie soft diet. Studies have reported lower intake of non-starch polysaccharides (dietary fibre) with tooth loss (Moynihan et al., 1994, Joshipura et al., 1996). Other evidence suggests that chewing efficiency does not have any major effect on the ability of the gut to digest food, so tooth loss has been associated with nutritional deficiency in older people because of changes in food preferences (Brodeur et al., 1993, Moynihan et al., 1994, Krall et al., 1998, Sheiham et al., 2001). There are many studies reporting the adverse effects of tooth loss on nutritional status. Sheiham and colleagues in 2001 examined participants aged 65 years and older in the British National Diet and Nutrition Survey and compared their dental status with their dietary intake. They reported that fewer teeth were related to poor dietary intake. There was a general trend, in many of the haematological and biochemical measures of nutritional status, toward higher values among the dentate and those with most natural teeth (Sheiham et al., 2001). Among participants with natural teeth, those with more teeth had significantly greater mean daily intakes of energy, protein, fat, total carbohydrate, intrinsic and milk sugars, non-starch polysaccharides (fibre), calcium, non-haem iron, pantothenic acid, and vitamins C and E (Sheiham et al., 2001).

Periodontal disease has also been implicated as a risk factor for cardiovascular disease (CVD), either indirectly as a complication of diabetes or directly by causing low-grade systemic inflammation and transient bacteraemia. It is not clear if there is a separate pathway, whereby periodontal disease causes tooth loss which itself has been related to CVD, diabetes and death (Hujoel et al., 2001). In recent years, studies have reported the relationship between periodontitis and atherosclerotic CVD and a few studies also related periodontitis with CVD related mortality (Saremi et al., 2005, Bahekar et al., 2007).

A common risk factor approach has also been reported for the association between periodontitis and CVD. For example, Kebschull and colleagues in 2010, reviewed the state of the evidence linking periodontitis and atheromatous cardiac disease (Kebschull et al., 2010). In this review they discussed the risk of spurious associations between established risk factors for atheromatous vascular disease (AVD) and poor periodontal health, using smoking as the obvious risk factor associated with both periodontitis and AVD. These authors also pointed to the potential of unknown confounders to underlie the association between periodontitis and AVD and cited evidence of a common genetic susceptibility to both diseases which may not have been taken into account in some studies (Schaefer et al., 2009, Kebschull et al., 2010).

Another issue in the association between periodontitis and atherosclerotic CVD is that like other chronic diseases, it has a long induction time with many known risk factors such as diabetes, obesity and poor socioeconomic status. There are studies that provide evidence of the early signs of cardiovascular disease in adolescents, particularly those who were obese or who had diabetes (Berenson et al., 1998, McGill et al., 2000). In 2009, Thurston and Matthews reported differences in pulse-wave velocity and to a lesser extent thickness of the carotid intima-media in adolescents that were related to social class and race (Thurston and Matthews, 2009). Galobardes and colleagues in 2006 noted that childhood socioeconomic status predicted CVD outcomes in adult life that are not fully explained by adult socioeconomic status (Galobardes et al., 2006). So multiple cofactors are associated in the relationship of periodontal disease with atherosclerotic CVD. In this section literature of the relationship between oral health and CVD is explored as follows.

2.6.3.2 The relationship between periodontitis and CVD

For the relationship between periodontitis and CVD, most of the studies have reported an association between periodontitis and atherosclerotic diseases; coronary artery or coronary heart disease (CAD/CHD), stroke, and peripheral artery disease and a few have reported a relationship between periodontitis and hypertension or CVD-related mortality (Holmlund et al., 2006, Al-Emadi et al., 2006, Bahekar et al., 2007, Humphrey et al., 2008, Dietrich et al., 2008). Although from the last two decades, the relationship between periodontal disease and atherosclerotic cardiovascular has been reported but the causative effect is lacking (Lockhart et al., 2012, Schenkein and Loos, 2013)

In the relationship between periodontitis and CVD, there has been consistent and strong epidemiological evidence that periodontitis was an additional risk factor for future cardiovascular disease (Tonetti and Dyke, 2013). For example, in 2008, Humphrey and colleagues concluded from a meta-analysis of 7 prospective cohort studies, that periodontal disease was an independent risk factor for coronary artery disease (CAD). They used different aspects of periodontal disease including gingivitis, periodontitis, bone loss and tooth loss for risk assessment of CAD. Their results showed that the estimated relative risk of different categories of periodontal disease ranged from 1.24 (95% CI=1.01-1.51) to 1.34 (95% CI=1.10-1.63) (Humphrey et al., 2008). In 2007, Bahekar and colleagues using meta-analysis of 5 case-control studies, 5 cohort studies (with more than 6 years of follow up) and 5 cross-sectional studies (total 15 studies) reported that the incidence and prevalence of CAD were significantly greater among adults with periodontitis. They also reported that periodontitis was an independent risk factor for CAD when each study in the meta-analysis was adjusted for covariates of age, sex, diabetes and smoking (Bahekar et al., 2007). In 2010, Kebschull and colleagues also reported that periodontal infections were independently associated with subclinical and clinical atherosclerotic vascular disease (Kebschull et al., 2010).

In contrast to the reports of Tonetti and Dyke in 2013, Bahekar and colleagues in 2007 and Kebschull and colleagues in 2010, in 2008 Dietrich and colleagues (in a 35-year cohort study of 1203 men in the Veterans Affairs Normative Ageing and Dental longitudinal study) evaluated the age-dependent relationship between chronic periodontitis and coronary heart disease (CHD). Their results reported a significant dose-dependent association between periodontitis and CHD in men aged less than 60 years without other CHD risk factors; age, BMI, smoking, alcohol intake, diabetes mellitus, fasting glucose, total cholesterol, high-density lipoprotein cholesterol, triglycerides, hypertension, systolic and diastolic blood pressure, education, marital status, income, and occupation. No such association was found among men aged more than 60 years, without risk factors. This suggests that perhaps in older people (>60 years) periodontitis is less associated with CHD or other risk factors play important role in this association, though this finding needs further investigation (Dietrich et al., 2008). In contrast to the study of Dietrich and colleagues, Shearer and colleagues reported no association between periodontitis and markers of cardiometabolic risk at an earlier age (among adults aged 38 years old) (Shearer et al., 2018). Apart from methodological variations between two studies one reason for this difference between two studies could be the exclusion of other risk factors from Dietrich and colleagues study. It could be possible that the common risk factor approach plays a more important role among older adults for the association of periodontal disease and atherosclerotic heart disease than younder adults. Dietrich and colleagues study was more valuable because it controlled for other common risk factors which could have played a important role in the association of periodontitis and CHD, but this study had a limitation as it was carried out among males only.

Libby and colleagues suggested that systemic inflammation affects all stages of CVD, from initiation to progression to the thrombotic complications of atherosclerosis (Libby et al., 2002). In adults with periodontitis, the daily activities of chewing, brushing and flossing were also related to bacteraemia whereas only one study reported an association between plaque and gingivitis and bacteraemia (Tonetti and Dyke, 2013). It has also been reported that scaling and periodontal treatment caused a bacteraemia for 24-48 hours which may lead to increases in systemic inflammatory and pro-thrombotic mediators and decrease in endothelial function. It is not clear whether it is the pathogens or the bacterial antigens that are active in the inflammatory process. Tonetti and Dyke reported, "Only eight studies have reported the presence of sub-gingival pathogens in vascular lesions, and very little evidence supports the presence of bacterial antigens in the athero-thrombotic lesions which leaves some confusion about the cause of the inflammatory changes in the endothelium," (Tonetti and Dyke, 2013).

Unlike the bidirectional relationship between diabetes and periodontitis, the relationship between CVD and periodontitis has been reported as a unidirectional relationship. Because most of the studies related to the effect of periodontitis on CVD have reported that periodontitis was present before any incidence of CVD disease reflecting that periodontitis can be a risk factor for CVD but CVD (unlike diabetes) is not a risk factor for periodontitis (Tonetti and Dyke, 2013).

2.6.3.3 Effect of periodontal treatment on CVD

In contrast to the effect of periodontal treatment on improved glycaemic control in diabetes, there is very limited evidence in relation to any effect of periodontal treatment on CVD. A few studies reported that periodontal treatment reduced the systemic C-reactive protein level and improved the endothelial function but no effect on systemic lipid profile was seen (Tonetti and Dyke, 2013). There are limited data on the effect of periodontal therapy on activation of endothelial cells biomarkers, improvements in coagulation, arterial blood pressure and sub-clinical atherosclerosis. A consensus report of the Joint EFP/AAP workshop on periodontitis and systemic diseases stated, " There is moderate evidence that periodontal therapy helped in the reduction of systemic inflammation by a decrease in systemic C-reactive proteins and clinical and surrogate measures of endothelial function" (Tonetti and Dyke, 2013).

No study has evaluated whether, among adults with Type-1 and Type-2 diabetes, the prevention or treatment of periodontal disease reduced the CVD prevalence. The link between periodontitis and triglycerides, serum cholesterol and C-reactive proteins has been reported from a case-control study and from another large epidemiological study in the USA, which reported higher levels of serum cholesterol and C-reactive proteins associated with periodontitis (Wu et al., 2000, Lösche et al., 2005). In the USA, a study by Al-Emadi and colleagues reported that hypertension was more common among adults with alveolar bone loss (Al-Emadi et al., 2006) and similarly a study in Sweden also reported hypertension was prevalent in adults with periodontitis (Holmlund et al., 2006). Apart from the above reported possible connections between periodontitis and CVD, periodontitis is also related to CVD because they share common risk factors, for example, smoking, BMI and diabetes.

Although the reported studies were in different populations, had different sample specifications in relation to gender and age groups, measured various different parameters of periodontal health and CVD, with different covariates, most studies concluded that periodontitis was a risk factor for CVD, independent of established CVD risk factors. However, periodontitis as a risk factor for CVD varied across population groups by age, gender and with the type of CVD disease. For example, the increased risk of CHD in adults with periodontitis aged 60 years and over is weaker than in adults younger than 60 years (Dietrich et al., 2008).

2.6.3.4 Tooth loss and cardiovascular disease and CVD mortality

Tooth loss has been reported to be associated with cardiovascular disease (CVD) and CVD related mortality. While tooth loss is more easily assessed than periodontal disease, the reasons for loss of teeth are often difficult to accurately ascertain and may lead to assumptions being made about the reasons for their loss. Whereas a periodontal assessment includes objective measures of conditions such as bleeding of the gingivae, calculus and periodontal attachment loss. Nonetheless, tooth loss may be a marker of previous periodontal disease and so related to CVD. It may also change the dietary pattern and nutrition status of an individual which is also associated with CVD.

Edentulism has been reported as an independent risk factor for coronary heart disease (CHD). For example, a 35-year long cohort study of 1203 men in the Veterans Affairs Normative Ageing and Dental longitudinal study evaluated the age-dependent relationship between chronic periodontitis and edentulism with CHD. This study evaluated the relationship between clinical and radiographic measures of periodontitis and edentulism with the incidence of CVD (angina, myocardial infarction, or fatal CVD) by comprehensive medical and dental examinations repeated every 3 years. As reported in the section on the relationship between periodontitis and CVD, among adults aged 60 years and over, periodontitis was not found to be an independent risk factor for CHD. However, independent of other risk factors, among men aged 60 years and over, edentate men had a higher risk of CHD than dentate men without severe periodontal disease (Dietrich et al., 2008). The sample size, a long follow-up and the use of medical and dental examinations in the Veterans Affairs Normative Ageing and Dental longitudinal study are strengths in this study. But one limitation to study was that the sample consisted of just males.

In 2012 a study of Watt and colleagues reported that edentate adults were at higher risk of CVD mortality and all-cause mortality than dentate adults. After adjusting for demographic, socioeconomic, behavioural and health status, they reported that a significantly higher risk of all-cause (HR, 1.30; 95% CI= 1.12-1.50) and CVD mortality (HR, 1.49; 95% CI= 1.16-1.92) was present among edentate adults compared with adults with only natural teeth. A separate analysis of CVD mortality indicated that edentate subjects had 2.97 (95% CI, 1.46-6.05) times higher risk of stroke-related mortality than adults with natural teeth only. The study concluded that edentulism was a predictor for all-cause mortality and CVD mortality (Watt et al., 2012).

A significant independent association between self-reported missing teeth and CVD was also reported from a cross-sectional study of 275,424 adults aged 50 years and older (Wiener and Sambamoorthi, 2014). The sample analysed was of adults with complete data on the presence or absence of cardiovascular disease and self-reported numbers of teeth lost due to caries or periodontal disease. Participants were also asked to differentiate between reasons for tooth loss. For adults who had lost 1 to 5 teeth compared to adults who had no missing teeth, the adjusted odds ratio (AOR) for cardiovascular disease was 1.27 (95% CI=1.19-1.35). The AOR for cardiovascular disease for the participants with 6 or more missing teeth, but not all missing teeth was 1.65 (95%CI= 1.54-1.77), and the AOR for cardiovascular disease among the participants who had all of their teeth missing was 1.85 (95%CI= 1.71-2.01). This study concluded that an increase in the number of missing teeth increases the risk of CVD. It was also noted that adults who visited the dentist in the past year were less likely to report cardiovascular disease compared to those who did not, the AOR was 0.88; 95%CI = 0.83-0.93 (Wiener and Sambamoorthi, 2014).

A linear inverse relationship has been reported between the self-reported number of teeth and carotid arteries with plaques by Holmlund and Lind in 2012. They did a population-based study of 1016 adults (507 males and 509 females), aged 70 years (invited for study within 2 months of their 70th birthday). They found a linear inverse relationship between the self-reported number of teeth (used 5 quintiles of the number of teeth for analysis) and carotid arteries with plaques (OR= 0.85, CI =0.82-0.98, P=0.016) after adjusting the covariates of age, sex, smoking, BMI, blood pressure, waist/hip ratio, blood glucose, triglycerides, cholesterol, C-reactive protein, leukocyte count, blood pressure and Framingham risk score (Holmlund and Lind, 2012). They also reported that the adults aged 70 years with fewer teeth in quintile 1 had suffered previous periodontal disease and adults with more teeth in quintiles 4, 5 did not previously suffer from periodontal disease. Risk reduction in atherosclerotic plaques of the carotid artery was 33% to 45% from 1 to 5 quintile and this effect was equal to the effect of anti-lipid and anti-hypertensive treatment (Holmlund and Lind, 2012). However, Holmlund and Lind did not find any relationship between the self-reported number of teeth and intima-media thickness of the carotid arteries (IMT) (by an ultrasonic recording of the intima-media thickness) which leads to atherosclerosis. The explanation given for this finding was that the adults were older and that thickening of the intima-media is an early precursor of atheromatous plaque formation (Holmlund and Lind, 2012). This finding suggests that measuring intima-media thickening in older adults may be of limited value. Another limitation to the study was that self-reporting of the number of teeth in older adults can be inaccurate. So, the authors suggested that cause-and-effect conclusions could not be drawn from this study. However, the authors emphasised tooth loss may be an easily recorded risk indicator of atherosclerosis and age is one of the important independent factor affecting it (Holmlund and Lind, 2012). Although the number of teeth was self-reported but large sample sizes and inclusion of older adults in studies of Holmlund and Lind and Wiener and Sambamoorthi provide good evidence about the relationship of the number of missing teeth with CVD.

Some studies also reported that clinically recorded number of missing teeth was a risk factor for incident diabetes, CVD and can assist in mortality prediction. For example, a 13-year, cohort study based on the National FINRISK 1997 study (a population-based cohort study in Finland of 8446 adults, aged 25-74 years) stated, “Tooth loss can predict CVD, diabetes and death”. At baseline, adults were recorded for CVD and diabetes and the number of teeth present. Numbers of teeth were not counted after the baseline examination, but a 13-year follow-up was done for diabetes, CVD, coronary heart disease and death. The results indicated that after adjusting for other covariates such as age, sex, education, BMI, blood cholesterol, the number of teeth at baseline examination was related to the incidence of diabetes, myocardial infarction, coronary heart disease and death. The results also revealed that having five or more missing teeth was associated with 60% to 140% increased risk of a coronary heart disease event ($p<0.020$) and acute myocardial infarction ($p<0.010$) and nine or more missing teeth were associated with incidence of CVD ($p<0.043$), diabetes ($p<0.040$) and death of any cause ($p<0.019$) after adjustment for covariates (Liljestrand et al., 2015). The authors suggested that as tooth loss indicates a history of chronic inflammatory oral disease (caries or periodontitis) and along with other traditional risk factors, the number of missing teeth can assist in mortality prediction.

Other cohort studies reported tooth loss as a direct predictor of CVD related mortality and all-cause mortality independent of other variables (Cabrera et al., 2005, Holmlund et al., 2010). Cabrera and colleagues reported from a 24-year cohort study, that missing teeth were related with CVD mortality (RR= 1.46, 95% CI=1.15-1.85 per 10 missing teeth) and all-cause mortality (RR= 1.36, 95% CI=1.18-1.58) independent of socioeconomic status (Cabrera et al., 2005). This study provides strong evidence in relation to the effect of missing teeth on CVD mortality and all-cause mortality because it had a long follow up, large sample and physical health was examined clinically and by questionnaire at examination in 1962-63, 1974-75, 1980-81 and 1992-93 and dental health was recorded by dental survey in 1968-69 and dental examination in 1980-81 and 1992-93. The study had one limitation that it had a sample of women only. Whereas Holmlund and colleagues reported that the number of teeth predicted all-cause mortality and mortality because of CVD after adjusting for covariates of age, sex and smoking, adults with less than 10 teeth had 7 times higher risk of mortality because of coronary heart disease than adults with more than 25 teeth. However, in this study clinically examined periodontal health did not relate to all-cause mortality (Holmlund et al., 2010). The studies of Cabrera and colleagues in 2005, Holmlund and colleagues in 2010 and Liljestrand and colleagues in 2015 supported tooth loss as a marker of previous periodontal disease that led to systemic inflammation, CVD and mortality, whereas the study of Watt and colleagues provided more support for the link between edentulism and CVD.

However, some other studies also reported that independent of other risk factors, tooth loss was significantly related with CVD mortality but not with all-cause mortality (Polzer et al., 2012, Schwahn et al., 2013). For example, in 2012, a systematic review and meta-analysis reported that tooth loss was related to CVD mortality, but less evidence was present in relation to tooth loss and all-cause mortality. They further advised that it would be desirable to investigate whether the replaced teeth are protective against mortality (Polzer et al., 2012). In 2013, Schwahn and colleagues also reported that 9 or missing teeth were associated with CVD related mortality but not significantly with all-cause mortality (Schwahn et al., 2013).

The methods and sample sizes in the above-mentioned studies are different and apart from this, different studies use a different number of teeth such a 6 or more missing teeth, 9 or more missing teeth and some used teeth as a continuous variable but most of these studies concluded tooth loss was related with CVD and CVD mortality. Further investigation is required to clarify the relationship between tooth loss CVD, CVD mortality and all-cause mortality independent of other covariates of age, systemic health, physical and mental health and socioeconomic status.

2.6.3.5 Periodontal disease, diabetes and cardiovascular disease

Apart from a direct relationship between periodontitis and CVD as reported in the studies of Humphrey and colleagues, Bahekar and colleagues and Dietrich and colleagues, an indirect relationship has been reported between periodontitis severity and CVD, through Type-2 diabetes complications (atherosclerotic plaque calcification, thickening of the carotid intima-media) (Bahekar et al., 2007, Humphrey et al., 2008, Dietrich et al., 2008). This is because severe periodontitis causes an increase in HbA1c in adults with diabetes and uncontrolled diabetes leads to diabetes complications such as CVD. For example, in 2005 Saremi and colleagues carried out a 16-year long cohort study of 628 adults aged 35 years and over, with Type-2 diabetes, to evaluate the effect related to the severity of periodontal disease on CVD related mortality and overall mortality.

They found overall that adults with severe periodontitis and with Type-2 diabetes had 3.5 times higher mortality rate than adults with mild or moderate periodontitis and Type-2 diabetes. However, the death rate due to CVD was 2.5 times higher in adults with severe periodontitis and Type-2 diabetes as compared with adults with mild to moderate periodontitis and Type-2 diabetes. This study concluded that while controlling for the other cofactors of age, gender, hypertension. BMI, current smoking, duration of diabetes, HbA1c, microalbuminuria, serum cholesterol concentration and electrocardiographic abnormalities, periodontitis can predict mortality from the complications of Type-2 diabetes such as ischaemic heart disease and diabetic neuropathy. Periodontal disease was reported as an additional risk factor for ischaemic heart disease and neuropathy (Saremi et al., 2005). However, Holmlund and colleagues, in 2010 reported that clinically examined periodontal health did not relate to any cause of mortality (Holmlund et al., 2010). Whereas, limited evidence was present in relation to periodontitis and Type 1 diabetes complications (Friedewald et al., 2009).

2.6.3.6 Summary

The studies reviewed in this section suggest an association between periodontal disease and CVD, and periodontal disease being an additional risk factor for CVD, although this association between periodontal disease and CVD was more pronounced in older adults and adults with severe periodontitis. However, periodontal disease was also indirectly related to CVD and death as a complication of Type-2 diabetes and as a cause of tooth loss which has also been reported a risk factor for CVD. Unlike the diabetes relationship with periodontitis, the relationship between periodontitis and CVD is reported as a unidirectional. Similarly, the Joint European Federation of Periodontology/American Academy of Periodontology Workshop stated, “There is consistent and strong epidemiologic evidence that periodontitis imparts increased risk for future cardiovascular disease” (Tonetti and Dyke, 2013). There is limited evidence for the effect of periodontal therapy on activation of endothelial cells biomarkers, improvements in coagulation, arterial blood pressure and sub-clinical atherosclerosis. Similarly, the American Heart Association reported, “While observational studies support an association between periodontal disease and atherosclerotic cardiovascular disease, but they do not support a causative relationship, and neither was there any evidence that periodontal interventions modify atherosclerotic cardiovascular outcomes." (Lockhart et al., 2012). However, periodontitis and CVD also share other common risk factors such as smoking, obesity and diabetes.

The studies above also concluded that tooth loss and edentulism were related with CVD and CVD related mortality by inflammatory, infection or nutritional pathways. Missing teeth were an additional risk factor for CVD and CVD mortality and can predict CVD mortality. Either being a present or past marker of periodontal disease (inflammatory and infection pathway) which itself is a risk factor of CVD. Apart from this tooth loss may cause changes in the dietary pattern (nutritional pathway) which potentially leads to increase risk of CVD. Further investigations are required to evaluate this relationship after controlling common risk factors.

2.6.4 Oral health and osteoporosis

2.6.4.1 Introduction

Worldwide, tooth loss, periodontal disease and osteoporosis are major health issues affecting adults aged 50 years and over (National Institutes of Health, 2000). Osteoporosis is a chronic systemic disease in which bone becomes weaker and is more prone to damage because of decreased bone mineral density (Wang and McCauley, 2016). In osteoporosis, there is an imbalance between osteoblastic and osteoclastic activity that results in improper remodelling of bone along with a decrease in bone mass and disruption in bone architecture. Multiple mechanisms relate to bone remodelling including osteoblastic, osteoclastic and other bone marrow cell activity along with the interaction of systemic hormones, local cytokines, growth factors and transcription factors. Age, low body weight, and hormones (oestrogen, testosterone, cortisol) play important roles in osteoporosis, while calcium and vitamin D deficiencies, body weight, family history, and secondary hyperparathyroidism also contribute (Wang and McCauley, 2016).

It has been estimated that one out of five men and one in three post-menopausal women have osteoporosis (European Parliament Osteoporosis Interest Group and EU Osteoporosis Consultation Panel, 2005). Among Caucasian people, 15% of adults aged 50 years and over and 70% those over 80 years were affected (Wade et al., 2014). At the same time periodontitis (loss of alveolar bone and of soft tissue attachment to the tooth) is one of the important causes of tooth loss and edentulism among adults and affects half of the adult population (American Academy of Periodontology, 2001). Bone resorption is a common feature of both periodontitis and osteoporosis, but osteoporosis leads to systemic degeneration of skeletal cancellous bone whereas periodontitis causes a local inflammatory loss of alveolar cortical bone. Both diseases are related because the systemic skeletal bone changes inevitably affect alveolar and the bones of the jaws. Apart from disruption of the homeostasis concerning bone remodelling, other mechanisms suggestive of a link between the two diseases are hormonal imbalance and disruption in inflammatory resolution (Wactawski-Wende, 2001).

Measurement of bone mineral density (BMD) is used for the diagnosis and monitoring the progression of osteoporosis. A dual-energy x-ray absorptiometry (DXA) scan of either certain vertebrae, hip, femur, wrist, heel or meta-carpal bones is used for the BMD calculation. DXA scan reports BMD as a T-score. The T- score represents the number of standard (SD) deviations away from the mean BMD score of adult aged 20-35 years (at peak bone density). Each SD decrease represents about a 12% reduction in BMD and fracture risk doubles for every SD decrease. Osteoporosis is considered to be a T score of -2.5 or lower, osteopenia a T score -1 to −2.5, and normal a T score > -1 (World Health Organization, 1994). Periodontitis is clinically recorded by measurement of pocket depths and clinical attachment loss (CAL) and by radiographic measurement of alveolar crest height (Wang and McCauley, 2016).

Some studies have reported a positive relationship between systemic osteoporosis and tooth loss however, evaluation of the interrelationship between osteoporosis and periodontal disease and alveolar bone resorption has shown conflicting results. The causes of tooth loss and periodontal disease are multifactorial, but many studies as reported in this section have attempted to evaluate whether osteoporosis is one of the contributing factors towards periodontal disease and tooth loss in adults.

2.6.4.2 Relationship between osteoporosis and periodontal disease

This section reports the studies that evaluated the relationship between osteoporosis and periodontal disease, although these studies used different methods for assessing periodontal disease and osteoporosis. For example, some studies used CPITN, some used clinical attachment loss and some used alveolar bone resorption for periodontal disease assessment. The bones measured for BMD to record systemic osteoporosis also varied among the studies. Some of the studies reported below also compared pre-menopausal and post-menopausal women, because of reduced oestrogen levels, post-menopausal women are at higher risk of osteoporosis.

Studies have reported a relationship between periodontitis and metacarpal BMD (m-BMD) in both pre-menopausal, post-menopausal females and in males (Tezal et al., 2000, Inagaki et al., 2001, Yoshihara et al., 2004). For example, in 2001, Inagaki and colleagues reported that in pre-menopausal Japanese women, the proportion of subjects with periodontitis (CPITN ≥3) increased as m-BMD decreased, it was, 18.2%, 36.9%, and 66.6% in the normal, borderline, and very low m-BMD groups ($p < 0.02$) and in post-menopausal Japanese women increase was, 41.5%, 54.8%, 60%, and 68.4% in the normal, borderline, low, and very low m-BMD groups ($p < 0.05$). They concluded low m-BMD had a statistically significant association with periodontitis among the whole sample, but a higher proportion of post-menopausal women had periodontitis with a decrease in m-BMD. Low m-BMD was also associated with tooth loss only in post-menopausal Japanese women ($P < 0.01$) (Inagaki et al., 2001).

In 2004, Yoshihara and colleagues reported that the BMD was a risk predictor for periodontal disease progression in older adults. They found a significant relationship between clinical attachment level and osteopenia recorded from BMD of the heel bone by DXA in a 3-year cohort study of community-dwelling adults aged 70 years (total of 179 (males n= 93, Females n=86)). The adults in this study had more than 20 teeth, had no diabetes mellitus (blood sugar was <140 mg/dl), were non-smokers, and did not take medication for osteoporosis. In 3 years, there was an increase of 3mm attachment loss in progressive periodontal disease sites among adults with osteopenia (Yoshihara et al., 2004). The strength of this study is that the other factors affecting alveolar bone loss and periodontal disease progression such as age, gender, smoking, diabetes and intake of medications were excluded from the study. Also, the study was restricted to people with twenty or more teeth at the age of 70 years or older, though the authors did wonder if this group might be “periodontitis resistant”.

In 2000, Tezal and colleagues found a relationship between skeletal BMD and interproximal bone loss in the jaws but a weak relationship between periodontal attachment loss and skeletal BMD in post-menopausal women. They concluded that post-menopausal osteopenia was a risk factor for interproximal bone loss in jaws (periodontal disease) among Caucasian women (Tezal et al., 2000). However, in 1990, Kribbs reported that among dentate women, osteoporotic women had the same periodontal measurements when compared with non-osteoporotic women (Kribbs, 1990).

In contrast to the studies of Tezal and colleagues in 2000 and Kribbs in 1990, Mohammad and colleagues in 2003, recorded plaque index, probing depths, clinical attachment levels and tooth loss for periodontitis assessment and BMD of the *os calcis* by DXA scan for osteoporosis assessment, among 30 Asian-American post-menopausal with mean age of 63.4 years. They found a significant relationship between BMD and attachment loss and tooth loss which was independent of plaque score (Mohammad et al., 2003). But small sample size in the study of Mohammad and colleagues is questionable. In 2005, Bodic and colleagues, also reported that the alveolar bone resorption and tooth loss were more common in osteoporotic women as compared to women with bone density within the normal range (Bodic et al., 2005).

Apart from the effect of osteoporosis on periodontal health, periodontal health has also been reported as an indicator of osteoporosis and osteopenia in post-menopause women. For example, in 1995, Taguchi and colleagues reported that CPITN score can provide an indication of osteoporosis and osteopenia (low m-BMD) and a decrease in systemic bone mineral density was a risk factor for periodontal disease after menopause in Japanese women, because the proportion of women with periodontitis score of CPITN 3 and 4 increased with the decrease in m-BMD among post-menopausal women (Taguchi et al., 1995).

The studies above report inconsistent findings about the association between periodontal disease and osteoporosis. Alveolar bone resorption increases with osteoporosis and this might be linked with periodontal disease severity (Tezal et al., 2000, Inagaki et al., 2001). But the study of Wovern and colleagues reported that osteoporosis affected the severity of periodontal disease in patients who already had periodontal disease by increasing the interproximal bone resorption (Wowern et al., 1994).

It would appear that either by the presence of other covariates such as age, smoking and number of teeth or directly, there was an association between tooth loss and increased alveolar bone resorption which may lead to periodontal disease. In 2010, a systematic review of 35 studies also reported that there was a positive relationship between periodontitis and osteoporosis in the majority of studies, although the methods for recording of periodontal disease and osteoporosis (as mentioned above) were different. The authors suggested that well-controlled studies should be done for further evaluation of the relationship between systemic osteoporosis, alveolar osteoporosis and periodontal disease (Martinez-Maestre et al., 2010).

2.6.4.3 Relationship between osteoporosis and tooth loss

Relationship between osteoporosis and tooth loss has also been reported. A study in Japan by Yoshihara and colleagues reported a significant relationship between tooth loss and BMD of the heel bone (DXA scan) in both males and females, in a sample of 640 respondents of aged 70 years. The osteopenia group had a lower mean number of teeth as compared to the non-osteopenia group in males (16.3 vs 18.1) and in females (15.9 vs 18.3) (Yoshihara et al., 2005).

Different studies have reported the role of different cofactors in the relationship between osteoporosis and tooth loss. For example, in 2009, a study concluded that age had a significant effect on tooth loss with osteoporosis whereas smoking did not affect the association between osteoporosis and tooth loss among females aged 45-70 years (Nicopoulou-Karayianni et al., 2009). This study of women aged 45-70 years, evaluated the relationship between tooth loss and osteoporosis, along with the cofactors of age and smoking among 665 females including 521 healthy females and 140 females who were diagnosed with osteoporosis in the previous six months (to avoid long term medication effects). They compared the two groups of healthy and osteoporotic females in relation to number of teeth, with and without adjusting for covariates age and smoking. The results indicated that osteoporotic females had a mean of 3.3 fewer teeth compare to normal bone density females, this figure was 2.1 fewer teeth when edentate females were excluded. Overall osteoporotic females had 1.8 fewer teeth before and after adjusting for smoking and 1.2 teeth after adjusting for age. So the authors concluded that the relationship between osteoporosis and fewer teeth among females was also present (although reduced slightly) after adjusting for smoking and age (Nicopoulou-Karayianni et al., 2009).

Krall and colleagues used the covariates of education, BMI with smoking in the evaluation of the relationship between osteoporosis and tooth loss (Krall et al., 1994). They reported a significant relationship between the number of teeth and BMD at the lumbar spine and distal radius and neck of femur, after controlling for covariates of education, BMI, smoking and years since menopause. Their study supported the theory that systemic bone loss contributes towards tooth loss because the BMD of the lumbar spine was very low in patients who needed dentures before the age of 40 years (Krall et al., 1994). Astrom and colleagues found a significant association between tooth count and hip fractures (Astrom et al., 1990). Kribbs reported that osteoporotic women had less mandibular bone density, and more were edentulous. However, among dentate women tooth loss was higher in osteoporotic women whereas periodontal measurements were the same between normal and osteoporotic women, which seems to undermine the association between periodontitis and osteoporosis (Kribbs, 1990).

Higher mean numbers of tooth loss after menopause have also been reported among osteoporotic women than in women without osteoporosis. For example, in 2003, Mohammad and colleagues found that mean tooth loss was 6.8 with normal BMD, compared to 10.5 in osteopenia group, and 16.5 teeth in the osteoporotic group ($p < 0.001$). This study had the shortcoming of being a very small (n=30) sample size (Mohammad et al., 2003). Among post-menopausal women, fewer than 20 teeth have also been reported to have an association with low metacarpal BMD. For example, in 1995, Taguchi and colleagues reported that in post-menopausal women with less than 20 teeth were 1.6 times more likely to have low m-BMD than women who had 20 and more teeth. There was more than a 50% chance that tooth loss and CPITN score can provide an indication of osteoporosis and osteopenia in postmenopausal Japanese women (Taguchi et al., 1995).

Some studies did not find any association between tooth loss and osteoporosis. For example, Elders and colleagues did not find any association between osteoporosis and tooth loss among pre-menopausal women of age 46-55 years (Elders et al., 1992). Another study by May and colleagues of post-menopausal women aged 65-76 years also did not find an association between hip and spine BMD and self-reported tooth loss (MAY et al., 1995). It may be that in the study of May and colleagues, self-reported tooth loss, is not an accurate enough metric to demonstrate an association between BMD and tooth loss. However, in 1997, Mohammad and colleagues reported the role of other factors such as age, smoking, periodontal health in tooth loss along with osteoporosis in the elderly population of 44 post-menopausal women. After controlling these factors with tooth loss, they found there was no statistically significant difference in tooth loss between respondents of low and high spinal bone density. So, they concluded that tooth loss was not directly related with systemic BMD as other covariates play important roles in tooth loss (Mohammad et al., 1997). As the sample size of this study was very small, the results may not be so reliable. Whereas, Taguchi and colleagues reported (from a study 269 adults aged more than 70 years with no metabolic disease) that having fewer teeth was also related to less mandibular cortex thickness among post-menopausal women without osteoporosis. However, no relationship was found among males without osteoporosis between tooth loss and mandibular cortex thickness (Taguchi et al., 1995). This finding suggests that osteoporosis is not a factor in mandibular cortex thickness, so for tooth loss.

Other studies found that more adults with osteoporosis were edentate than adults without osteoporosis, and suggested that they became edentate early because of the effects of osteoporosis along with other factors affecting the tooth loss (Kribbs, 1990, Bando et al., 1998). However, the study of Bando and colleagues also reported sufficient masticatory function with less missing teeth and good periodontal health may inhibit or delay the progress of osteoporotic changes in skeletal bone, or that edentulous women may be more susceptible to osteoporosis (Bando et al., 1998).

In addition to the evaluated relationship between low systemic BMD and tooth loss, some studies have also related osteoporotic fractures with tooth loss. For example, the studies of Taguchi and colleagues in 1995, Kribbsin 1990 and Astrom and colleagues in 1990 reported that increased tooth loss in females was related with self-reported osteoporotic fractures (vertebral compression fractures) and fewer teeth in elderly patients could predict the hip fractures (Kribbs, 1990, Astrom et al., 1990, Taguchi et al., 1995).

However, in 2004, the Washington University School of Dentistry reported a case-control study of community-dwelling adults aged 60 years and over, receiving treatment in the dental school. This study related self-reported osteoporotic fractures with the number of teeth and alveolar ridge resorption measured by panoramic radiograph among the sample of 487 respondents with covariates of age, smoking, height and weight. They found self-reported osteoporotic fracture did not influence the number of teeth and residual ridge resorption. Although age and smoking had a statistically significant effect on the number of teeth and residual ridge resorption (Bollen et al., 2004). A limitation in the study of Bollen and colleagues was, that other studies used DXA scan for osteoporosis diagnosis whereas this study used self-reported evidence of osteoporotic fractures, which might have provided unreliable data. This study also used different covariates but the other studies of Astrom and colleagues, Kribbs and Taguchi and colleagues did not use smoking as a covariate, so they found a correlation between number of teeth and reduced mandibular bone density and fractures. The respondents in Bollen and colleagues' study were also getting treatment in dental school so this may be a reason that fewer teeth were removed and there was no relationship between number of teeth and self-reported fractures.

In short, most of the above-reported studies suggested a positive relationship between osteoporosis and tooth loss among older adults although the methods of osteoporosis recording and co-factors used, varied in the different studies. However, well-controlled studies are needed for the investigation of this relationship because, in older age, osteoporosis and tooth loss can be present but the reasons for tooth loss may be other than osteoporosis in old age. So for the causal effect of osteoporosis on tooth loss, the role of common risk factors in this association needs further evaluation.

2.6.4.4 Summary

The reported relationship between tooth loss and osteoporosis appears to be clear, but inconsistent findings have been reported about the association of periodontal disease with osteoporosis. These findings may be because of issues in relating osteoporosis with periodontitis and tooth loss. One reason may be that the skeleton is heterogenic, different regions are related to each another but yet have some degree of independence in relation to bone density, bone turnover and bone remodelling (Parfitt, 2001). These studies used Dual Energy X-ray Absorptiometry (DXA) scan of different bones to check the bone mineral density (BMD); lumbar spine, femoral neck, hip and forearm. In most of these studies, the sample was stratified as either osteoporotic or not, using the WHO recommended standardised T-score calculation of BMD (World Health Organization, 1994). Some studies also used the self-reported history of fractures by minimum trauma (osteoporotic fracture) and fracture by severe traumatic events (non-osteoporotic) as a tool for recording osteoporosis and related it with alveolar bone height. Apart from osteoporosis recording, periodontitis was also recorded differently in these studies. For example, some studies did a radiographic evaluation of periodontitis while others used clinical examinations. Another factor may be that the adults included in these studies to determine the relationship between osteoporosis and periodontitis may have had different levels periodontitis before having osteoporosis, and the periodontitis may have worsened because of osteoporosis. Further research is required in this context for the relationship between periodontitis and osteoporosis.

2.6.5 Oral health and cognition

2.6.5.1 Introduction

Cognitive function changes throughout life but it declines with age and these changes can be physiological or pathological in one, or multiple, domains of cognition (Plassman et al., 2007). Cognitive impairment increases with age and about 36% of adults aged 70 years and over, suffer cognitive impairment (Prud'hommeaux and Roark, 2015). Usually, cognitive impairment is reported as confusion, poor motor coordination, loss of short-term or long-term memory, identity confusion and impaired judgment (Prud'hommeaux and Roark, 2015).

Dementia is an acquired clinical syndrome in which there is an observed decline in mental abilities. It is defined as “A chronic or persistent disorder of the mental processes caused by brain disease or injury leading to damage to brain cells. It is marked by memory disorders, personality changes, and impaired reasoning”. There are 400 types of dementia, the most common form is Alzheimer’s disease (60-80% of dementia) and the second common type is vascular dementia because of stroke (Gustafson, 1996). Alzheimer’s disease is a progressive, degenerative and irreversible disease in which the brain starts to degenerate. It leads to a progressive decline in the ability to remember, to learn, to think, to reason and subjects with dementia have difficulty in using words correctly and recognising people, places and objects (Longley and Warner, 2002).

The studies reviewed in this section used different tests to assess cognition decline such as Mini-Mental State Examination (MMSE), a Likert scale, Digit Symbol Substitution Test (DSST) and Story recall test (SRT). However, most of the studies related cognition decline with a low score in MMSE and a few with a diagnosis of dementia and Alzheimer’s disease. The Mini-Mental State

Examination (MMSE) or Folstein test is a 30-point questionnaire that is used to measure cognitive impairment. It is commonly used as a screening tool for dementia. Any score greater than or equal to 24 points (out of 30) indicates a normal cognition. Below this, scores can indicate severe (≤9 points), moderate (10-18 points) or mild (19-23 points) cognitive impairment (Pangman et al., 2000).

As ageing populations are increasing worldwide, in the last decade there has been an increase of 4.6 million people per year with dementia and overall 25 million people suffer from dementia worldwide (Prince et al., 2013). It is expected that more than 81 million people worldwide will suffer dementia by 2040 (Ferri et al., 2005). In the USA, Alzheimer's disease (the most common form of dementia) became the seventh most common cause of death by 1995 (Hoyert and Rosenberg, 1997). Also in the USA, 5.1 million were suffering from dementia by 2010 and it is expected to double by 2050 (Daviglus et al., 2010, Hebert et al., 2013). These figures, of adults with dementia and Alzheimer's disease, highlight the importance of identifying the risk factors of cognitive impairment and its correlates such as dementia and Alzheimer's disease.

Along with other general health conditions, the bidirectional relationship of cognitive function with periodontal disease and missing teeth has been investigated (Petersen and Yamamoto, 2005, Syrjala et al., 2007, Delwel et al., 2017, Delwel et al., 2018, Weijenberg et al., 2019). This section will review the effect of cognition on oral health (periodontal health and tooth loss) in older adults and effect of oral health on cognition. Although the tests used for measurement of cognition decline are different in different studies and some studies specifically related dementia and Alzheimer's disease with oral health, nonetheless the purpose of each study was to explore any relationship between poor oral health and cognitive decline and vice versa.

2.6.5.2 The effect of decline in cognition on oral health

It is not surprising that studies have reported that the patients with mild cognitive impairment, dementia and Alzheimer's disease had poor oral health (Petersen and Yamamoto, 2005, Syrjala et al., 2007, Delwel et al., 2017, Delwel et al., 2018). Cognitive impairment leads to reduced self-care, including oral health care, with the result that tooth loss, poor gingival and periodontal health and dental caries have all been related to poor cognition.

In 2008, Wu and colleagues reported that in older adults, oral health was worse among adults with poor cognition particularly those with dementia. They analysed data from the NHANES 1999–2002 study, of 1984 dentate community-dwelling adults aged 60 years and over and reported that the mean number of decayed teeth increased by 0.01, missing teeth increased by

0.02 and the proportion of sites with periodontitis increased by 0.02 for every Digit Symbol Substitution Test (DSST) score decrease of 1 point. The DSST primarily assesses psychomotor performance, along with sustained attention, response speed, visuomotor coordination, and incidental memory. So the investigators concluded that adults with low cognition score had poor oral health (Wu et al., 2008). Edentulism has also been associated with lower cognitive function (Naorungroj et al., 2015).

Poor oral health has been associated with cognitive decline throughout life not only in old age. For example, in 2008, Stewart and colleagues did a secondary analysis from the examination data of NHANES III, to evaluate the relationship between oral health and cognitive function among early, middle and older-aged adults (all were 20 years and over) along with other cofactors of age, gender education, poverty, ethnicity and cardiovascular risk factors. They used three oral health measurements (tooth loss, gingival bleeding and periodontal attachment loss) and three cognitive tests. Two cognitive tests, the (Symbol Digit Substitution Test (SDST) and the Serial Digit Learning Test (SDLT) were analysed for a sample of 5138 participants of age 20-59 years and only one test, a Story Recall test (SRT) was used in 1555 participants aged 70 years and over. The results showed that after adjusting for age, the three oral health measurements were significantly associated with a low score in all three cognitive tests throughout adult life. Although education, poverty and cardiovascular risk factors were important cofactors in the association between missing teeth and a low score on all three cognitive tests. When the socioeconomic factors were adjusted among adults aged 70 years and over, tooth loss was not associated with the Story Recall Test (Stewart et al., 2008). The reason for mixed results in this study may be due to the large variation in the age of respondents and that different cognition tests were used on the sample according to age.

Grabe and colleagues reported that tooth loss was associated with low cognition (MMSE score), among a population-based study of health in Pomerania (1336 adults aged 60–79 years). In an age-adjusted model tooth loss was associated with MMSE score in both males and females (Grabe et al., 2009). In 2007, in Finland, a large population-based (n=2320) of adults aged 55 years and over reported that adults with dementia had more caries and poorer denture hygiene as compared to healthy adults even when in a relatively younger age group (Delwel et al., 2017).

However, in 2016, Wu and colleagues (in a systematic review of 5 cohort studies) reported that although the oral health of elderly adults was worse among those with poor cognition, particularly those with dementia, there was no statistically significant difference in tooth loss among adults with and without dementia. The adults with dementia had more decayed teeth than those without dementia and poor Mini-Mental State Examination (MMSE) score was related to gingival bleeding, plaque and poor mucosal health. All these results were not statistically significant although they were differences between the two groups. The authors suggested the reason for these results may have been the small sample sizes (Wu et al., 2016). Another study by Mathews and colleagues evaluated the data from a stroke study of 8-states in the USA for a sample aged 45 years and over. They used self-reported number of teeth and their analysis showed that adults with six or more missing teeth had low cognition scores for learning and delay recall as compared to the adults with loss of no teeth. But after adjusting for other socioeconomic variables this association was lost. They concluded that there was no association between number of teeth and cognitive function after adjusting for other covariates (socioeconomic status, demographic factors, BMI and C-reactive protein level) (Matthews et al., 2011).

The studies reviewed concluded that adults with any type of cognition decline had poor oral health, whether there was a statistically significant relationship or not between poor cognition and poor oral health. The possible reason may be reduced self-care of oral health among adults with poor cognition. However, other covariates such as age, socioeconomic variables, physical and systemic health conditions played important roles in this association. It is also possible that adults with poor cognition might have had poor oral health, because of other reasons before cognition decline, which just got worse with cognition decline. So the association of poor cognition and oral health needs further investigation.

2.6.5.3 The effect of oral health on cognition decline

Apart from the obvious effect of poor cognition causing poor oral health self-care, many studies have linked the poor periodontal health and tooth loss with cognitive decline and neurological diseases such as dementia and Alzheimer’s disease (Gatz et al., 2006, Ono et al., 2010).

Most of the studies below have explored complete and partial tooth loss as a risk factor for cognitive decline and have reported mixed results for the effect of periodontal health on cognitive decline. Previously it was thought that the complete tooth loss and fewer teeth, affected cognition by causing poor nutritional status (Furuta et al., 2013). But in the last few decades neuroimaging in humans has revealed that the chewing process increases the activity of learning and memory regions in the brain (Onozuka et al., 2002). Because the masticatory process increases the cerebral blood flow which in turn increases cognitive task performance. Furthermore, increased blood flow reduces brain degeneration and cognitive decline (Miyamoto et al., 2005, Narita et al., 2009). Three possible mechanisms relate tooth loss and cognition decline, (i) mastication-induced sensory stimuli, (ii) poor nutritional status and (iii) periodontal disease inflammatory biomarkers (Onozuka et al., 2002, Yaffe et al., 2004, Tucker et al., 2005, Narita et al., 2009, Paganini-Hill et al., 2012). However, the association between oral health and cognitive decline is also affected by other common risk factors such as age, socioeconomic status, systemic diseases, physical health and dental care.

Tooth loss has been reported as a risk factor for dementia (Gatz et al., 2006, Cerutti-Kopplin et al., 2016). For example, in 2016 a systematic review of 10 cohort studies and meta-analysis of 8 cohort studies reported that individuals with less than 20 teeth (inadequate dentition) were at 20% higher risk of getting cognitive decline (HR = 1.26, 95% CI=1.14-1.40) and dementia (HR=1.22, 95% CI=1.04-1.43) (HR = hazard ratio) than the adults with 20 or more teeth (adequate dentition) (Cerutti-Kopplin et al., 2016).

In 2006, Gatz and colleagues also reported that tooth loss before the age of 35 years was also a risk factor for dementia. They did a case-control study of elderly identical twins of adults aged 65 years and older and reported that adults who lost half of their teeth before the age of 35 years were at greater risk of having Alzheimer's disease and other forms of dementia. Low education level was also a risk factor for tooth loss and Alzheimer's disease (Gatz et al., 2006). Impaired masticatory function because of tooth loss, causing a change in dietary habits, was associated with a higher risk of dementia or mild memory impairment as suggested by Korean and Japanese studies (Kim et al., 2007, Okamoto et al., 2010).

Self-reported tooth loss along with not wearing dentures have also been reported as risk factors for dementia (Yamamoto et al., 2012). For example, Yamamoto and colleagues did a 4-year prospective cohort study of 4425 older adults aged 65-years and over, in Japan. Covariates were age, income, body mass index, present illness, alcohol consumption, exercise, and forgetfulness. The results showed that 220 adults developed dementia in 4 years and adults with few teeth and without dentures had the highest risk of dementia (HR=1.85, 95%CI=1.04-3.31) (Yamamoto et al., 2012).

Edentulism and few teeth increased the incidence of dementia in older age among women. For example, a 10-year longitudinal study collected oral health data for 101 female Milwaukee participants aged 75-98 years from the Nun Study (a longitudinal study of ageing and Alzheimer's disease). Ten-year dental records were used to assess the number of teeth, denture status and periodontal health to relate with dementia records. Among these elderly women, those that had 9 or fewer teeth were at twice the risk of developing dementia as compared to women who had 10 or more teeth. However, women with severe alveolar bone loss were at more risk of developing dementia but there was no statistically significant relationship between alveolar bone loss and dementia (Stein et al., 2007). The strength of this study is that it excluded the effects of behavioural and environmental variations on cognition, as the sample was of nuns who had the same lifestyle of no smoking, little alcohol consumption, they were unmarried, had no children, lived in the same environmental conditions and agreed to post mortem examinations. So, in the controlled behavioural and environmental conditions, having fewer than 10 teeth increased the risk of dementia among women.

In contrast to above studies, in 2012, Arrive and colleagues in a 15-year cohort study of French adults aged 66-80 year, reported that adults with few teeth and less education surprisingly had a statistically significant low risk of dementia, but no effect was seen after adjusting for education. They also did not find that mean DMFT and periodontal health were risk factors for dementia, although they did a clinical examination of teeth and periodontal health (Arrive et al., 2012). In 2015, Naorungroj and colleagues also reported that although edentulism was associated with lower cognitive function, edentulism, number of teeth and poor periodontal health could not predict subsequent cognitive decline (Naorungroj et al., 2015).

As with cardiovascular disease, both acute and chronic inflammation have been associated with an increased cognitive decline (Holmes et al., 2009) including periodontal disease-related inflammation/immune responses (Kamer et al., 2009, Stewart, 2009, Holmes et al., 2009). In addition, an association between a serological marker of periodontitis, *Porphyromonas gingivalis* IgG, (*Porphyromonas gingivalis* is a pathogen causally associated with chronic periodontitis) and impaired delayed memory, has also been reported by Noble and colleagues from the data of 2355 older adults (60 years and over) of the NHANES III study (Noble et al., 2009). The adults with the highest level of *P gingivalis* IgG (>119 ELISA Units (EU)) were more likely to have poor delayed recall (OR 2.89, 95% CI= 1.14-7.29) and difficulty with serial subtractions (OR 1.95, 95% CI= 1.22-3.11) than those with the lowest *P gingivalis* IgG levels (≤57 EU). The results were the same after adjusting for the co-variables of socioeconomic status and vascular diseases. The poor Delay Verbal Memory or Serial Subtractions Score were significantly associated with *P gingivalis* IgG levels. However, no significant relationship was found between *P gingivalis* IgG and Immediate Verbal Memory Score (Noble et al., 2009). So, they reported that mild levels of poor cognition were related to periodontitis. This study had a good sample size and well-controlled co-variables but has a limitation of lacking the clinical and radiographic evaluation of periodontitis along with serological marker of periodontitis.

Other studies have also reported the effect of poor oral health on low MMSE score without specifying any cognitive impairment such as dementia or Alzheimer’s disease. For example, in

2010, Kaye and colleagues reported that tooth loss and periodontal disease predicted poor cognitive function in community-dwelling older men. Their 32-year cohort study found that the risk of low MMSE score (hazard ratio (HR)=1.09, 95% CI=1.01-1.18) and low spatial copying score (HR=1.12, CI=1.05-1.18) increased with each tooth loss per decade. These risks were further accentuated by the progression of alveolar bone loss around each tooth and caries. Alveolar bone loss increased the risk of cognition decline by 2% to 5%. The older men were at more risk than younger men (Kaye et al., 2010).

Adults with self-reported edentulism and few teeth were also reported to have had a higher risk of cognitive decline with covariates of age, sex and cardiovascular disease-related risk factors, in a 5- year follow up. Whereas self-reported periodontal health in the form of bleeding gums was not associated with a decline in cognition (Batty et al., 2013). Similarly, in 2013, Reyes-Ortiz and colleagues reported that "In presence of other cofactors (socio-demographic variables, physical limitation, near vision impairment, depressive symptoms, and functional status) self-reported few teeth can predict cognition decline in Mexican Americans aged 65 years and over " (Reyes-Ortiz et al., 2013). In this 5 year of follow-up, among adults with fewer teeth, the total MMSE score decreased 0.12 per year (SE ± 0.05, p <0.01) as compared to adults with more teeth (Reyes-Ortiz et al., 2013). Although the Reyes-Ortiz and colleagues study had a large population sample, the self-reporting of number of teeth especially in adults with fewer teeth and lower total MMSE score is questionable (Reyes-Ortiz et al., 2013).

The studies above were of large sample and cohort studies and their results cannot be underestimated. However, it is important to keep in mind the validity of self-reported number of teeth or oral health status and the special characteristics of some samples such as in studies of Naorungroj and colleagues and Batty and colleagues (Batty et al., 2013, Naorungroj et al., 2015). This is because the self-reported number of teeth and periodontal health can be quite different from clinically examined as reported in section 2.5 of the literature review. Whereas multiple cofactors need to be considered in this respect. For example, it may be that in one sample, the adults with fewer teeth were older as compared to adults with more teeth and cognitive decline was not because of fewer teeth only as it can be due to many other covariates such as age, poor physical health, systemic conditions and by other socioeconomic factors.

Most of the above studies in relation to the effect of oral health on cognition decline (dementia/ Alzheimer's disease or on low MMSE score) supported the association between tooth loss and cognitive decline except for that of Shimazaki and colleagues, Mathews and colleagues and Naorungroj and colleagues. In contrast to tooth loss, a few studies supported that periodontal health was related with cognitive decline, such as Kaye and colleagues and Noble and colleagues. The possible reasons could be, most of the studies did not use inflammatory biomarkers for periodontal disease, methods of periodontal assessment were different in each study and self-reporting of periodontal disease. As mentioned in the section 2.5 of literature review, the sensitivity of self-reported periodontal disease is very low and people are unaware of it, which suggests that self-reported periodontal disease is not a good indicator of cognition.

2.6.5.4 Masticatory function and cognition

Emerging evidence supports a relationship between masticatory ability and cognition. A reduction in mastication leads to a decrease in cerebral blood flow and decrease activity in the frontal cortex (Weijenberg et al., 2011, Weijenberg et al., 2019). The studies reported that among older adults the risk of cognitive impairment increased with decreased mastication because of chewing difficulties. For example, Cardoso and colleagues reported that among institutionalised adults aged 65 years and over, more occluding units (regardless of nature or location of occluding units) were significantly related with less cognitive decline because of better mastication (Cardoso et al., 2019). Similarly, Weijenberg and colleagues found a positive relationship between masticatory performance, assessed by the ability to mix two different colours of chewing gum and general cognition and verbal fluency among older adults in institutional care with dementia (mean age was 85.3) (Weijenberg et al., 2015).

Studies have also reported that among older adults, masticatory function is more closely related to cognitive impairment than number of dental units (teeth or prosthesis). A large population study of community-dwelling adults in Sweden (n=557, age 77 years and over) found that onset of dementia caused difficulties in eating hard foods and number of teeth or prosthesis had no influence on this finding. This study reported that without masticatory difficulties, tooth loss does not necessarily lead to cognitive impairment (Lexomboon et al., 2012). Similarly, Elsig and colleagues compared the masticatory function of 29 adults (75 years and over) with dementia to 22 adults without cognitive impairment (75 years and over) by chewing two different colours of chewing gum. Both groups had the same number of teeth or prosthesis. They concluded that because of reduction in motor skills in dementia, reduced masticatory function was more related to cognitive impairment than to number of teeth or presence of a prosthesis (Elsig et al., 2015).

In 2019, Weijenberg et al and colleagues suggested that cognitive ability and oral health influence each another in a vicious cycle. Dementia worsens the oral health and poor oral health reduces masticatory activity and ability, which leads to having a soft diet which further causes less masticatory activity and which in turn causes further decline in cognition, but the cause-effect relationship has not been proven (Weijenberg et al., 2019).

2.6.5.5 Summary

The methods of assessing oral health and cognition, the cofactors, sample characteristics, follow up time and analysis tools were different in the above-mentioned studies, yet they all concluded that not only poor cognition is associated with poor oral health (tooth loss, poor periodontal health and dental caries), having fewer teeth and reduced masticatory ability is associated with cognitive decline among older adults and edentulism was more associated with poor cognition and mortality along with multiple cofactors in this context (Arrive et al., 2012, Lexomboon et al., 2012, Yamamoto et al., 2012, Reyes-Ortiz et al., 2013, Weijenberg et al., 2015, Cerutti-Kopplin et al., 2016, Weijenberg et al., 2019, Cardoso et al., 2019). Whereas few studies reported that periodontal disease was associated with cognition decline (Stein et al., 2007, Kaye et al., 2010, Batty et al., 2013, Cerutti-Kopplin et al., 2016). It is also possible that adults with fewer teeth might have had periodontitis as a cause of tooth loss. In this way periodontal disease, although not proven by many studies as having a direct association with cognition decline, it may have an indirect association through tooth loss. It is also possible that untreated severe periodontitis or a painful mouth can also affect mastication induced sensory stimuli or can lead to poor nutritional intake which may also lead to cognition decline. Effect of periodontitis on cognition decline might need further evaluations.

2.6.6 Overall conclusions of section 2.6.

Section 2.6 reported on the interrelationship between oral health and four systemic health conditions. These four (diabetes, CVD, osteoporosis and cognition) systemic conditions were selected because there is sufficient existing research data to suggest an association between them and oral health and these conditions are objectively measured in this research.

The strongest relationship appears to be between periodontal disease and diabetes. It is well established that periodontal disease has a causal relationship with diabetes mellitus (Type-1, Type-2) probably due to common pathophysiology (both are inflammatory diseases). There is some evidence that there may be a bidirectional relationship between periodontal disease and diabetes. Studies have shown a relationship between simple periodontal therapy and improved glycaemic control. Although the studies were different in relation to sample size, methods, and covariates (Safkan-Seppala and Ainamo, 1992, Patino Marin et al., 2008, Demmer et al., 2008, Chapple and Genco, 2013).

Further investigations are required to evaluate the effect of periodontal therapy on glycaemic control in diabetic adults (Chapple and Genco, 2013, Engebretson and Kocher, 2013). The role of other common risk factors such as obesity and smoking in a bidirectional relationship between periodontitis and diabetes also require further research.

However, a limited evidence-base in the literature, provided information about the relationship between Type-2 diabetes and tooth loss and some studies reported that after adjusting for other covariates the relationship between Type-2 diabetes and tooth loss was more pronounced in younger adults than older adults (Taylor et al., 2004, Kapp et al., 2007, Demmer et al., 2008). The literature also did not provide sufficient evidence for Type-2 diabetes as a risk factor for coronal and root caries (Taylor et al., 2004).

Some studies suggested that tooth loss was related with CVD and CVD mortality (Cabrera et al., 2005, Holmlund et al., 2010, Holmlund and Lind, 2012, Schwahn et al., 2013, Wiener and Sambamoorthi, 2014). Tooth loss also causes changes in dietary patterns which may lead to increased risk of CVD and a study also concluded that edentulism was a predictor for all-cause mortality and CVD mortality (Watt et al., 2012).

Periodontitis is believed to be related to CVD either by the direct increase in systemic inflammation or by an indirect relationship with CVD (Wu et al., 2000, Lösche et al., 2005). For example, periodontitis is associated with diabetes which is a risk factor for CVD whereas, tooth loss is a present or past marker of periodontal disease and is a risk factor of CVD (Saremi et al., 2005). Apart from these possible connections, periodontitis and CVD shares common risk factors for example smoking, obesity and diabetes.

In relation to oral health and osteoporosis, studies suggest that tooth loss is related to low skeletal BMD (osteoporosis/osteopenia) and with increased alveolar bone resorption especially in elderly adults. However, the relationship between tooth loss and osteoporosis is more pronounced in post-menopausal women and less among man and pre-menopausal women (Taguchi et al., 1995, Inagaki et al., 2001). Age is an important covariate and smoking is a moderate covariate in the relationship between tooth loss and osteoporosis (Mohammad et al., 1997, Nicopoulou-Karayianni et al., 2009). Whereas, self-reporting of osteoporosis and tooth loss have shown conflicting associations (Taguchi et al., 1995, Bollen et al., 2004).

Inconsistent findings have been reported about the association of periodontal disease with osteoporosis (Tezal et al., 2000, Mohammad et al., 2003, Yoshihara et al., 2004). These findings may be because of different issues in relating osteoporosis with periodontitis, for example, the difference in recording methods of both osteoporosis and periodontal disease, co-variates in different studies and the heterogeneity of osteoporosis. However, periodontal disease has an indirect relationship with osteoporosis as a cause of tooth loss.

For the relationship between oral health and cognition, many studies supported the fact that poor cognition led to poor oral health (periodontal disease and tooth loss). Most of the studies have also reported that among older adults tooth loss was one of the risk factors for cognition decline and edentulism was more associated with poor cognition and mortality along with multiple cofactors in this context (Arrive et al., 2012, Yamamoto et al., 2012, Reyes-Ortiz et al., 2013, Cerutti-Kopplin et al., 2016). However, a few studies reported above did not find that tooth loss was one of the risk factors for cognition decline (Shimazaki et al., 2001, Matthews et al., 2011, Naorungroj et al., 2015). This may be because different methods were used for reporting and calculation of both diseases and because of different covariates were used. For example, self-reporting of tooth loss and differences in the number of teeth used as a cut point in the different studies, such as, loss of 6 or more teeth or loss of 9 or more teeth or having 20 or more teeth. Other reason in this context could be a role of reduced masticatory function because of tooth loss towards cognition decline despite of just the tooth loss (Weijenberg et al., 2011, Lexomboon et al., 2012, Weijenberg et al., 2015, Weijenberg et al., 2019, Cardoso et al., 2019). However, conflicting results were reported in relation to periodontal disease as a risk factor for cognition decline, especially in older adults (Stein et al., 2007, Kaye et al., 2010, Batty et al., 2013, Cerutti-Kopplin et al., 2016).

When considering any relationship between oral and systemic health, including any effect of treatment for the oral health condition, problems arise when the pathophysiology of a condition such as cognitive decline is not well understood. In this situation, it will be very difficult to establish the nature of the relationship between oral health and cognitive decline.

However, the problem in relating oral health and cognition is similar to that in the other systemic diseases reviewed is that, both diseases are multifactorial, and it is not known what kind of pathophysiological relationship exists between oral health and cognition. It is suggested that it is necessary to develop an oral-cognitive health model with limited covariates. This will exclude from the sample people with other physical and systemic conditions causing cognitive decline and include oral health and cognition clinical assessments. In such samples, longitudinal cohort studies with control of other risk factors for both conditions, are required to evaluate the direct effect of oral health decline on cognitive decline and vice versa.

The studies reported in this section on oral health and systemic health conditions concluded that there is an association between oral health and diabetes, CVD, osteoporosis and cognition, though the strength of the evidence varies among these conditions. So oral health is important for overall systemic health of the individual and vice versa. Future, longitudinal studies are required for further investigation between oral health and the above-mentioned systemic conditions (diabetes, CVD, osteoporosis and cognition) with well-controlled covariates of the common risk factors.

2.7 Aims and objectives

2.7.1 To evaluate the oral health status of a sample of community-dwelling adults aged 50 years and over living in Ireland

Overall, loss of natural teeth is considered to be a key indicator of poor oral health in older people (Thorstensson and Johansson, 2010) whereas dental caries and periodontal disease, are the most common chronic oral diseases affecting the adult population worldwide and in Ireland (Whelton et al., 2007, Chapple and Genco, 2013). Understanding the value of natural teeth present and their minimum functioning number in older adults is important as increased retention of natural teeth, and reduction in the levels of total tooth loss, are vital for the health and wellbeing of older adults (Sheiham et al., 2002). Adults with poor socioeconomic status have poor oral health. The WHO in 2005 reported that treatment need for oral health was highest among disadvantaged and more vulnerable groups both in developed and developing countries (Petersen, 2005). So the first aim of the study was to describe, the oral health status of community-dwelling adults of 50 years and over in Ireland and its relationship with socioeconomic status.

Objectives:

1- Objective assessment of oral health according to age and gender using the following indices

a. Periodontal health assessment (CPITN)
b. Mean number of teeth
c. Functional dentition (tooth contacts)
d. 18+ SUNT (sound, untreated, natural teeth)
e. Mean DMFT at cavitation and visual caries level
f. Root Caries Index
g. Denture wearing and need (complete/partial)

2- Comparison of the oral health status of this sample of adults with previous Irish studies and with other comparable studies of older adults.

3- Description of the oral health status of the sample according to selected socioeconomic factors (education, urban/rural, medical card status, income).

2.7.2 To explore the relationship between self-reported oral health status and objectively measured oral health

Self-reported oral health assessment is relatively inexpensive and has been used in many oral health studies (Guiney et al., 2011, O'Sullivan and O'Connell, 2015), but it has the shortcomings of being influenced by personal views and assessment abilities. Self-reported oral health may be different from clinically assessed oral health (Liu et al., 2010). For this reason, it is important to compare self-reported oral health conditions with clinically recorded oral health condition in the same TILDA cohort, to check the validity of self-reported oral health assessment methods and future use.

Objectives:

1- Comparison of self-reported oral health status and difficulties with mouth, teeth or dentures with the mean number of teeth, mean DMFT, functional tooth contacts and periodontal health.

2- Comparison of self-reported frequency of dental visits with the objectively measured mean number of teeth, mean DMFT, functional tooth contacts and periodontal health.

2.7.3 To examine any relationship between systemic health conditions and objectively measured oral health

Oral diseases share both risk and preventable factors with other non-communicable diseases that are related to lifestyle. For example, dietary habits that are important in the development of diabetes and cardiovascular disease may also cause dental caries in the oral cavity (Allen, 2005). Adults with diabetes are at greater risk of poor periodontal health, and poor periodontal health may also worsen diabetes (Chapple and Genco, 2013). Therefore, it was important to look at the relationship between oral health and systemic health conditions

Objectives:

1-Evaluation of the relationship of periodontal health and tooth loss, with diabetes, cardiovascular disease, osteoporosis, cognitive function.

2-Evaluation of the relationship of periodontal health and tooth loss, with diabetes, cardiovascular disease, osteoporosis, cognitive function in presence of cofactors of age, gender, BMI, smoking, education level and area of residence.

3 Methods

3.1 TILDA study

3.1.1 TILDA sample

The TILDA study sample includes community-dwelling adults aged 50 years and over (and their spouse/partner of any age) living in residential addresses in Ireland. At the start of the study, it excluded adults living in institutions but respondents who went into long-term residential care during the study were included in subsequent waves.

TILDA used the geodirectory-based RANSAM (a computerised system of selecting a random sample from the electoral register that is updated every year) system developed by the Economic and Social Research Institute of Ireland (ESRI) to select the sample (Whelan and Savva, 2013). The TILDA sample was selected in two stages and the oral health sample was selected from Wave 3 respondents who attended the health centre assessment in Dublin (Whelan and Savva, 2013).

Stage 1: In the first stage the RANSAM system grouped residential addresses in Ireland into 3,155 first stage clusters or units. Each cluster or unit consisted of 500 to 1,180 addresses. For stratification, all addresses in the country were pre-sorted by socioeconomic groups (three equal groups on the basis of employment and geography). To keep the probability of selection proportional to the estimated number of persons aged 50 years and over in each cluster, 640 clusters or units were randomly selected from the first stage clusters (500-1,180 addresses in each cluster) along with indirectly proportionate stratification of clusters by socioeconomic groups (3 groups) and geography, where each socioeconomic group was further stratified by RANSAM geographic snake pattern. This pattern preserved contiguity by ordering clusters within the county, based on a north/south pattern (Whelan and Savva, 2013).

Stage 2: To ensure the equal probability of each address being chosen, a probability sample of 50 addresses (10 addresses were kept reserved out of 50 addresses) was selected from each of the randomly selected 640 clusters. In this way two groups of addresses were made, an initial sample of 25,600 addresses at the start of research fieldwork (40 randomly selected addresses from each of 640 clusters). A second group of 6,400 addresses (10 randomly selected addresses from each of 640 clusters), was reserved to be utilised if the target sample of 8,000 participants of age 50 years and over was not obtained from the first group. All persons aged 50 and over along with their spouse and partner of any age were invited to participate in TILDA research.

Two-stage selection with stratification, clustering and multistage selection in sample design provides an equal probability of the sample of both households containing members of the target population and of persons in the target group. So, the final sample is self-weighting and EPSEM (equal probability of selection method), with the exception of bias caused by non-random variations in response rate. Calibration weights are used at the analysis stage to deal with bias in non-random response rate (Whelan and Savva, 2013).

3.1.2 TILDA Methods

At the time of writing, four waves of TILDA had been completed and Wave 5 was under process (Donoghue et al., 2017, Donoghue et al., 2018). TILDA uses three modes of data collection: 1) Computer-assisted personal interview (CAPI) (1.5 hours), conducted in the home by trained interviewers; 2) Paper-based self-completion questionnaire (SCQ) (30 minutes), conducted at home, completed privately by the participant; 3) Comprehensive health assessment (more than 3 hours), conducted by trained research nurses in a health centre or a modified version conducted in the participant's home (Donoghue et al., 2017).

TILDA cohort maintenance strategies have been classified into seven broad categories: project identity and bond; study information and impact; adaptable methods of data collection; personnel; tracing, scheduling and contacting; persistence and reminders; incentives and reimbursements (Donoghue et al., 2017). The TILDA cohort size has decreased with each wave of TILDA. This decrease was because of; deceased respondents, respondents who moved away from Ireland and those who were not accessible by TILDA. The attrition across each TILDA wave has been described elsewhere (Donoghue et al., 2018).

3.1.3 Timelines and modes of data collection at each wave of TILDA

Four waves of TILDA have been completed to date, with health assessments being carried out in every second wave as shown below.

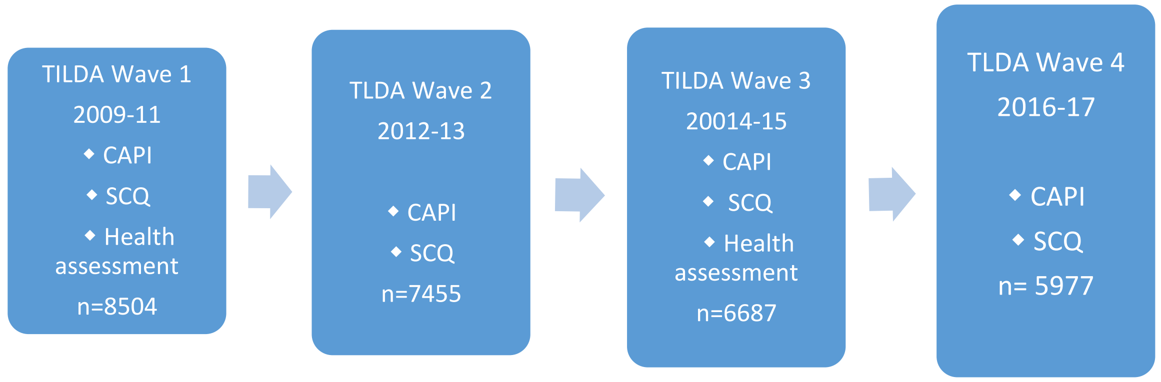


Figure 3-1: TILDA waves and methods of data collection.

First wave 2009-11 (n= 8504)

- CAPI (Computer-assisted personal interview)
- SCQ (Self-completion questionnaire)
- Health assessment carried out in Dublin and Cork (physical, mental, systemic, cognitive health)

Second wave 2012-13 (n= 7455)

- CAPI (Computer-assisted personal interview)
- SCQ (Self-completion questionnaire)

Third wave 2014-15 (n=6687)

- CAPI (Computer-assisted personal interview)
- SCQ (Self-completion questionnaire)
- Health assessment at TCD only (physical, mental, systemic, cognitive health) (n=4256)
- Oral health assessment

Fourth wave 2016 (n= 5977)

- CAPI (Computer-assisted personal interview)
- SCQ (Self-completion questionnaire)

(Donoghue et al., 2017, Donoghue et al., 2018)

3.2 Oral health research design and methodology

Methodology refers to the process that inquiry takes to let the researcher identify what can be known about reality, as they hold it to be (Lincoln and Guba, 1985). According to Creswell, "Quantitative research attempts to quantify, collect and analyse numerical data. It also focuses on the links among a smaller number of attributes across many cases" (Creswell, 2013). Quantitative research focuses less on each individual and more about the common features of groups of people. It is helpful in large population-based studies, because it provides more generalised and comparable data of large samples in a systematic way. It also represents overall population trends and is helpful in comparing generalised data from different population groups. Most oral health surveys use a quantitative research approach (Black, 1999, Fuller et al., 2011, Dye et al., 2014).

Quantitative research method involves experiments, surveys, testing, and structured content analysis, interviews which use predetermined instrument-based questions and objectives (Bryman, 2003). In this research, the predetermined instrument was the oral health examination which followed well-established clinical criteria and methods to fulfil the objectives of research mentioned in chapter 2 (section 2.7).

In this study, quantitative research methods were used to report on the oral health status of the sample of adults by age group, gender and socioeconomic status and to evaluate the relationship between self-reported oral health and objectively measured oral health. Furthermore, the association between oral health (number of teeth and periodontal health) and some systemic conditions (diabetes, CVD, osteoporosis and cognition) was evaluated by the quantitative method of regression analysis.

3.3 Oral health assessment sample and population

The oral health assessment sample was selected from the TILDA Wave 3 cohort which consisted of respondents who participated in the computer-assisted personal interview (CAPI) and self-completion questionnaire (SCQ). Out of the TILDA Wave 3 cohort, those who participated in the TILDA health assessment at the TILDA centre in TCD were offered an oral health assessment, whereas participants who had a modified assessment at home were not included in oral health assessment.

As the oral health assessment was the last part of the health assessment, which took in total 3 to 3.5 hours, the oral health assessments did not commence until approximately 11.30am to 12.00pm and those respondents appointed for 3.00pm or later were not available for the oral health assessment until 6.30pm or later. Limited resources meant that it was not possible to carry out oral health assessments on Saturdays and after 5.30pm on weekdays.

3.4 Ethical approval of oral health study

Ethical approval was obtained from the Faculty of Health Sciences Research Ethics Committee in Trinity College Dublin. During the study, the consent of each respondent for the oral health assessment was sought and those who refused were asked for any reasons for the refusal (see chapter 4). Only those respondents who agreed to the oral health assessment were included in this research. Ethical approval was also obtained from TILDA to access the data at specially designated hot desks in TILDA research centre TCD. No data were removed from the TILDA system.

3.5 Equipment used in the oral health study

Standardized dental equipment was used for the oral health examination. It consisted of a reclinable dental chair with floor-mounted DARAY LED examination light (Model- XL200 LED examination light, 12-30v/ 5.8-8.2w), standard dental mirror and WHO recommended CPITN-E probe with 0.5mm ball tip and black band between 3.5mm and 5.5mm from ball tip (World Health Organization, 2013). The methods and equipment were similar for all examinations. Teeth were examined wet with a standard dental mirror and CPITN-E probe and dental radiographs were not taken. Four dentists participated in the oral health examinations. Calibration exercises were carried out before and during the study to maintain the similarities of methods and standard of examination by each dentist (see section 3.9). Due to time constraints, it was not possible to carry out duplication examinations to monitor inter or intra-examiner reliability.

3.6 Cross infection

Standard infection prevention protocols were followed during examinations to avoid any cross infection risk. A new set of sterilized instruments (dental mirror and CPITN-E probe) and disposable gloves were used for each participant. Face masks were also changed frequently. Each participant was questioned before examination about heart disease and to avoid any post-examination complications, participants with the valvular heart disease, stents, pacemakers and those on anticoagulants were excluded from periodontal examination.

3.7 Data protection

To ensure confidentiality, TILDA followed legislation of the Data Protection Act 1988 and the Data Protection (Amendment) Act 2003 during collection, handling and reporting on data (Data Protection Commissioner, 1988 and 2003).

TILDA allotted an ID number to each participant and this was used to maintain the anonymity of each participant during the oral health examination. A coding system was developed for each component of the oral health assessment (Appendix 3). All oral health data was recorded in codes for the purpose of data protection and convenience. Data cleaning was completed before analysis. As with all TILDA data, to ensure protection it was only accessible at designated hot desks at the TILDA research centre in TCD and data could not be exported from the server. TILDA also issued an appropriate user ID and password to access data at designated hot desks in the TILDA research centre TCD.

3.8 Oral health assessment methods and data collection

The examination criteria used in this research were similar to those used in previous Irish surveys and those recommended by the WHO (Whelton et al., 2007, World Health Organization, 2013). The oral health assessment methods used in this research were the same for all examinations and were practised by calibration exercises. The TILDA oral health assessment was carried out by trained dentists at the TILDA health assessment centre in Trinity College Dublin without the assistance of a recorder.

In this research, only the most important indicators of oral health were recorded (an oral mucosal examination was not included in assessment), because of time constraints. The oral health assessment consisted of the following components.

3.8.1 Dentate status and denture status

Dentate status was recorded where there was one tooth in the mouth irrespective of the condition of the tooth. Denture status was recorded by possession and wearing or not of dentures and need for dentures in each jaw, for both partial and complete dentures (Appendix 2 and Appendix 3).

The need for denture replacement, repair or adjustment for each jaw was also recorded after inspecting dentures, mucosa and ridges under dentures. Furthermore, patients were also asked whether they were happy with dentures or wanted to change them because of any issues with dentures.

3.8.2 Tooth presence

Tooth presence was recorded for each of 32 teeth to calculate the number of natural teeth present in each adult. Missing teeth spaces were also recorded, no space was recorded if space was replaced by a conventional or resin-bonded bridge and replaced by a denture or implant (Appendix 2 and Appendix 3). The examiners used clinical judgement regarding tooth morphology and took into account the respondent's previous dental history if doubt still existed as to the correct notation for a particular missing tooth.

3.8.3 Tooth status

Tooth status was recorded separately for the crown and root of each tooth. For crown and root, the examination for caries was mostly a visual one. The teeth were examined wet, a CPITN probe was used to remove debris and no radiographs were taken. Where needed, the CPITN probe was also used to confirm cavitation.

Each tooth crown was examined and recorded as; sound (untreated), decayed at cavitation, decayed at visual caries level, filled (each type of filling was recorded separately), filling and caries, visual caries, crowned due to caries, crowned not due to caries, veneer and trauma (Appendix 2 and Appendix 3). Crown caries was recorded at cavitation and visual levels using WHO and British Association for the Study of Community Dentistry (BASCD) criteria (Pitts et al., 1997, World Health Organization, 2013). Root status was examined separately; recession, filled (each type of filling was recorded separately), filled and caries and wear of more than 2mm were all recorded (Appendix 2 and Appendix 3). Later root caries was calculated by using the Root Caries Index (RCI) of Katz (Katz et al., 1982). These findings of tooth presence, crown and root status were used to evaluate crown and root treatment need among the study sample.

3.8.4 Tooth Contacts

Tooth contacts at maximum intercuspal position (MIP) were recorded only for lower teeth to evaluate the functional dentition (Allen et al., 1996, Witter et al., 1999, Armellini and Von Fraunhofer, 2004, Khan et al., 2014) and the need for replacement of teeth. To achieve MIP participants were asked to swallow and keep their teeth closed together. The lower teeth were used for this measurement. An occlusal unit was a single premolar or half a molar tooth (mesial or distal) (Steele et al., 1998).

Two contacts (anterior and posterior) were recorded for each of six lower molars and one contact was recorded for each premolar at maximum intercuspal position (MIP). One contact was recorded for each anterior tooth at maximum intercuspal position (MIP) or appear to contact in normal functional movement. Tooth contact was recorded as present "1" or absent "0". Missing teeth were marked as "X" (Appendix 2 and Appendix 3).

3.8.5 Periodontal status

In this study, the Community Periodontal Index of Treatment Need (CPITN) was used to evaluate the periodontal health and treatment need of sample adults. The WHO recommended ball ended epidemiological periodontal probe (CPITN-E) of 5gm weight was used for periodontal examination of index teeth in six sextants (World Health Organization, 2013). In the periodontal examination, the mouth was divided into six parts or sextants defined by teeth numbers 18-14, 13-23, 24-28, 38-34, 33-43 and 44-48. A sextant was examined only if there were two or more teeth present and not indicated for extraction. When only one tooth remained in a sextant, it was included in the adjacent sextant. The index teeth per person recorded for periodontal examination were as follows:

17/16	11	26/27
47/46	31	36/37

The two molars in each posterior sextant were paired for recording, and if one was missing, there was no replacement. If no index teeth or tooth were present in a sextant qualifying for examination, all the remaining teeth in that sextant were examined and the highest score was recorded as the score for the sextant. Third molar teeth were only recorded with other teeth if the first and second molars were absent.

CPITN-E probe was used as a “sensing” instrument to determine the pocket depth and to detect calculus and bleeding response. The sensing force used was no more than 20 grams. A practical test for establishing this force is to place the probe point under the thumbnail, parallel to the long axis of the thumb, and press until blanching occurs. For sensing sub-gingival calculus, the lightest possible force that will allow movement of the probe ball end along the tooth surface was used.

CPITN-E probe ball ended point followed the anatomical configuration of the surface of the tooth. If the patient felt pain during probing it was indicative of too much force. The probe tip was inserted gently into the gingival pocket and the depth of the insertion read against the black band. The total extent of the pocket was explored: the probe was placed in the pocket at the distobuccal surface of the second molar, as close as possible to the contact point with the third molar, keeping the probe parallel to the long axis of the tooth. The probe was then moved gently with short up and down movements through the buccal pocket to the mesial contact area of the second molar and from the distobuccal pocket of the first molar towards the contact area with the premolar. A similar procedure was carried out for the lingual surfaces, starting distolingually to the second molar. The maximum score per tooth was the tooth score and maximum score per sextant was recorded as sextant score. The codes used for periodontal health recording were, “0” No disease, “1” Bleeding on examination, “2” Presence of supra or sub-gingival calculus, “3” Pocket depth up to 4-5mm, “4” Pocket depth >6mm and “X” No teeth present in a sextant/ unable to record (Appendix 2 and Appendix 3).

Attachment loss was not recorded in this study, though the presence of recession was recorded in tooth status. Patients with cardiac problems and on anticoagulants were excluded from the periodontal examination.

3.8.6 Tooth wear

The Bardsley tooth wear index was used in this study (Bardsley, 2008). As with CPITN, the mouth was divided into six parts or sextants. In this research wear into dentine was recorded by visual assessment and the highest score per person was recorded as a person’s wear score. All of six teeth (if present) in each sextant were visually examined for wear. A minimum of two teeth was required to represent a sextant, if only one tooth was present in the sextant it was included in the adjacent sextant (Appendix 2).

Each sextant was individually scored and the worst tooth in a sextant was recorded as the sextant score. Visually recorded tooth wear was scored as “0” No wear, “1” Dentine exposed <1/3 of worst surface of a tooth, “2” Dentine exposed >1/3 of worst surface of a tooth and “X” Sextant excluded as no teeth present or only one tooth in sextant that was included in to adjacent sextant (Appendix 3).

3.8.7 Treatment need

Treatment need was recorded on the basis of the restorative, functional and aesthetic need of the participant, guided by the coding sheet (Appendix 2 and Appendix 3). Denture need was recorded according to the respondent’s and the dentist’s opinion from the clinical examination. Other treatment need was judged by the examiner and there might have been differences between examiners’ scores particularly in respect of treatment need for a fixed prosthesis.

3.9 Calibration exercise

The examining dentists undertook initial training based using slides of the different conditions and codes and observed each other during oral health examinations at the TILDA health centre Trinity College Dublin (TCD).

Although four dentists participated in the oral health examination but AN carried out 85% of examinations while others did 15%, which also maintained consistency of examinations. Calibration exercises were carried out before and during the study to maintain similarities of methods and standards in examinations by each examiner. A manual on methods used in this research for oral health assessment was given to dentists before calibration. During the calibration exercise, every dentist, in turn, examined eight specially arranged patients in the Dublin Dental University Hospital (DDUH) for calibration with JMcL acting as the gold standard. At the beginning of the TILDA study, the senior investigators (JMcL and BO'C) observed examinations by the other investigators (AN and MM) and any ambiguous scoring was discussed with reference to the training manual. This process continued over a number of days until consistency was achieved. Spot checks continued by the examiners on each other throughout the study. In addition, assessment sheets were compared to rule out inter-examiner variations in the scoring of the oral health examinations.

The TILDA health assessment was long (approximately three hours) and TILDA management allowed a maximum 10 minutes for each oral health examination. Because of this time constraint, it was not possible to carry out duplicate examinations during the data collection.

3.10 Pilot study

The data collection was first piloted on approximately 20 participants to analyse the feasibility of the examination and the time required for each examination (to fulfil TILDA time limit of maximum ten minutes per participant). After the pilot study, a few minor changes were made in the oral health assessment chart. The oral health examination was also practised to make sure that it could be completed in ten minutes.

3.11 Oral health assessment feedback

At participants' request, in the middle of the study, an oral health assessment feedback was introduced (Appendix 4). This short feedback informed participant whether they needed or not to consult their dentist for some reason. Participants were also informed about their denture treatment need.

3.12 Data processing

Data was first recorded on paper charts, later it was entered into a laptop using software specially designed for the oral health recording. The software was designed to be the same as the assessment sheet in digital form and was connected to the TILDA server. For data protection assurance, data entered in the laptop was uploaded to the TILDA server immediately and access to the internet was disabled on the laptop. No participant data was stored in the laptop itself. Oral health data was only accessible after approval from TILDA management at specially designated TILDA hot desks.

3.13 Data cleaning

Data cleaning was performed after the data was securely processed and uploaded to the TILDA server. A sample of 150 respondents was randomly selected for data verification purposes. Each variable of oral health status from the paper charts was rechecked with the data in the TILDA server, at a TILDA hot desk. It was calculated that there were 4 % errors in the data uploaded to the TILDA server when compared with data on the paper charts, these errors were mostly typing mistakes in DMFT data and these errors were corrected. After data cleaning, data analysis was started.

3.14 Weighting process

The whole TILDA sample is nationally representative population sample, but to overcome the bias of non-random response rates TILDA applied weights in order to make nationally representative conclusions (Whelan and Savva, 2013). These weights corresponded to the number of members of the population that was represented by each participant. Weight applied to total TILDA sample were calculated by comparison between the number of participants in the sample with a given combination of characteristics and the same number in the population. The population numbers were estimated by using the Quarterly National Household Survey (QNHS 2010). Three characteristics, age, gender and education level were compared with QNHS to estimate weights (Whelan and Savva, 2013). The weight applied in full TILDA sample for each participant was the reciprocal of the probability of that participant's inclusion in the final sample, given their characteristics and that they were a member of the targeted population (Whelan and Savva, 2013).

As the oral health sample was smaller than the total TILDA sample weightings were not applicable to the oral health sample. To overcome bias in the oral health sample selection comparisons were done between the oral health assessment sample (OHA) and the total TILDA Wave 3 sample. The similarities between the two samples (OHA sample and TILDA wave 3 samples) were evaluated by two-sample proportion test (Z test) (see chapter 4, Table 4-1).

3.15 Data Analysis

The oral health assessment data uploaded to the TILDA server were in string form (in computer programmes a special sequence of letters, numbers or other characters is called a string when it defines a variable, and such data is called string data). The variable form determines what can or cannot be done with the data. Calculations can only be done with the numeric form of variables, not with string variables (Hallgren, 2012). So, before data analysis, all dental assessment codes were changed from string to numeric form and all data was re-coded. Data analysis was started after completion of data cleaning and recoding by accessing a TILDA hot desk. STATA software (Stata 14.1 Stata Corp LLC Texas USA) was used for data analysis purposes.

In Chapter 4, to evaluate the oral health status of adults aged 50 years and over, descriptive statistics were calculated by age group and gender. Multinomial regression analysis, Wilcoxon Rank Sum and Kruskal-Wallis Rank Test were done for the relationship between socioeconomic status and oral health.

In Chapter 5, of self-reported versus objectively measured oral health, descriptive statistics and Chi-square analysis were done. In Chapter 6, for evaluation of relationship between oral health and systemic health conditions multinomial and logistic regression analysis were done.

4 Results and discussion of oral health status

This chapter reports the results of the oral health status of the sample of community-dwelling adults aged 50 years and over as follows:

- Oral health assessment sample selection
- Comparison of the TILDA sample with the oral health assessment (OHA) sample
- Oral health assessment sample description
- Oral health status of the sample of community-dwelling adults aged 50 years and over
- Oral health status and its relationship with socioeconomic status

4.1 Oral health assessment sample selection

The oral health assessment sample was selected from the TILDA Wave 3 cohort, which consisted of 6618 respondents who participated in the Computer Assisted Personal Interview (CAPI) and Self-Completed Questionnaire (SCQ). From the TILDA Wave 3 sample (n=6618), 4309 (65.1%) respondents participated in TILDA health assessment at the TILDA centre in TCD (Kearney et al., 2011).

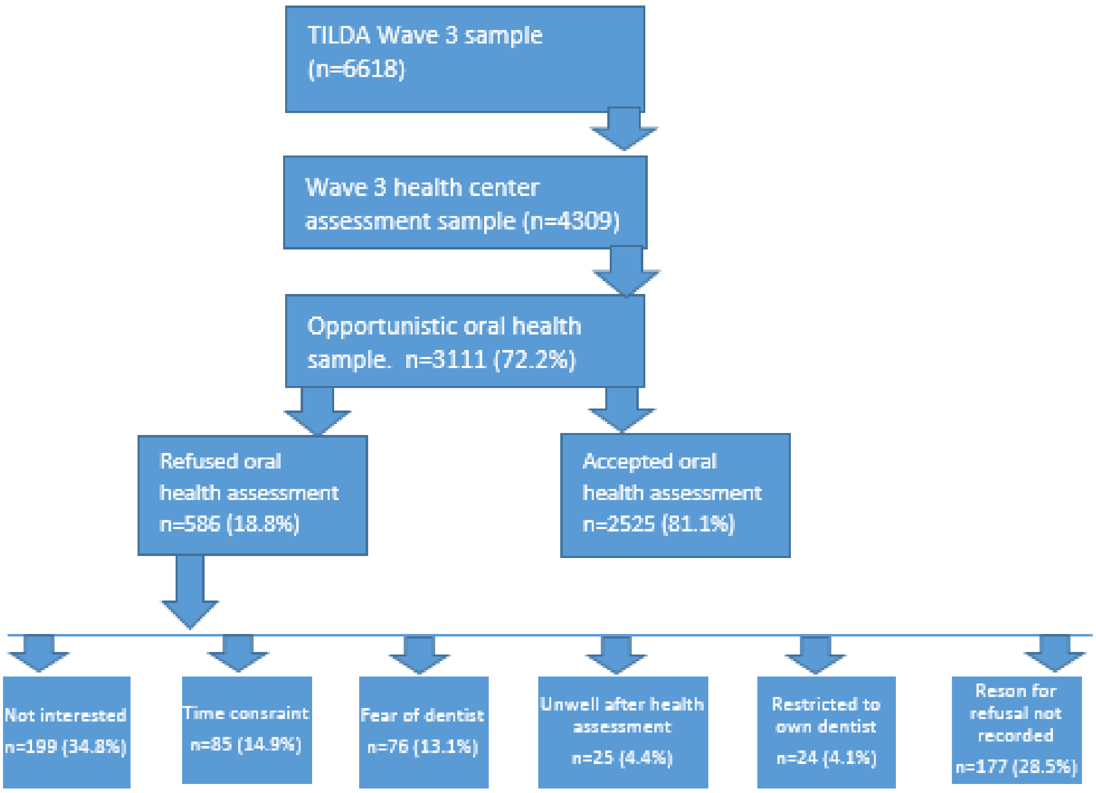


Figure 4-1: Number and percentage of participants offered an oral health assessment, the number who accepted and rejected the assessment along with reasons for refusal.

Figure 4-1 shows how an opportunistic sample of 3111 (72.2%) was selected for the oral health assessment (OHA) from the TILDA Wave 3 health assessment sample (n=4309). OHA sample consisted of 38.2% (n=2525) of overall TILDA Wave 3 sample (n=6618). Of the 3111 respondents invited to have an oral health assessment, 2525 (81.1%) agreed to the assessment whereas 586 (18.8%) refused. Reasons for the refusal were also elicited and are shown in Figure 4-1. The total number of respondents who agreed to the oral health assessment (OHA) was 2525; those adults aged less than 50 years (n=17) were omitted from the analysis. The full OHA sample consisted of 2508 respondents, however, the data for 4 of these respondents was not available at the time of the analysis, so the final sample used for analysis in this research was 2504 respondents.

4.2 Comparison of the TILDA sample with the oral health assessment (OHA) sample

In the analysis of the TILDA cohort, to reduce the bias of a non-random response rate, weights were applied for statistical analysis (see chapter 3). As the OHA sample was much smaller than the TILDA sample, it was not possible to apply weights to the OHA sample to approximate the population. Table 4-1 below, reports the two-sample proportion test (Z test) for comparison of the characteristics between the OHA sample and the TILDA sample (population sample) to find out the similarities between OHA sample and TILDA sample.

Table 4.1 shows, OHA sample and Tilda Wave 3 sample were similar in relation to adults with secondary education, separated/divorced, living in other than Dublin/Co-Dublin, grew up in rural area, self-reported general health, ‘good’, with no health insurance or medical card and in proportion of females.

Table 4-1: Comparison of the oral health assessment (OHA) sample with the TILDA Wave 3 sample by a two-sample proportion test (Z test). P values less than 0.05 are shown in bold.

Characteristic	Oral Health Assessment sample (n=2508)	TILDA Wave 3 sample (n=6618)	Hypothesis test of proportions TILDA vs OHA
Age group	n (%)	n (%)	P value
50-64 years	1219 (48.6)	3036 (45.9)	**0.0196**
65-74 years	918 (36.6)	2110 (31.9)	**< 0.001**
≥75 years	371 (14.8)	1472 (22.2)	**< 0.001**
Female	1386 (55.3)	3679 (55.6)	0.7786
Education level			
Primary	478 (19.1)	1737 (26.3)	**< 0.001**
Secondary	1005 (40.1)	2610 (39.4)	0.5805
Tertiary/higher	1024 (40.8)	2269 (34.3)	**< 0.001**
Marital status			
Married	1889 (75.3)	4573 (69.1)	**< 0.001**
Never married	168 (6.7)	562 (8.5)	**0.0048**
Separated/divorced	192 (7.7)	469 (7.1)	0.3494
Widowed	259 (10.3)	1014 (15.3)	**< 0.001**
Locality			
Dublin/Co Dublin	681 (27.1)	1592 (24.1)	**0.0023**
Other urban	661 (26.4)	1840 (27.8)	0.1664
Rural	1166 (46.5)	3186 (48.1)	0.1588
Grew up in rural area	1440 (57.4)	3891 (58.8)	0.2331
Never lived abroad	669 (26.7)	1534 (23.2)	**0.0005**
Current or former smoker	1302 (51.9)	3609 (54.5)	**0.0251**
No health insurance or medical card	209 (8.3)	591 (8.9)	0.3681
Self-reported health			
Excellent	394 (15.7)	921 (14.2)	**0.0294**
Very good	897 (35.8)	2169 (33.4)	**0.0069**
Good	851 (34.0)	2227 (34.2)	0.8001
Fair	312 (12.4)	970 (14.9)	**0.0065**
Poor	52 (2.1)	215 (3.3)	**0.0029**

4.3 Oral health assessment sample description

For the purpose of the analysis, the oral health assessment (OHA) sample was stratified into three age groups, following the recommendations of the WHO (World Health Organization, 2013). Group 1 was 50-64 years old, group 2 was 65-74 years old and group 3 was 75 years and over. For the comparison of oral health conditions with general health conditions, these age groups are also comparable with TILDA health assessment, age groups used for analysis (Whelan and Savva, 2013). Table 4-2 shows the breakdown of the OHA sample by the three age groups and gender.

Table 4-2: Description of TILDA Wave 3 oral health assessment sample by gender and age group (n=2504).

Gender	**Age group**			**Total**
	50-64 years	**65-74 years**	**75 years and over**	
Male	511	422	187	1120
	42.0%	46.1%	50.5%	44.7%
Female	707	494	183	1384
	58.0%	53.9%	49.5%	55.3%
Total	1218	916	370	2504
	48.6%	36.6%	14.8%	100%

4.4 Oral health status of a sample of community-dwelling adults aged 50 years and over living in Ireland

This section will report the descriptive statistics of the oral health status of the adults by age group and gender. Oral health status will include, edentate/dentate, denture wearing, mean number of teeth, 20 or more teeth, 18 or more sound untreated natural teeth (SUNT), decayed missing and filled teeth (DMFT), root caries by the root caries index (RCI), tooth contacts, periodontal health (CPITN) and tooth wear. During the statistical analysis, some oral health indicators were calculated for the whole OHA sample (edentate and dentate, number of teeth, 20 or more teeth, 18 and more SUNT and DMFT) and other oral health indicators (tooth contacts, root caries index (RCI) and periodontal health, tooth wear) were calculated for the dentate sample only, resulting in two bases for results. “Base-edentate and dentate” means the statistical analysis involved the complete oral health assessment sample of edentate and dentate adults (n=2504), whereas “Base- dentate” means the statistical analysis was run only on the dentate sample (n=2255).

4.4.1 Edentate/dentate

Adults with at least one tooth in the mouth were recorded as dentate. Table 4-3 shows that 9.9% of the adults were edentate. The proportion of edentate adults was greater in the older age groups and more females were edentate than males in all age groups. This difference between males and females was evident among all age groups and was greater among older age groups.

Table 4-3: Percentage of edentate/dentate by age group and gender (Base-edentate and dentate n=2504).

Dentition Status		**50-64 years**		**65-74 years**		**75 years & over**		**Total**
		Male	**Female**	**Male**	**Female**	**Male**	**Female**	
Edentate	**n**	15	33	36	71	39	55	249
	%	(2.9%)	(4.7%)	(8.5%)	(14.4%)	(20.9%)	(30.1%)	(9.9%)
Dentate	**n**	496	674	386	423	148	128	2255
	%	(97.1%)	(95.3%)	(91.5%)	(85.6%)	(79.1%)	(69.9%)	(90.1%)

Table 4-4 shows that 57.0% of adults had one or more teeth in both arches and a higher proportion of the sample was edentate in the lower arch only, compared with those who were edentate in the upper arch only and edentate in both arches.

Table 4-4: Percentage of adults by both arches edentate, upper arch edentate and lower arch edentate *(Base-edentate and dentate, n=2504).*

Edentate or partially edentate	**Upper & lower arches edentate**	**Upper arch edentate**	**Lower arch edentate**	**Neither arch completely edentate**
n	249	350	477	1428
%	9.9%	14%	19.0%	57.0%

4.4.2 Denture wearing

Table 4-5 indicates that overall 46.9% of the adults aged 50 years and over, were wearing some type of denture and out of these, 18.4% were wearing a complete upper denture only, complete upper and lower dentures and complete upper and partial lower dentures (C/C, C/P, C/), while the remaining 28.5% were wearing other combinations of dentures (P/P, P/, /P, P/C).

Table 4-5: Denture wearing by age group and type of denture (Base-edentate and dentate, n=2504).

Age group	**Not wearing a denture**		**C/C**		**C/P**		**C/**		**All other P/P, P/, /P, P/C**		**Total**
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**
50-64 years	838	68.8	42	3.5	10	0.8	41	3.4	287	23.6	1,218
65-74 years	392	42.8	98	10.7	51	5.6	67	7.3	308	33.6	916
75years & over	100	27.0	88	23.8	24	6.5	41	11.1	117	31.6	370
Total	1330	53.1	228	9.1	85	3.4	149	5.9	712	28.5	2504

Table 4-5 shows that 9.1% of the OHA sample was wearing complete dentures in both arches, which is similar to the finding of 9.9% edentulism and indicates that 0.8% of the adults who were edentate, were not wearing dentures at the time of the assessment. It also indicates that the percentage of adults wearing all types of dentures was greater in the older age groups. For example, in those aged 50-64 years, 31.2% were denture wearers whereas in those aged 75 years and over, 73% were denture wearers. The type of denture being worn also changed with age. Fewer adults were wearing complete dentures in the younger age groups compared to the oldest age group. These findings suggest that with age adults tended to lose their retained teeth and partial and complete dentures became necessary.

4.4.3 Number of teeth

Figure 4-2 shows the frequency distribution of the number of teeth present in the OHA sample. It shows that 9.9% of adults had no teeth and 54.3% of adults had 20 or more teeth.

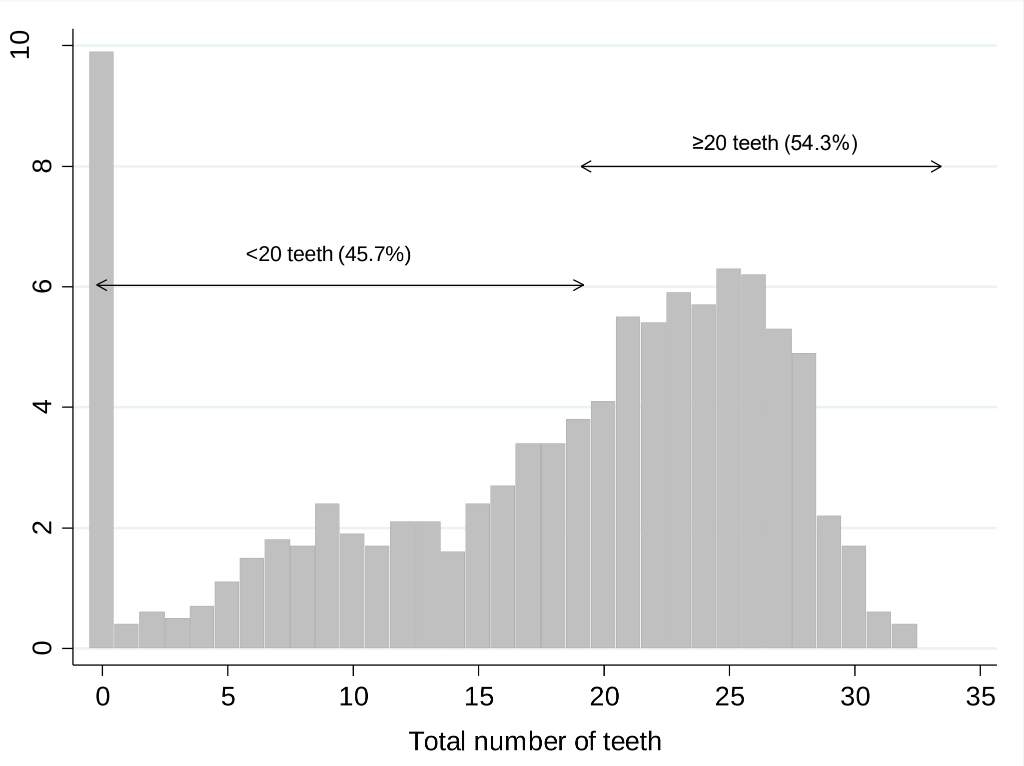


Figure 4-2: Percentage of adults aged 50 years and over by total number of teeth (Base-edentate and dentate, n=2504). Mean number of teeth is 17.9, SD = 8.9, Median=21, IQR= 13.

The negatively skewed density plot indicates a positive effect on the number of teeth; more adults who had 20 or more teeth compared to those with fewer than 20 teeth. The mean number of teeth (17.9) is less than the median (21).

Table 4-6 shows that the mean number of teeth present per person among the sample of adults aged 50 years and over was 17.9. Overall the mean number of teeth decreased from those aged 50-64 years to those aged 75 years and over.

Table 4-6: Descriptive statistics of mean number of teeth per person by age group and gender (Base-edentate and dentate, n=2504).

Age group	Male	Female	Total
50-64 years	21.1	21.5	21.3
65-74 years	16.3	15.4	15.8
75 years & over	11.9	11.1	11.5
Total	17.7	17.9	17.9

4.4.4 Possession of twenty or more teeth

Studies have reported that 20 or more teeth are required to maintain oral functions (Sheiham et al., 1999, Gotfredsen and Walls, 2007). As possession of more than 20 teeth fulfils functional, dietary and aesthetic needs of an individual without the need for a partial denture (Sheiham et al., 1999). The World Dental Federation (FDI), World Health Organization (WHO), and the International Association for Dental Research (IADR) have also defined a functional dentition as having 21 or more natural teeth (World Health Organization and Federation Dentaire International, 1982, World Health Organisation, 1992, Hobdell et al., 2003). In this research, the percentages of adults with fewer than 20 teeth (< 20 teeth) and 20 or more teeth (≥20 teeth) were calculated by age group and gender.

Table 4-7 shows that between those aged 50-64 years and the group aged 75 years and over, there was a marked decrease in the percentage of adults with 20 or more teeth in both males and females. Overall, 2.8% more females, had 20 or more teeth than males (55.6% vs 52.8%). Gender difference was present in all three age groups. In those aged 50-64 years, more females had 20 or more teeth (73.8% vs 69.7%). This gender difference was reversed in the older age groups, in those aged 65-74 years and those aged 75 years and over, more males had 20 or more teeth than females (43.8% vs 40.9% and 26.7% vs 24.6%) respectively. This supports the findings in Table 4-6, which showed that only in the age group 50-64 years the females had slightly more teeth than males.

Table 4-7: Number and percentage of adults with fewer than 20, and 20 or more teeth, by age group and gender (Base-edentate and dentate, n=2504).

Number of teeth	**Age group**								**Total**
	50-64 years		**65-74 years**		**75 years and over**		**Total**		
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	
< 20 Teeth									
n	155	185	237	292	137	138	529	615	1144
%	30.3%	26.2%	56.2%	59.1%	73.3%	75.4%	47.2%	44.4%	45.7%
≥ 20 Teeth									
n	356	522	185	202	50	45	591	769	1360
%	69.7%	73.8%	43.8%	40.9%	26.7%	24.6%	52.8%	55.6%	54.3%

4.4.5 Eighteen or more sound untreated natural teeth (≥18 SUNT)

Sound untreated natural teeth (SUNT) represents those teeth that have not been decayed, filled for any reason, or traumatised. The proportion of an adult population with 18 or more SUNT is similar to the proportion of a child or adolescent population being caries free and is a measure of the effectiveness of caries prevention programmes (Whelton et al., 2007). Although possession of 18 or more sound untreated natural teeth (≥18 SUNT) is an arbitrary measurement, some oral health surveys use it to represent healthy undamaged teeth (caries and trauma free), along with other oral health indicators (Whelton et al., 2007, Fuller et al., 2011). In this research, the crown of each tooth was examined on all surfaces for caries, restorations and trauma and subsequently the number of SUNT per person was counted.

Table 4-8 indicates that among the sample only 10.9% had 18 or more sound untreated natural teeth. Among the three age groups, fewer of the oldest age group had ≥18 SUNT (3.0%) compared with the youngest age group (17.4%). As with mean DMFT, these figures for SUNT do not provide any indication of when teeth were restored, lost or damaged. The differences between the age groups may be simply a reflection of better preventive dental care that was available to the youngest age group in previous years. Another factor that may need to be taken into account in future studies of older adults is the prevalence of restorations, such as veneers and crowns, placed on teeth to improve aesthetics or support fixed bridges instead of removable partial dentures.

Table 4-8: Number and percentage of adults with ≥ 18 SUNT by age group (Base-edentate and dentate, n=2504).

Sound Untreated Natural Teeth (SUNT)	**50-64 years**	**65-74 years**	**75 years and over**	**Total**
	n (%)	**n (%)**	**n (%)**	**n (%)**
< 18 SUNT	1006 (82.6%)	864 (94.3%)	359 (97.0%)	2229 (89.1%)
≥ 18 SUNT	212 (17.4%)	52 (5.7%)	11(3.0%)	275 (10.9%)

In Table 4-9 it can be seen, that overall more males had 18 or more SUNT than females (13.7% vs 8.7%). This gender difference was present in all three age groups and was highest among those aged 50-64 years (21.7% vs 14.3%). In those aged 75 years and over, very few women (0.5%) had 18 or more SUNT.

Table 4-9: Number and percentage of adults with <18 SUNT and ≥ 18 SUNT by age group and gender (Base-edentate and dentate, n=2504).

Sound Untreated Natural Teeth (SUNT)	Age groups								
	50-64 years		65-74 years		75 years and over		All ages		Total
	Male	Female	Male	Female	Male	Female	Male	Female	
< 18 SUNT									
n	400	606	389	475	177	182	966	1263	2229
%	(78.3%)	(85.7%)	(92.1%)	(96.2%)	(94.7%)	(99.5%)	(86.3%)	(91.3%)	(89.1%)
≥ 18 SUNT									
n	111	101	33	19	10	1	154	121	275
%	(21.7%)	(14.3%)	(7.9%)	(3.8%)	(5.3%)	(0.5%)	(13.7%)	(8.7%)	(10.9%)

4.4.6 Tooth contacts

In this study, the percentages of adults with 10 or more tooth contacts (≥ 10 contacts), was calculated among dentate adults by age group and gender (n=2255). Ten tooth contacts indicate 20 teeth in occlusion; 20 or more teeth in occlusion is considered to be a minimal functioning dentition (Steele et al., 1998, Sheiham et al., 1999, Hobdell et al., 2003, Gotfredsen and Walls, 2007). It should be noted that in the indices used in this study, molar teeth were recorded as having two contacts and tooth contacts were calculated for the dentate respondents only (Steele et al., 1998, Witter et al., 1999). Figure 4-3 shows that among the dentate sample (2255), 13.6% of adults had no tooth contacts and 56.8% had 10 or more tooth contacts.

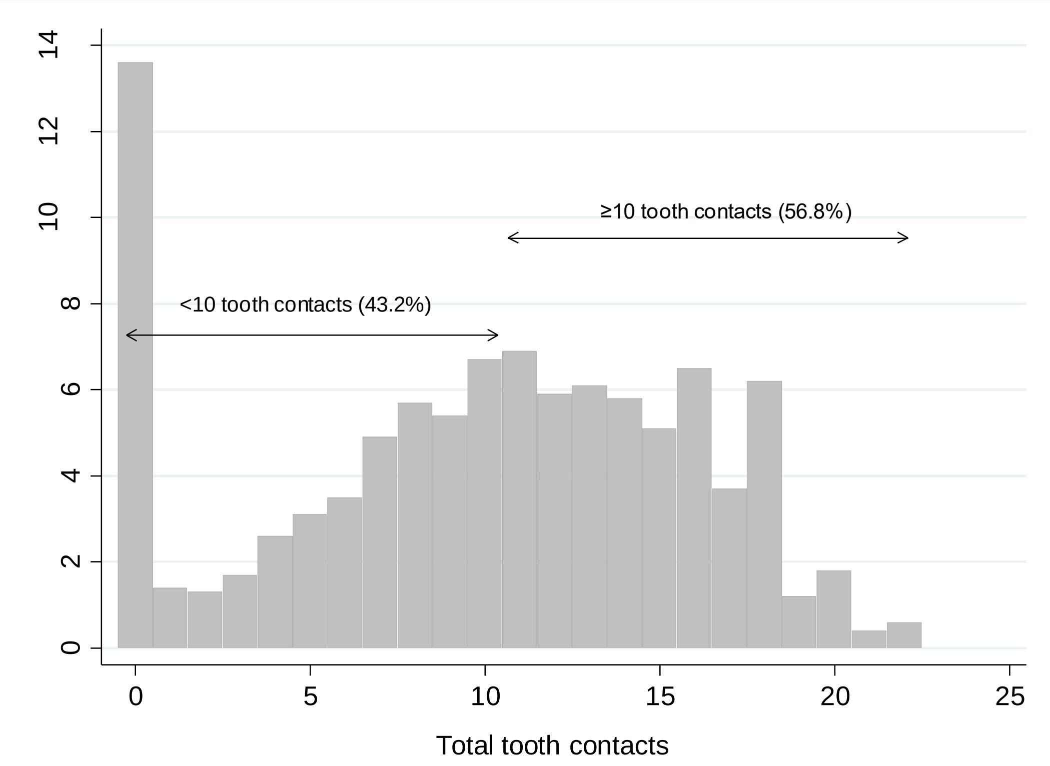


Figure 4-3: Percentage of adults aged 50 years and over by total number of tooth contacts (Base-dentate, n=2255). Mean 9.9, SD= 5.9, Median= 11, IQR=9.

This graph is slightly negatively skewed showing a higher percentage of adults had 10 or more tooth contacts and the median (11) was greater than the mean (9.9). The 13.6% of dentate adults had no contacts; these adults were single arch edentate, wearing dentures, had crossbites, or teeth, not in contact with other teeth, or just roots remaining.

Table 4-10 indicates that proportion of dentate adults with 10 or more contacts was much less in the older age groups, and more females had 10 or more contacts than males, which matches the findings of 20 or more teeth in Table 4-7. This gender difference was present among all three age groups but was reduced in the older age groups.

Table 4-10: Percentage of adults with fewer than 10 contacts, and equal to or more than 10 contacts, by age group and gender (Base-dentate, n=2255).

Number of tooth contacts	50-64 years		65-74 years		75 years & over		Total
	M	F	M	F	M	F	
<10 Contacts							
n	172	179	214	225	101	84	975
%	34.7%	26.6%	55.4%	53.2%	68.2%	65.6%	43.3%
≥ 10 Contacts							
n	324	495	172	198	47	44	1280
%	65.3%	73.4%	44.6%	46.8%	31.8%	34.4%	56.7%

4.4.7 Decayed, missing and filled teeth

Caries was recorded as decayed, missing and filled teeth at cavitation (DMFT-c) and at visual caries level (DMFT-v), for the total sample (Base-edentate and dentate, n=2504). This section will report the mean DMFT-c along with its components (D, M and F) as a proportion of the DMFT-c, as well as a comparison between DMFT-c and DMFT-v by age group and gender.

During the OHA it was possible to identify that some teeth were missing for reasons other than dental caries. These were missing premolars with no residual spaces (orthodontic extractions or congenital absence), third molars extracted due to impaction and teeth lost due to trauma. Where there was certainty about the reasons for their loss, these teeth were recorded as missing for other reasons and not counted in the M component of DMFT (Appendix 3). Where it was unclear, or there was doubt about the reasons for tooth loss, these teeth were recorded as missing due to caries. Similarly, in the edentate group, third molar teeth were not recorded as missing due to caries. For this reason, the maximum DMFT score for edentate adults was 28 and for dentate adults, it was 32.

However, to facilitate national comparisons the mean DMFT was also calculated using the WHO method, which requires that in adults aged more than 30 years, teeth missing for all reasons should be included in the missing component of DMFT (World Health Organization, 2013). Using the WHO method, the maximum DMFT score was 32 for edentate adults (Figure 4-5).

Table 4-11, Table 4-12, Table 4-13 and Figure 4-4 report DMFT using the TILDA method. Table 4-11 shows only a slight difference between DMFT-c and DMFT-v, which was consistent (18.5 vs 18.6) among all age groups (0.1).

Table 4-11: Mean DMFT-c and DMFT-v by age group, according to TILDA method of DMFT calculation (Base-edentate and dentate, n=2504).

Age group	DMFT-c	DMFT-v
50-64 years	16.7	16.8
65-74 years	19.5	19.6
75 years & over	21.6	21.7
Total	18.5	18.6

Table 4-12 shows, there was no difference between mean DMFT-c and DMFT-v among females (18.6) whereas among males it was 0.1 (18.3 vs 18.4) which suggests the visual caries prevalence was very low and was only among males.

Table 4-12: Mean DMFT-c and DMFT-v by gender, according to TILDA method of DMFT calculation (Base-edentate and dentate, n=2504).

Gender	DMFT-c	DMFT-v
Male	18.3	18.4
Female	18.6	18.6
Total	18.5	18.6

As this difference was so small, only mean DMFT-c will be reported in these results as mean DMFT. Figure 4-4 shows that DMFT is negatively skewed with a greater percentage of adults having high values for DMFT.

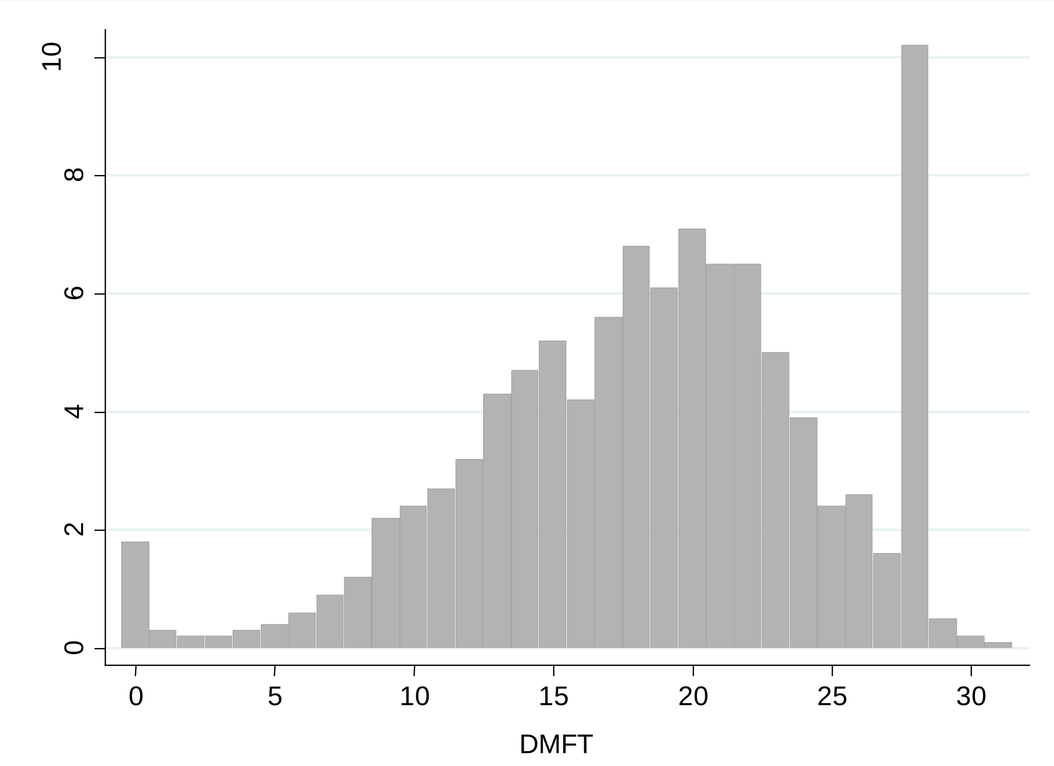


Figure 4-4: Percentage of adults aged 50 years and over by DMFT score (Base-edentate and dentate, n=2504, TILDA method of DMFT calculation). Mean= 18.5, SD= 6.3, Median=19, IQR=9.

Figure 4-4 shows that overall, 10.22% had a DMFT score of 28, including the 9.9% edentate adults. and only 1.8% of adults had a DMFT score of 0. The negative skewness demonstrates that the mean DMFT (18.5) is smaller than the median DMFT (19). This indicates that the proportion of adults with higher DMFT score was greater. There is an uneven distribution of adults with DMFT, with most adults having a DMFT score between 13-28, as seen in Figure 4-4.

Mean DMFT and its components along with the percentage attribution of each component in mean DMFT are reported in Table 4-13. Percentage attribution represents the percentage contribution of each component of DMFT (decayed, missing and filled teeth) in total mean DMFT. Reporting the DMFT in this manner gives an indication of the unmet need (%D/DMFT) and the restorative index (%F/DMFT) which are valuable for planning service provision.

When the components of DMFT were considered by gender and age group, overall males had a higher mean number of decayed teeth compared to females (0.6 vs 0.3) and this difference between males and females was very similar in the three age groups. On average males also had more missing teeth and had fewer filled teeth than females. In both males and females, the decayed teeth component of DMFT remained constant, whereas the missing teeth component was higher, and the filled teeth component was lower in older age groups (Table 4-13). This finding suggests that the oldest age group had more access to extractions than restorations for the treatment of caries. However, it is important to reiterate that no detailed conclusions can be drawn about the progression of disease or treatment over time in this cross-sectional study.

Table 4-13: Mean DMFT at cavitation level and its components (D, M or F as % of mean DMFT) by age group and gender according to TILDA method of DMFT calculation (Base-edentate and dentate, n=2504).

Age group		Decayed teeth		Missing teeth		Filled teeth		Mean DMFT		Total DMFT
		Male	Female	Male	Female	Male	Female	Male	Female	
50-64 years	Mean DMFT	0.6	0.3	7.7	7.1	7.9	9.6	16.4	17.0	16.7
	% of mean DMFT	3.7%	1.8%	46.9%	41.8%	48.2%	56.5%			
65-74 years	Mean DMFT	0.6	0.4	12.1	12.0	6.8	7.2	19.4	19.6	19.5
	% of mean DMFT	3.1%	2.1%	62.4%	61.2%	34.7%	36.7%			
75 years & over	Mean DMFT	0.6	0.3	15.7	16.2	5.0	5.6	21.3	22	21.6
	% of mean DMFT	2.8%	1.4%	73.7%	73.6%	23.5%	25.5%			
Total	Mean DMFT	0.6	0.3	10.7	10.0	7.0	8.2	18.3	18.6	18.5
	% of mean DMFT	3.3%	1.6%	58.5%	53.8%	38.3%	44.1%			

In Figure 4-5 and Table 4-14 the DMFT calculations have been done using the WHO methodology of counting teeth missing for any reason in the DMFT.

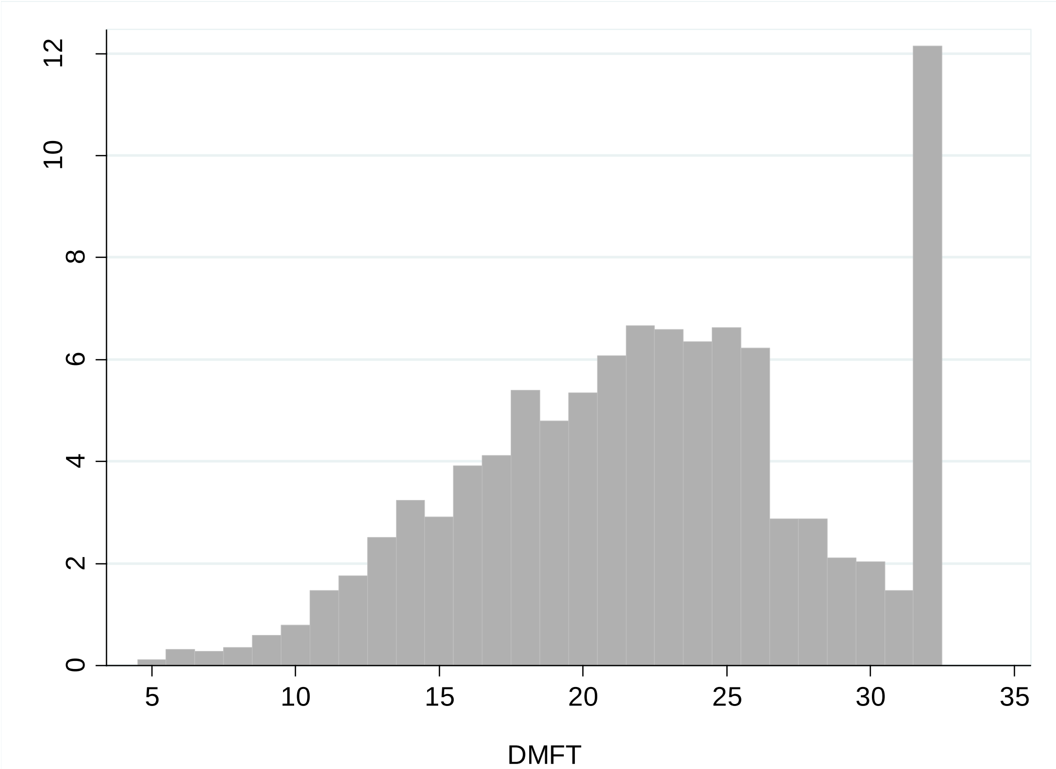


Figure 4-5: Percentage adults aged 50 years and over, by DMFT score (Base-edentate and dentate, n=2504, WHO method of DMFT calculation). Mean= 22.3, SD=6.09, Median=22, IQR=8.

Table 4-14 shows that the mean DMFT calculated by WHO method among the sample was 22.3, when teeth known to be missing for reasons other than caries were included. This was an increase of 3.8 in the mean DMFT compared to the calculation that excluded teeth missing for reasons other than caries (Table 4-13 and Table 4-14).

Table 4-14: Mean DMFT at cavitation level and its components (mean and %) by age group and gender (Base-edentate and dentate, n=2504) according to WHO recommended method of DMFT calculation.

Age group		Decayed teeth		Missing teeth		Filled teeth		Mean DMFT		Total DMFT
		Male	Female	Male	Female	Male	Female	Male	Female	
50-64 years	Mean DMFT	0.6	0.3	10.9	10.5	8.0%	9.7	19.5	20.5	20.1
	% of mean DMFT	3.1%	1.5%	55.9%	51.2%	41.0%	47.3%			
65-74 years	Mean DMFT	0.6	0.4	15.7	16.6	6.8	7.2	23.1	24.1	23.6
	% of mean DMFT	2.6%	1.7%	67.9%	68.9%	29.4%	29.9%			
75 years and over	Mean DMFT	0.6	0.3	20.2	20.9	4.9	5.6	25.7	26.7	26.2
	% of mean DMFT	2.3%	1.1%	78.6%	78.3%	19.1%	21.0%			
Total	Mean DMFT	0.6	0.3	14.3	14.1	7.0	8.2	21.9	22.6	22.3
	% of mean DMFT	2.7%	1.3%	65.3%	62.4%	32.0%	36.3%			

4.4.8 Root surface caries

Exposed roots, root caries and restorations due to root caries were recorded during the oral health assessments. The Root Caries Index (RCI) of Katz was calculated by calculating the mean number of decayed and filled roots as a proportion of the mean number of exposed roots among the dentate adults (n=2255) (Katz et al., 1982).

Table 4-15 shows that overall from those aged 50-64 years to those aged 75 years and over, there was an increase in RCI (4.3 vs 10.2) and mean decayed/filled roots (0.5 vs 1.1). The mean exposed roots (11.1 vs 10.4) were also fewer in the older age group, which was probably due to the smaller number of retained teeth in older age groups. In the youngest age group, females had a higher RCI than males, but in the oldest age group females had a lower RCI than males, which probably reflects the more retained teeth among females in the youngest age group and fewer retained teeth in females in the oldest age group compared to males, as reported in Table 4-6.

Table 4-15: Mean exposed roots, mean decayed roots and RCI by age group and gender (Base-dentate, n=2255).

Age group	Mean number decayed/filled roots (DFR)			Mean number of exposed roots (ER)			RCI=100*DFR/ER		RCI
	Male	Female	Total	Male	Female	Total	Male	Female	Total
50-64 years	0.4	0.5	0.5	11.6	10.7	11.1	3.6	4.9	4.3
65-74 years	0.8	0.9	0.9	11.1	10.7	10.8	7.2	8.3	7.8
75 years and over	1.1	1.0	1.1	10.1	10.6	10.3	10.6	9.8	10.2
Total	0.7	0.7	0.7	10.7	11.2	10.9	6.5	6.3	6.4

4.4.9 Periodontal Health

The severity of periodontal disease was calculated among dentate adults (n=2255) by the maximum CPITN score per person and the extent of periodontal disease was expressed as the mean number of sextants per person with the different CPITN scores.

Table 4-16 shows that in the dentate sample the highest percentage of adults (50.8%) had shallow pockets (P1) followed by 31.7% with calculus (C), 5.8% had a maximum score of healthy (H), 5.7% had deep pockets (P2), 3.5% had bleeding on probing (B) and 2.6% had missing sextants (X). When the age groups were considered, the proportion of adults with scores of healthy, bleeding and calculus was greater in the older age groups whereas the proportion of adults with scores of deep and shallow pockets was less in the older age groups. These differences between the age groups may be in part a reflection of the lower mean numbers of teeth present in the older age groups. Table 4-16, Table 4-17 and Table 4-18 show that in all three age groups females had a higher proportion and a higher mean number of healthy sextants than males and this gender difference of mean healthy sextants, was highest in the youngest age group. Males had more deep pockets and missing sextants than females. So overall, females had better periodontal health than males.

Table 4-16: Number and percentage of adults with maximum CPITN score of H (healthy), B (bleeding), C (calculus), P1 (shallow pocket), P2 (deep pocket) and X (missing sextant) by age group (Base-dentate, n=2255).

Age group	H		B		C		P1		P2		X		Total
	n	%	n	%	n	%	n	%	n	%	n	%	n
50-64 years	61	5.2	36	3.1	343	29.3	642	54.9	77	6.6	11	0.9	1170
65-74 years	47	5.8	29	3.6	272	33.6	394	48.7	40	4.9	27	3.3	809
75 years and over	23	8.3	14	5.1	99	35.9	109	39.5	11	4.0	20	7.3	276
Total	131	5.8	79	3.5	714	31.7	1145	50.8	128	5.7	58	2.6	2255

Table 4-17: Number and percentage of adults with a maximum of CPITN score of H (healthy), B (bleeding), C (calculus), P1 (shallow pocket), P2 (Deep pocket) and X (missing sextant) by age group and gender (Base-dentate, n=2255).

Age group		H		B		C		P1		P2		X		Total
		M	F	M	F	M	F	M	F	M	F	M	F	
50-64 years	**n**	16	45	13	23	128	215	284	358	48	29	7	4	1170
	%	1.4%	3.9%	1.1%	2.0%	10.9%	18.4%	24.3%	30.6%	4.1%	2.5%	0.6%	0.3%	
65-74 years	**n**	19	28	7	22	116	156	201	193	22	18	21	6	809
	%	2.4%	3.5%	0.9%	2.7%	14.3%	19.3%	24.9%	23.9%	2.7%	2.2%	2.6%	0.7%	
75 years & over	**n**	10	13	9	5	44	55	61	48	7	4	17	3	276
	%	3.6%	4.7%	3.3%	1.8%	15.9%	19.9%	22.1%	17.4%	2.5%	1.5%	6.2%	1.1%	
Total	**n**	45	86	29	50	288	426	546	599	77	51	45	13	2255

The CPITN results also show that most of the adults aged 50 years and over, had simple periodontal treatment needs and fewer adults required more complex and invasive periodontal treatment (those with deep pockets) (Table 4-16, Table 4-17 and Table 4-18).

Table 4-18: Mean number of sextants affected by different CPITN score (healthy), B (bleeding), C (calculus), P1 (shallow pocket), P2 (deep pocket) and X (missing sextant) among the dentate sample by age group and gender (Base-dentate, n=2255).

Age groups	H		B		C		P1		P2		X	
	M	F	M	F	M	F	M	F	M	F	M	F
50-64 years	1.6	2.2	0.6	0.7	1.4	1.3	1.5	1.2	0.2	0.1	0.7	0.5
65-74 years	1.4	1.9	0.5	0.5	1.4	1.3	1.1	0.8	0.1	0.1	1.5	1.4
75 years and over	1.4	1.7	0.4	0.4	1.1	1.2	0.9	0.8	0.1	0.1	2.2	1.8

4.4.10 Tooth wear

The Bardsley tooth wear index was used in this study to record wear into dentine (Bardsley, 2008). The mouth was divided into six sextants and each sextant was individually scored. The worst affected tooth in a sextant was recorded as the sextant score. Tooth wear was recorded by visual examination. It was recorded as, no wear, dentine exposed <1/3 of the worst surface of a tooth, dentine exposed >1/3 of the worst surface of a tooth and sextant excluded as no teeth present in sextant or unable to record. The severity of tooth wear was calculated by the maximum dentine wear score per person and extent of tooth wear was calculated by the mean number of sextants per person by different dentine wear score among dentate adults (n=2255).

This section will report the proportion of adults by maximum dentine wear score per person and mean number of sextants affected by different dentine wear scores per person by age groups and gender. As can be seen in Table 4-19, among the dentate sample, the highest number of adults in all age groups had dentine exposed on less than one-third of a tooth surface and very few adults had no wear. There was a gradual decrease in tooth wear with age, which is probably a reflection of less retained teeth with age. When gender difference was considered, in all age groups more females were recorded as having no wear. Similarly, more females had wear on less than one-third of a tooth surface in all age groups whereas there was the opposite trend in respect to more severe wear. It is interesting to note that with both categories of dentine wear, females in the oldest age group had less wear than the youngest age group which again is probably a reflection of increased tooth loss in the oldest group females. An opposite trend was seen in males with age. These findings suggest that overall, the worst level of dentine wear was more common in males and mild wear was more common in females.

Table 4-19: Number and percentage of adults with maximum wear score of; no wear, dentine exposed less than 1/3 of worst surface, dentine exposed more than 1/3 of worst surface, X (sextant excluded) by age group and gender (Base-dentate, n=2255).

Age group		**No wear**		**Wear <1/3 of dentine**		**Wear >1/3 of dentine**		**Excluded**		**Total**
50-64 years		**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	
	n	39	81	237	378	217	207	3	8	1170
	%	3.3%	6.9%	20.3%	32.3%	18.5%	17.7%	0.3%	0.7%	
65-74 years	**n**	27	44	162	227	193	149	4	3	809
	%	3.3%	5.4%	20.2%	28.1%	23.9%	18.4%	0.5%	0.4%	
75 years and over	**n**	7	13	66	70	72	45	3	0	276
	%	2.5%	4.7%	23.9%	25.4%	26.1%	16.3%	1.1%	0%	
Total	**n**	73	138	465	675	482	401	10	11	2255

Table 4-20: Mean number of sextants per person affected by different wear scores of; no wear, dentine exposed less than 1/3 of worst surface, dentine exposed more than 1/3 of worst surface, and sextant excluded by age group and gender (Base-dentate, n=2255).

Age group	**No wear**		**Wear <1/3 of dentine**		**Wear >1/3 of dentine**		**Excluded**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
50-64 years	3.7	4.0	1.2	1.2	0.7	0.5	0.4	0.4
65-74 years	3.1	3.3	1.1	1.1	0.9	0.6	1.0	1.1
75 years & over	2.4	2.9	1.0	1.1	0.9	0.6	1.6	1.5

In Table 4-20 the mean number of sextants with no wear was quite high, especially in the youngest age group where the mean for females was 4.0 and 3.7 for males. There were very low mean numbers of sextants affected by more severe wear, it was less than one sextant in all age groups and in both males and females. There was very little gender difference in all categories.

4.5 Oral health status and its relationship with socioeconomic status

In health care systems, there is intense competition for resources and so it is vital to be able to target resources to achieve the maximum benefit and improve equity of outcomes. For this reason, it is important to evaluate the effect of socioeconomic status on oral health. Providing an evidence-base for the identification of adults at risk of poor oral health in relation to socioeconomic status helps the policymakers to prioritise target groups and improves the cost-effectiveness of services. The oral health status of the sample by age and gender has been described in the above section. This section will report the relationship of oral health status with the socioeconomic status of the sample (n= 2504). To evaluate this relationship, three indicators of oral health status; number of teeth, periodontal health (CPITN) and DMFT were used along with four indicators of socioeconomic status; education level, medical card status (possession of medical card has been used as a proxy for poor economic status in Ireland), area of residence and household income. These socioeconomic indicators were recorded in the TILDA self-completed questionnaire (SCQ) and computer-assisted personal interview (CAPI) (Kearney et al., 2011).

Multinomial regression analysis was used to report the relationship between the number of teeth and periodontal health with the chosen socioeconomic indicators. The regression analysis explained how predictors (socioeconomic indicators) could be the risk indicator for oral health (number of teeth and periodontal health) and what type of relationship there was between predictors (socioeconomic indicators) and factor variables (number of teeth and periodontal health). The regression analysis examined the risks of being edentate, having 1-19 teeth and having bleeding/calculus and shallow/deep pockets by different socioeconomic variables. These results can be used to identify the high-risk adults that should be prioritised for dental services. To evaluate the relationship between DMFT and socioeconomic indicators (education, medical card status, area of residence and household income) non-parametric tests of hypothesis were used because the DMFT distribution and its transformations did not fulfil the normality assumptions and DMFT cannot be divided into categories for logistic and multinomial regressions.

4.5.1 Number of teeth and socioeconomic status

To evaluate the relationship between the number of teeth and four socioeconomic variables; education level, possession of the medical card, area of residence and household income (income quantiles, higher quantile had higher income), multinomial regression analysis on the full sample was used (Base-edentate and dentate, n=2504).

As the distribution of the number of teeth and its transformations did not fulfil the normality assumptions, respondents were stratified into three groups by number of teeth; adults with no teeth (n=249, 9.94%), adults with 1-19 teeth (n=895, 35.7%) and those with 20 or more teeth (n=1360, 54.3%) as recommended by WHO and FDI (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004). Table 4-21 reports the descriptive statistics of different independent variables by the number of teeth categories and Chi-square analysis of relationship between each independent variable and categories of the number of teeth.

Table 4-21: Chi-square analysis and percentage of edentate adults, adults with 1-19 teeth, and adults with 20 or more teeth by medical card status, area of residence, education level and household income quantiles (Base-edentate and dentate, n=2504).

Number of teeth	**0 n= 249**	**1-19 n= 895**	**20 or more n= 1360**	**Total number of respondents in each category of socioeconomic variable and number of missing data points for each**
Characteristic	Count	Count	Count	
Medical Card	**n=249**	**n=895**	**n=1360**	Missing n = 0 Total = 2504 P<0.0001
No	4.86	29.89	65.25	
Yes	17.56	44.51	37.92	
Residence	**n=249**	**n=895**	**n=1360**	Missing n = 0, Total = 2504 P<0.0001
Dublin/Co. Dublin	6.91	32.94	60.15	
Other town/county	9.68	34.80	55.52	
Rural	11.87	37.92	50.21	
Education	**n=249**	**n=895**	**n=1359**	Missing n = 1, Total = 2503 P<0.0001
Primary	20.29	47.70	32.01	
Secondary	9.38	38.42	52.20	
Third level/higher	5.67	27.57	66.76	
Income Quantile	**n=203**	**n=753**	**n=1124**	Missing income quantiles n = 424 Total = 2080, P<0.0001
1	14.56	41.53	43.91	
2	13.15	41.95	44.90	
3	8.91	38.17	52.93	
4	6.41	34.55	59.04	
5	5.38	23.85	70.77	

Table 4-22 shows the multinomial regression analysis of number of teeth (factor variable) and socioeconomic variables as predictors (education level, medical card, area of residence and household income). In this multinomial regression, 20 or more teeth were used as the reference (base) category. The results showed that the regression model was statistically significant with P < 0.0001. Education level, possession of medical card and area of residence had a statistically significant relationship with the number of teeth with p<0.05 whereas household income had no statistically significant relationship with the number of teeth p>0.05 (Table 4-22).

Table 4-22: Multinomial regression analysis of relationship between number of teeth and socioeconomic variables (education level, medical card, area of residence and household income quantiles). Base-edentate and dentate, n=2504 (observations =2080 and missing =425).

Predictor Variables (Reference group)	**Factors associated with edentulism (n=203) and 1-19 teeth (n=753) compared to (base) possession of 20 or more teeth (n=1124)**			
	Edentate		**1-19 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Medical card (No medical card)				
Had medical card	4.43 (2.99-6.56)	<0.0001	1.89 (1.52-2.37)	<0.0001
Education (Primary)				
Secondary	0.36 (0.25-0.53)	<0.0001	0.59 (0.45-0.77)	<0.0001
Third level/higher	0.20 (0.13-0.31)	<0.0001	0.39 (0.29-0.51)	<0.0001
Locality (Dublin/Co Dublin)				
Another town/city	1.52 (0.95-2.41)	0.079	1.18 (0.91-1.54)	0.220
Rural area	2.08 (1.37-3.15)	0.001	1.39 (1.20-1.76)	0.007
Income Quantile (Income quantile 1)				
2	0.93 (0.60-1.44)	0.750	1.02 (1.75-1.37)	0.923
3	0.80 (0.49-1.30)	0.365	0.95 (0.70-1.30)	0.751
4	0.89 (0.52-.51)	0.653	0.98 (0.71-1.34)	0.880
5	0.88 (0.48-1.62)	0.689	0.65 (0.46-0.92)	0.015

Missing values; Number of teeth=0, Medical card=0, Education level=1, Area of residence=0, Household income=424. RRR (Relative risk ratio).

Table 4-22 shows that after adjusting for other variables in the model (education, area of residence and household income) the relative risk of being edentate relative to have 20 or more teeth, in respondents with a medical card was increased in comparison with those without medical card possession (RRR= 4.43, 95% CI = 2.98-6.56).

After adjusting for other variables in the model (medical card possession, area of residence and household income) the relative risk of being edentate was expected to decrease in adults having a secondary education (RRR= 0.36, 95% CI= 0.25-0.53) relative to adults having primary education. Similarly, the expected risk of being edentate among respondents having a third level of education was decreased in comparison with those having a primary education (RRR= 0.20, 95% CI = 0.13-0.31). In short, adults having a primary education were at greater risk of being edentate, relative to having 20 or more teeth, as compared to adults having a secondary or third level education.

Table 4-22 also shows that living in rural areas, in comparison to living in Dublin city or county, the relative risk of being edentate (no teeth) relative to have 20 or more teeth, was expected to increase by a factor of 2.08 (RRR= 2.08, 95% CI= 1.37-3.15).

Table 4-22 shows that after adjusting for other variables in the model (education level, area of residence and household income), the relative risk to have 1-19 teeth was expected to increase in adults with medical card (RRR= 1.89, 95% CI= 1.52-2.36), in comparison with those without a medical card.

After adjusting for other variables in the model (medical card possession, household income and area of residence), the relative risk of having 1-19 teeth was expected to decrease in adults with secondary education (RRR= 0.59, 95% CI= 0.45-0.77) compared to the adults with primary education. Similarly, the relative risk of having 1-19 teeth was less in adults with third-level education (RRR= 0.39, 95% CI= 0.29-0.51) compared to adults with primary education.

The relative risk to have 1-19 teeth compared to have 20 or more teeth was higher among the adults living in a rural area (RRR= 1.39, 95% CI= 1.10-1.76) than adults living in Dublin city/Co-Dublin. However, living in another city/town did not have a significant effect on having 1-19 teeth compared to have 20 or more teeth.

4.5.2 Periodontal health and socioeconomic status

Multinomial regression analysis was done to evaluate the relationship of four socioeconomic variables; possession of a medical card, education level, area of residence and household income with periodontal health of the dentate adults (Base-dentate, n=2255). The maximum CPITN score of each respondent was used as a periodontal health indicator. Adults with missing values of CPITN (X) were omitted from the analysis and for multinomial regression three periodontal health categories were made; Healthy (CPITN score 0), bleeding and calculus (CPITN score 1 and 2), periodontal pockets (CPITN score 3 and 4). Table 4-23 shows the proportion of dentate adults in different periodontal health categories.

Table 4-23: Percentage of adults in three categories of CPITN by the maximum CPITN score per person (Base-dentate, n=2252).

CPITN	Healthy (CPITN score =0)	Bleeding and Calculus (CPITN score =1 and 2)	Shallow and deep pockets (CPITN score =3 and 4)	Missing	Total
n	131	793	1273	58	2255
%	5.8%	35.2%	56.5%	2.6%	

Table 4-24 shows the proportion of adults in each periodontal health categories of healthy, bleeding or calculus and shallow or deep pockets (factor variable) by regression model predictor variables (medical card, education level, area of residence and household income), along with total number of respondents and missing respondents in each socioeconomic variable category.

In the multinomial regression analysis shown in Table 4-25, the periodontal health category of “healthy” (CPITN score 0) was used as the reference (Base) category. The results showed that the model was statistically significant with P <0.0001. Possession of a medical card, education level and household income had no statistically significant relationship with periodontal health (p> 0.05), whereas the area of residence did have a statistically significant relationship with periodontal health with p<0.05 (Table 4-25).

Table 4-24: Chi-square analysis and percentage of adults in periodontal health categories of healthy, bleeding/calculus, and shallow/deep pockets by medical card status, area of residence, education level and income quantiles (Base-dentate, n=2255, observations= 2197).

Periodontal health categories	**Healthy**	**Bleeding& Calculus**	**Shallow & deep Pockets**	**Total n=2197**
Characteristic	**Count**	**Count**	**Count**	
Medical Card	**n=131**	**n=793**	**n=1273**	**Total n=2197**
No	6.34	35.61	58.05	**Missing n=58**
Yes	5.30	36.95	57.76	**P>0.05**
Residence	**n=131**	**n=793**	**n=1273**	**Total n=2197 Missing n=58**
Dublin city/county	8.59	44.89	46.52	**p<0.0001**
Another town/city	4.48	33.73	61.79	
Rural	5.21	32.03	62.76	
Education	**n=131**	**n=793**	**n=1273**	**Total n=2197**
Primary	5.21	38.36	56.44	**Missing n=58**
Secondary	5.86	34.84	59.30	**P>0.05**
Third level/higher	6.35	36.40	57.25	
Income Quantile	**n=106**	**n=666**	**n=1056**	**Total n=1828 Missing n=427**
1	3.13	32.60	64.26	**P=0.012**
2	9.45	35.64	54.91	
3	4.51	38.20	57.29	
4	7.37	35.49	57.14	
5	4.89	39.36	55.75	

Table 4-25 shows that medical card possession, education level, area of residence and household income did not have a statistically significant effect on calculus/ bleeding. It also shows that after adjusting for other variables in the model (medical card possession, education level and income level), the expected risk for respondents living in another town/city to have shallow or deep pockets was higher in comparison with those living in Dublin/Co-Dublin (RRR= 2.59, 95% CI= 1.48-4.55). Similarly, after adjusting for other variables in model (medical card possession, education level and income level), the expected risk for respondents living in rural areas of having shallow or deep pockets, was higher compared to those living in Dublin/Co-Dublin (RRR= 2.13, 95% CI =1.36-3.34).

Table 4-25: Multinomial regression of relationship between periodontal health and socioeconomic variables (education level, medical card, area of residence and household income quantiles) (Base-dentate, n=2255, observations=1828, missing=427).

Predictor Variables (Reference group)	**Factors associated with bleeding &calculus (n = 666) and shallow& deep pockets (n = 1056) compared to (base) healthy (n= 106)**			
	Bleeding & calculus		**Shallow & deep pockets**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Medical card (No medical card)				
Had medical card	1.15 (0.70-1.88)	0.585	1.05 (0.65-1.70)	0.838
Education (Primary)				
Secondary	0.73 (0.38-1.41)	0.345	0.91 (0.48-1.75)	0.782
Third level/higher	0.63 (0.33-1.23)	0.177	0.73 (0.38-1.40)	0.346
Locality (Dublin/Co-Dublin)				
Another town/city	1.62 (0.91-2.86)	0.100	2.59 (1.48-4.55)	0.001
Rural area	1.14 (0.72-1.80)	0.591	2.13 (1.36-3.34)	0.001
Income Quantile (Income quantile 1)				
2	0.64 (0.32-1.29)	0.213	0.47 (0.24-0.94)	0.340
3	0.82 (0.39-1.72)	0.602	0.69 (0.34-1.43)	0.321
4	0.64 (0.31-1.30)	0.217	0.47 (0.23-0.94)	0.320
5	1.35 (0.60-3.03)	0.469	0.94 (0.42-2.07)	0.870

Missing values; CPITN=58, Medical card=0, Education level=1, Area of residence=0, Household income=378. RRR (relative risk ratio).

In short, this regression analysis showed that the adults living in another town or city and in rural areas were expected to have more periodontal pockets than adults living in Dublin/Co-Dublin. However, education, medical card possession and household income had no statistically significant relationship with shallow or deep pockets.

4.5.3 DMFT and socioeconomic status

To evaluate the relationship of DMFT with socioeconomic variables, DMFT was calculated by the WHO recommended method. Linear regression was carried out to find the relationship of DMFT with four socioeconomic variables; medical card possession, education, area of residence and household income quantiles, keeping DMFT as the independent variable (factor variable) and four socioeconomic variables as predictors, but the model fit was poor R=0.0450 and DMFT did not fulfil the normality assumption. DMFT variable transformations were also tried but it did not enhance the model fit and did not fulfil the normality assumption. As data for DMFT did not fulfil normality assumptions, so any parametric tests such as t-test, ANOVA and linear regression were not possible for checking the relationship of DMFT with selected socioeconomic variables (t-test was also not possible as socioeconomic variables were categorical variables). Then non-parametric tests were done to see if either DMFT values were the same or different for different categories of each socioeconomic variable.

4.5.3.1 DMFT and medical card possession

Medical card variable had two categories not possessing/possessing a medical card, so the Wilcoxon rank-sum test of hypothesis was run to check the difference in DMFT between two groups of respondents not possessing and possessing a medical card. The null hypothesis was both groups of adults, without and with a medical card were similar in relation to DMFT value. The results are as follows.

Table 4-26: Wilcoxon rank-sum test for DMFT and medical card possession (Base-edentate and dentate, n=2504, observations 2503, missing=1), p<0.0001.

Medical card	Observations	Rank Sum	Expected
No	1501	1667973	1879252
Yes	1002	1465783	1254504
Combined	2503	3133756	3133756

Table 4-26 shows the p-value was less than 0.0001, so the null hypothesis was rejected, and a statistically significant difference was present in DMFT score between the two groups of respondents, non-medical card holders and medical card holders.

Table 4-27 shows that mean and median DMFT for two groups of respondents was different and non-medical card holders had lower mean and median DMFT than medical card holders.

Table 4-27: Comparison of the mean, median and standard deviation of DMFT between non-medical card holders and medical card holders (Base-edentate and dentate, n=2504, observations 2503, missing=1).

Medical card Groups	Sample size	SD	Mean	Median
No medical card	1501	5.794537	21.1	21
Had medical card	1002	6.078204	24.1	24

4.5.3.2 DMFT and education

Education had three categories; primary, secondary and third/higher level. To check the distribution of DMFT for three groups of respondents according to education level, a one-sample Kruskal-Wallis test (non-parametric test) of hypothesis was carried out. The null hypothesis was that the distribution of DMFT scores was similar between the three groups of respondents by their education level. The results indicated that the P value was 0.0001 and so the null hypothesis was rejected and the DMFT scores was statistically significant different for the three groups of respondents according to their education level Table 4-28.

Table 4-28: Kruskal-Wallis test for DMFT and education (Base-edentate and dentate, n=2504, observations 2503, missing=1), P=0.0001.

Education	Observations	Rank Sum
Primary	478	722765.00
Secondary	1002	1.25e+06
Third/higher level	1023	1.16e+06

Table 4-29 shows that mean and median DMFT for respondents with the different levels of education was different, with the lowest mean DMFT score for respondents with third-level education.

Table 4-29: Comparison of the mean, median and standard deviation of DMFT by education level (Base-edentate and dentate, n=2504, observations 2503, missing=1).

Education	Sample size	Mean	SD	Median
Primary/no	478	24.5	6.089667	25
Secondary	1002	22.3	6.000084	22
Third/higher level	1023	21.3	5.905396	21

4.5.3.3 DMFT and area of residence

There were three categories for area of residence; Dublin city or county, another city or county and rural area. To check the distribution of DMFT for these three groups of respondents by their area of residence, a one-sample Kruskal-Wallis test (non-parametric test) of hypothesis was carried out. The null hypothesis was that the distribution of DMFT score between three groups of respondents was the same by their area of residence. Table 4-30 shows that P-value was 0.0907, so the null hypothesis was accepted and the distribution of DMFT score was not statistically significantly different for the three groups of respondents according to their area of residence.

Table 4-30: Kruskal-Wallis test for DMFT and area of residence (Base-edentate and dentate, n=2504), p=0907.

Area of residence	Observations	Rank Sum
Dublin city/county	680	824885.00
Another town/city	661	816614.50
Rural area	1163	1.49e+06

Table 4-31 shows that although the difference of DMFT score was not statistically significant among respondents by their area of residence, but respondents living in rural areas had a slightly higher mean and median DMFT score than respondents living in Dublin city or county and another town or city.

Table 4-31: Comparison of mean, median and standard deviation of DMFT by area of residence (Base-edentate and dentate, n=2504).

Locality	Sample size	Mean	SD	Median
Dublin city/county	680	22.0	5.921330	22
Another town/ city	661	22.1	6.196438	23
Rural area	1163	22.6	6.105863	23

4.5.3.4 DMFT and household income

Respondents were categorised into five quantiles by their household income (1^{st}quantile is the lowest income group and 5^{th} quantile the highest income group). To check the distribution of DMFT for the five quantiles of respondents by their income, a one-sample Kruskal- Wallis test (non-parametric test) of hypothesis was carried out. The null hypothesis was that the distribution of DMFT score was the same for five quantiles of respondents by their household income. Table 4-32 reports that P value was equal to 0.0001, so the null hypothesis was rejected and the difference in the distribution of DMFT scores was statistically significant for five quantiles of respondents by their household income.

Table 4-32: Kruskal-Wallis test for DMFT and household income quantiles (Base-edentate and dentate, n=2504, observations 2080, missing=424), p=0.0001.

Income quantiles	Observations	Rank Sum
1	419	474069.50
2	441	498440.00
3	393	416932.50
4	437	428374.50
5	390	346423.50

Table 4-33 below shows the mean and median DMFT for respondents by different levels of income. It shows that the mean DMFT score decreased with increase in income quantile. Respondents with the highest income level (5-quantile) had a lower mean DMFT score than respondents with the lowest income level (1-quantile).

Table 4-33: Comparison of mean, median and standard deviation of DMFT by 5-quantiles of household income (Base-edentate and dentate, n-2504, missing = 424).

Income quantiles	Sample size	Mean	SD	Median
1	419	23.3	6.089638	23
2	441	23.3	5.914627	23
3	393	22.6	5.989336	23
4	437	21.7	6.021406	22
5	390	20.8	5.8578	21

The non-parametric tests of hypothesis indicated that the difference in DMFT scores was statistically significant for different groups of respondents by medical card possession, education level and household income. However, DMFT was not statistically significantly different for groups of respondents by area of residence. The respondents with poor socioeconomic status (medical card possession, lower education and lower income levels) had a higher DMFT score than respondents with good socioeconomic status (no medical card possession, high education and higher income levels).

4.6 Conclusions from oral health status results and the relationship between oral health status and socioeconomic status

These findings suggest that oral health status deteriorated with age among community-dwelling adults aged 50 years and over in Ireland. This was due to fewer retained teeth, higher prevalence of edentulism, higher mean DMFT and higher RCI with age. Increase in tooth loss with age was reflected in a decrease in shallow and deep pockets along with no increase in tooth wear and increased use of complete and partial dentures with age. More females were edentate than males, but dentate females had slightly better oral health than males with more tooth contacts, better periodontal health and less tooth wear than males. Poor socioeconomic status (lower income level, lower level of education, having a medical card) and living away from Dublin/Co-Dublin had a negative effect on the mean number of teeth. Lower income level, lower level of education and having medical card also had a negative effect on mean DMFT but area of residence did not affect mean DMFT. However, among other socioeconomic variables only living away from Dublin or Co- Dublin had negative affect periodontal health.

These oral health status findings also reported that treatment need was more for restorative treatments in adults. Treatment needs increased with age and males had a higher need for treatment than females. Although the females in older age groups had slightly fewer retained teeth than males, but they had better oral health in terms of coronal and root caries, periodontal health and tooth wear. Adults with poor socioeconomic status and living away from Dublin or Co-Dublin required more restorative treatments. This finding suggests that these groups should be prioritised in oral health policy in Ireland.

4.7 Discussion of the oral health status results

This section includes the discussion of the comparison between OHA sample and TILDA cohort and national and international comparisons of different oral health indicators.

4.7.1 Comparison of the OHA sample with TILDA Wave 3 cohort (population sample)

It is important to mention that the sample of participants recruited for the oral health assessment (OHA) may not be a fully nationally representative sample as it differs from the TILDA Wave 3 (population) sample in certain aspects as reported in Table 4-1. The OHA sample had a similar proportion of males and females (p= 0.7786) and adults with no health insurance or a medical card (p=0.3681) as compared with TILDA Wave 3 sample. The OHA group had more adults in the younger age group than the TILDA Wave 3 sample. In education level there was no difference between the two samples in the proportion of adults those had a maximum of second-level education (p= 0.5805) but the oral health assessment (OHA) sample had significantly more adults with tertiary/higher education as a maximum (P< 0.001) and fewer with primary education as compared to TILDA Wave 3 sample.

In terms of residence, the OHA sample had significantly more people from Dublin, but similar proportions of other urban and non-urban dwellers and of those who grew up in a rural area. With regard to self-reported health, there was no difference between the OHA group and the TILDA group in those who reported their health as ‘Good’ (p=0.8001), however, the OHA group had a higher proportion reporting their health as ‘Excellent’ (p=0.0294) and ‘Very good’, (p=0.0069) (Table 4-1).

Nonetheless, the two population samples are the same in the key areas of gender, medical card status, urban-rural dwelling and their self-reported health status as ‘Good’. As the OHA sample size is large and there were small differences in baseline characteristics between the OHA sample and TILDA cohort, these may not be clinically significant. These oral health findings can give valuable insight into trends in the oral health status of adults aged 50 years and over in Ireland, though they may represent a slightly more favourable picture of this age group.

4.7.2 National comparisons of oral health status

From a policy point of view, it is valuable to measure the changes over time in the oral health status of adults in Ireland. There have been two national oral health surveys of adults in Ireland; in 1989-90 and 2000-02. As described in Chapter 3 (Methods), the WHO recommended methods and examination criteria, similar to previous Irish oral health surveys were used for the oral health assessments in this study. In the previous national surveys, the oldest age group of adults was of those aged 65 years and over, so this age group from this research (n=1286) was selected for the national comparisons. While the differences between the OHA and TILDA as described above need to be kept in mind when examining the comparisons below, it is also worth noting that there were only 714 people in this age group examined in the whole country in the 2000-02 national survey while the figure for 1989-90 was only 242 (O'Mullane and Whelton, 1992, Whelton et al., 2007).

4.7.2.1 Edentulism and denture wearing

Table 4-34 indicates that in Ireland, among adults aged 65 years and over, there has been a decrease of 32.4% in the prevalence of edentulism from 1989-90 to 2014-15 and 25.3% of that decrease occurred between 2000-02 and 2014-15.

Table 4-34: Changes in edentulism, among adults aged 65 years and over in Ireland from 1989-90 to 2014-15 by gender (Base-edentate and dentate).

Edentulism	Examination Years	Male	Female	Total
% Edentate	**2014-15**	12.3%	18.6%	15.6%
	2000-02	34.6%	45.6%	40.9%
	1989-90	33.0%	61.0%	48.0%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 4-34 shows from 1989-90 to 2014-15, among adults aged 65 years and over, the gender difference in edentulism has dramatically reduced in Ireland. In 1989-90, 28% more females were edentate than males, whereas the figure was 6.3% in 2014-15. When the changes over time in edentulism were considered separately for males and females, the percentage edentate is 2.7 times lower among males, while it is 3.3 times lower among females, from 1989-90 to 2014-15. This reduction in gender difference over time shows that the very sizeable discrepancy in oral health between males and females, that was very obvious in 1989-90, has reduced over this time period.

Table 4-35: Percentage denture wearing among adults aged 65 years and over, by type of denture and year of examination in Ireland (Base-edentate and dentate).

Examination Years	Type of denture					Total
	No upper or lower denture	Complete upper and lower dentures	Complete upper and part lower dentures	Complete upper only	All other combinations of complete and partial dentures	
2014-15	38.3%	14.5%	5.8%	8.4%	33.0%	1286
2000-02	26.0%	31.0%	5.4%	12.8%	24.7%	714
1989-90	42.6%	29.8%	4.6%	12.0%	11.2%	242

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 4-35 reports the changes from 1989-90 to 2014-15 in the percentages of people wearing dentures by type of dentures, among adults 65 years and over. Overall the percentage of adults not wearing any dentures decreased (42.6% to 38.3%) from 1989-90 to 2014-15 but this decrease was higher from 1989-90 to 2000-02 (42.6% to 26%) than from 1989-90 to 2014-15 (42.6% to 38.3%).

When Table 4-34 and 4-35 are compared, it should be noted that among the edentate group aged 65 years and older, 18.2% in 1989-90 and 9.9% in 2000-02 did not have complete dentures. This figure was just 1.1% for the same group in 2014-15. The 1989-90 figure probably reflected the lack of access to state-funded dental care in this age group. In 1994 a national dental scheme for medical card holders was phased in, with priority being given to the provision of complete dentures for those aged 65 years and older, which is likely to have made a considerable contribution to addressing this issue. From 2000-02 to 2014-15 there was an increase in adults who did not wear any type of denture (26.0% to 38.3%) which probably reflects improved tooth retention in adults aged 65 years and over during this time period. From 1989-90 to 2014-15, the proportion of adults with complete dentures for both upper and lower arches decreased by 15.3% (29.8% vs 14.5%) and denture combinations of partial upper, partial lower and complete lower dentures (P/P, P/, /P, P/C) increased (11.2% to 33.0%). These results suggest improved tooth retention among adults aged 65 years and over and increased usage of partial dentures compared with complete dentures over this time period. The changes in the proportion of edentate adults, reported in Table 4-34 support this trend. These trends in denture wearing suggest better access to dental care among this age group.

4.7.2.2 Number of teeth, 18 or more SUNT and 21 or more teeth

Table 4-36 shows that there has been a doubling in the mean number of teeth in adults aged 65 years and over from 1989-90 to 2014-15 (7.3 to 14.6) which indicates a very positive trend in oral health status in Ireland.

Table 4-36: Mean number of teeth per person among adults aged 65 years and over, in Ireland by gender and year of examination (Base-edentate and dentate).

Mean number of teeth	Examination Year	Male	Female	Total
	2014-15	14.9	14.2	14.6
	2000-02	9.9	7.4	8.5
	1989-90	10.1	4.9	7.3

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

This increase in mean number of teeth is greater between 2000-02 to 2014-15 (8.5 to 14.6) than between 1989-90 to 2000-02 (7.3 to 8.5). This trend of tooth retention in females is particularly positive where the mean number of teeth increased from 7.4 to 14.2 between 2000-02 and 2014-15. Gender difference in relation to the mean number of teeth has also reduced considerably in Ireland from 1989-90 to 2014-15 (5.2 to 0.7). Although mean number of teeth is a crude measure of oral health status, as it gives no indication of the condition of these teeth, it is nonetheless a very positive trend.

Table 4-37: Percentage adults aged 65 years and over, with 18 or more SUNT teeth by gender and year of examination in Ireland (Base-edentate and dentate).

Examination Years	% of adults with ≥ 18 SUNT		Total
	Male	Female	
2014-15	7.1%	3.0%	4.9%
2000-02	5.6%	1.6%	3.3%
1989-90	4.5%	0.0%	2.1%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 4-37 shows there has been an increase in the percentage of adults with 18 or more sound, untreated, natural teeth (SUNT) among adults aged 65 years and over. This increase was more than double from 1989-90 to 2014-15 (2.1% vs 4.9%) which is a positive trend.

Table 4-38 shows that the proportion of adults with 21 or more teeth tripled from 1989-90 to 2014-15 in Ireland among adults aged 65 years and over (10.7% to 33.2%). These changes are comparable with the changes reported in Table 4-36 about mean number of teeth.

Table 4-38: Percentage adults aged 65 years and over, with 21 and more teeth by gender and year of examination in Ireland (Base-edentate and dentate).

Examination Year	% of adults with ≥ 21 natural teeth		Total
	Male	Female	
2014-15	33.3%	33.1%	33.2%
2000-02	20.8%	13.5%	16.7%
1989-90	15.3%	6.9%	10.7%

(O'Mullane and Whelton, 1992, Whelton et al., 2007)

Table 4-38 also shows that over time the gender difference in relation to the possession of 21 or more teeth has also reduced in Ireland. For example, in 1989-90 the difference between males and females was more than double (15.3% vs 6.9%) but this gender difference had disappeared in 2014-15 (33.3% vs 33.1%).

4.7.2.3 Dental caries

As dental caries is one of the two most common diseases in the oral cavity, reporting its prevalence is vital in any research on oral health status. In adults, caries prevalence is typically reported as mean DMFT and the components of the mean DMFT as a proportion of the whole, which provides a useful insight into treatment need and patterns of treatment. The 'D' component, indicates untreated caries (unmet need), a higher 'M' than 'F' component indicates a low restorative index, which may suggest a need for a policy change.

The WHO recommends that in oral health surveys, caries is diagnosed at cavitation level which is quite an advanced stage, whereas the British Association of Community Dentistry (BASCD) has recommended criteria for the diagnosis of visual caries (DMFT-v) (Pitts et al., 1997, World Health Organization, 2013). These additional criteria allow for the recording of carious lesions requiring treatment that would otherwise be ignored using WHO criteria. This study used both the WHO and the BASCD criteria to diagnose caries. The WHO manual, Oral Health Surveys Basic Methods 5th Edition recommends that among adults aged over 30 years, teeth missing for all reasons (caries, periodontal disease and other reasons) are included in the 'M' component of DMFT. The rationale for this approach was probably the difficulty in being certain about the reasons for tooth loss in older age groups. While it may still be difficult to ascertain the reasons for tooth loss especially where most teeth are missing and especially in edentate people. However, with increased retention of natural teeth, many older adults can be sure about the reasons for missing teeth. So, in these cases, the WHO method provides an overestimation of the 'M' component of DMFT.

For this reason, the maximum DMFT score for edentate adults by the TILDA method of DMFT calculation was 28 but for dentate adults, it is 32. Using the WHO method, the maximum DMFT score for both edentate and dentate people was 32 (World Health Organization, 2013). During data analysis, it was decided to calculate DMFT by both methods and compare them, in both the edentate and dentate group, and the dentate group only. This section reports the comparison of the two different methods for the calculation of mean DMFT. This section also compares the mean DMFT at cavitation and visual levels (DMFT-c and DMFT-v) and root caries with the previous Irish oral health surveys.

Table 4-39 shows, the mean DMFT among different age groups by the WHO method and the TILDA method. With increasing age among the full sample, the DMFT increased among both edentate and dentate and dentate groups by both methods. This increase in mean DMFT with age was greater in the WHO method than the TILDA method, representing the inclusion of teeth missing for reasons other than caries in the 'M' component. For example, in the edentate and dentate group from those aged 50-64 years to 65-74 years (20.1 vs 23.7), mean DMFT increased 3.6 using the WHO method whereas it was 2.8 by the TILDA method (16.7 vs 19.5).

Another debatable issue in the calculation of DMFT is whether it should be calculated among dentate sample only. As per the WHO recommendation, DMFT should be calculated among the whole (edentate and dentate) sample. Some recent national surveys have reported DMFT among different samples, for example in the Australian and New Zealand oral health surveys DMFT was reported among dentate sample only. Whereas in the Irish oral health surveys mean DMFT was reported among the full samples (edentate and dentate) (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010). It should be noted that in the UK adult survey 2009, mean DMFT was not reported in any of the publications containing the results. In relation to caries, the percentages of adults with one or more decayed tooth and the mean number of restored and otherwise sound teeth were reported (White et al., 2012). Reporting mean DMFT in a standardised manner is very valuable to determine the trend in caries prevalence, which clearly from an oral health policy viewpoint is very important. While reporting percentages of adults with one or more decayed tooth may be useful for planning treatment services it does not give an indication of whether in the population there has been an increase in the level of caries.

Table 4-39: Mean DMFT among adults 50 years and over by WHO method and TILDA oral health method of missing teeth calculation (Base-edentate and dentate, n=2504 and dentate, n= 2255).

Age group	**DMFT**			
	WHO method		**TILDA method**	
	Edentate and dentate (n=2504)	**Dentate (n-2255)**	**Edentate and dentate (n=2504)**	**Dentate (n=2255)**
50-64 years	20.1	19.6	16.7	16.5
65-74 years	23.7	22.5	19.5	19.1
75 years and over	26.2	24.2	21.6	20.5
Total	22.3	21.2	18.5	17.9

These changes in how dental caries has been reported in various national adult surveys suggests that the traditional reporting of mean DMFT in older age groups is no longer a useful statistic, at least in part due to the effect of counting teeth missing for all reasons in the M component of adult populations especially with falling levels of edentulism and increasing levels of tooth retention.

Arising from the above variations in reporting mean DMFT, it was decided to calculate mean DMFT among the whole sample and among the dentate adults only (Table 4-39). It can be seen that the difference in the mean DMFT between the whole sample and the dentate adults (0.6) is lower in the TILDA method than the WHO method (1.1), probably in the main due to the exclusion from the calculation of third molars in the edentate group. Although in this sample the proportion of edentate adults was low (9.9%), but in samples with higher numbers of edentate adults, this difference of DMFT among the whole sample and the dentate sample would increase further. In all tables of national and international comparisons of this section, the reported mean DMFT is by WHO methods ('M' includes missing due to any reason not only because of caries).

In Ireland, the changes over time in DMFT-c and DMFT-v are reported in Table 4-40. It shows the decrease in the mean DMFT-c from 1989-90 to 2014-15 for those aged 65 years and older (27.3 vs 24.4). In the same period, there was an increase of 6.1 in the mean number of teeth per person from 2000-02 to 2014-15 compared with an increase of 1.2, from 1989-90 to 2000-02 (Table 4-36).

Table 4-40: Mean DMFT at cavitation and at visual caries level among adults aged 65 years and over in Ireland by gender and year of examination (Base-edentate and dentate).

	Examination Years	**Male**	**Female**	**Total**
Mean DMFT-c	**2014-15**	23.9	24.8	24.4
	2000-02	24.8	27.0	25.9
	1989-90	25.6	28.8	27.3
Mean DMFT-v	**2014-15**	23.9	24.9	24.5
	2000-02	24.8	27.0	26.0

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

When Table 4-36 and Table 4-40 are compared, it can be seen that from 1989-90 to 2014-15, the decrease in mean DMFT-c (2.9) was less than the increase in the mean number of teeth (7.3). This represents an increase in the 'F' and a decrease in the 'M' component, among adults aged 65 years and over in Ireland. Table 4-40 also reports that mean DMFT- v also decreased (26.0 to 24.5) from 2000-02 to 2014-15. Interestingly the difference between DMFT-c and DMFT-v in 2000-02 and in 2014-15 was same at 0.1. So visual caries prevalence did not change among adults aged 65 years and over in Ireland from 2000-02 to 2014-15, although the mean number of teeth per person increased by 6.1 from 2000-02 to 2014-15 (Table 4-36 and Table 4-40).

In Ireland, the changes over time in DMFT components are reported in Table 4-41. It shows from 1989-90 to 2014-15 among adults aged 65 years and over, the mean number of decayed teeth decreased by more than half (1.1 to 0.5), the mean missing teeth also decreased (24.6 to 17.4) and mean filled teeth increased (1.6 to 6.5), these comparisons were made with the same method of calculating the mean DMFT. As a proportion of the mean DMFT, the F component increased from 6.0% in 1989-90 to 26.6% in 2014-15 and similarly the M component fell from 90.0% in 1989-90 to 71.3% in 2014-15.

Table 4-41: Mean DMFT and % components of DMFT among adults aged 65 years and over, in Ireland by year of examination (Base-edentate and dentate).

Examination Years	Mean decayed Teeth		Mean missing Teeth		Mean filled teeth		Mean DMFT
	Mean	**% of DMFT**	**Mean**	**% of DMFT**	**Mean**	**% of DMFT**	
2014-15	0.5	2.0%	17.4	71.3%	6.5	26.6%	24.4
2000-02	0.5	1.9%	22.8	88.0%	2.6	10.0%	25.9
1989-90	1.1	4.0%	24.6	90.0%	1.6	6.0%	27.3

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

4.7.2.4 Root Caries Index

Table 4-42 shows that in Ireland among adults aged 65 years and over, the root caries index has reduced by more than half from 1989-90 to 2014-15 (18.5 vs 9.1). This is very positive and an interesting finding, as it had been thought that the prevalence of root caries in older people might increase with increased retention of natural teeth. As teeth tend to lose periodontal attachment with age, the exposed root surfaces are vulnerable to root caries. In addition, many older people require long term medication for chronic conditions such as hypertension, and many of these cause oral dryness which especially increases the risk of root caries.

Table 4-42: Mean exposed roots, mean decayed roots and RCI among adults aged 65 years and over in Ireland by year of examination (Base-dentate).

Examination Years	Mean exposed roots	Mean decayed roots	Root caries index (RCI)		
			Male	**Female**	**Total**
2014-15	10.7	1.0	9.1	9.1	9.1
2000-02	8.4	0.9	12.7	10.6	11.6
1989-90	8.0	1.4	20.9	14.9	18.5

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

Table 4-42 also shows that the gender difference in RCI had disappeared in 2014-15, which was reduced from 6.0 in 1989-90 to 2.1 in 2000-02. This decrease in gender difference of RCI corresponds with the higher increase in mean number of teeth among females than males from 1989-90 to 2014-15 in Ireland (see Table 4-36).

Table 4-42 also shows that from 2000-02 to 2014-15, although there was an increase in the mean exposed roots (8.4 to 10.7), the mean decayed roots remained almost the same (0.9-1.0). This suggests that the concern about an increase in root caries with increased retention of natural teeth has not materialised in adults aged 65 years and over in Ireland. These are very positive trends in both coronal and root caries, especially the low proportion in untreated coronal caries and the lower levels of root caries.

4.7.2.5 Periodontal health

The changes over time in the severity of periodontal disease are reported by the proportion of adults by maximum CPITN score from 2000-02 to 2014-15 in Table 4-43. It shows that from 2000-02 to 2014-15 the proportion of adults aged 65 years and over, with the maximum CPITN score of healthy has slightly reduced. There has been an increase in the proportion with bleeding, calculus and shallow pockets but a reduction in deep pockets. It is also important to note the fall in the number of excluded sextants (X) which indicates that more sextants had the minimum number of teeth for the CPITN examination to be carried out. The increase in the proportion with calculus and shallow pockets probably also reflects increased tooth retention.

Table 4-43: Changes over time in percentage of adults with maximum value of CPITN score (severity) of H (healthy), B (bleeding), C (calculus), P1 (shallow pocket), P2 (Deep pocket) and X (missing sextant) among dentate adults 65 years and over, in Ireland (Base-dentate).

Year of Examination	H	B	C	P1	P2	X	Total
2014-15	6.6%	4.0%	35.1%	46.4%	4.7%	4.3%	1085
2000-02	6.9%	3.6%	29.5%	37.6%	12.0%	10.1%	390

(Whelton et al., 2007)

The extent of periodontal disease is reported as the mean number of sextants affected by the different CPITN scores as shown in Table 4-44. It shows that the pattern of periodontal health status in adults aged 65 years and over, in Ireland has remained quite similar between 2000-02 and 2014-15, even though retention of natural teeth has improved considerably during that time. Periodontal disease was neither severe nor extensive and treatment needs were not complex.

Table 4-44: Mean number of sextants per person affected by different CPITN scores; (healthy), B (bleeding), C (calculus), P1 (shallow pocket), P2 (Deep pocket) and X (missing sextant) among dentate adults aged 65 years and over, by year of examination (Base-dentate).

Year of examination	H	B	C	P1	P2	X
2014-15	1.6	0.5	1.3	0.9	0.1	1.6
2000-02	0.8	0.2	1.0	1.1	0.2	2.7

(Whelton et al., 2007)

In summary, these national comparisons show that over the time period examined, there have been positive changes in the oral health of older adults in Ireland and these changes have been greater between 2000-02 to 2014-15 than 1989-90 to 2000-02, reflecting the positive influence of oral health policies in the previous years, in Ireland. These findings also suggest that the oral health care needs of older people in Ireland were for simple periodontal and restorative care, with less need for complete dentures and invasive periodontal treatment.

This study also found a low level of untreated coronal and root caries, and mostly mild periodontal disease, which suggests that community-dwelling older adults can maintain their oral health with simple supports. The challenge will be to provide adequate care for the growing number of frail older people who, in the future, will have a far greater number of natural teeth and will require support and care in their own homes or nursing homes.

4.7.3 International comparisons

In this section the oral health status of adults in Ireland is compared with similar studies from other countries, taking into consideration that sample selection criteria, the age groups and year of study may vary with each study. International comparisons of edentulism, mean teeth and mean DMFT are made with the TILDA oral health assessment (OHA) findings.

4.7.3.1 Edentulism

Table 4-45 reports comparisons of edentulism by age groups in different countries. It shows the similar trends in edentulism with age in different countries although the age groups and year of study were somewhat different in the studies. Interestingly the TILDA oral health assessment sample in 2014-15 had a similar prevalence of edentulism when compared with the USA National Health and Nutrition Examination Survey in 2012, for the group aged 65-74 years (11.7% vs 13%) and for the age group 75 years and over (25.4% vs 25.8%). For those aged 65-74 years, the TILDA oral health assessment sample (11.7% in 2014-15) and the UK (15.0% in 2009) were similar given the time difference between when these studies were carried out. It is interesting to compare the

UK and New Zealand, where both studies took place in 2009. New Zealand had much higher levels of edentulism in those aged 55-64 years (14.5% vs 5%) and in those aged 65-74 years (29.6% vs 15%) compared with the UK in the same year.

Table 4-45: Percentage edentate by age group, country and examination year.

Country	Year of Examination	Age group	% Edentate
Ireland	**2014-15 TILDA oral health sample**	**50-64 years**	3.9 %
		65-74 years	11.7 %
		75 years and over	25.4 %
UK	**2009**	**55-64 years**	5.0 %
		65-74 years	15.0 %
		75-84 years	30.0 %
		85 years and over	47.0 %
USA	**2012**	**65-74 years**	13.0 %
		75 years and over	25.8 %
Australia	**2006**	**55-74 years**	13.9 %
		75 years and over	35.7 %
New Zealand	**2009**	**55-65 years**	14.5 %
		65-74 years	29.6 %
		75 years and over	39.6 %

(Haisman et al., 2010, Dye et al., 2015, Fuller et al., 2011, Slade et al., 2007)

4.7.3.2 Mean number of teeth

Table 4-46 reports the comparison of the mean number of teeth per person by age groups in different countries. It shows that in 2014-15, for those aged 65-74 years and 75 years and over, the TILDA oral health sample had a lower mean number of teeth as compared to the UK, New Zealand and Australia despite the fact the studies in these countries were carried out 5-10 years before the TILDA study. One possible reason is that UK, New Zealand and Australia reported the mean number of teeth among dentate sample only, but when the TILDA figure was re-calculated based on the dentate sample only, there was only a small increase in mean number of teeth from 15.8 to 17.9, among OHA sample of age 50 years and over. Adults aged 65-74 years in New Zealand had a lower mean number of teeth as compared to adults of same age groups in Australia and UK, although the Australian survey was done 3 years before New Zealand whereas the New Zealand and UK studies were carried out in the same year. But dentate adults aged 65-74 years in New Zealand in 2009 (19.7) had a higher mean number of teeth than TILDA OHA sample (17.9) in 2014-15 (Table 4-46).

*Table 4-46: Mean number of teeth per person by age group, country and examination year (*Dentate sample).*

Country	Year of Examination	Age group	Mean number of teeth	
			Whole sample	Dentate only
Ireland	**2014-15 TILDA oral health sample**	**50-64 years**	21.3	22.2
		65-74 years	15.8	17.9
		75 years and over	11.5	15.4
UK*	**2009**	**55-64 years**		23.2
		65-74 years		20.9
		75-84 years	N/A	17.1
		85 years and over		14.0
Canada (CHMS)	**2007-09**	**40-59 years**	24.1	
		60-79 years	19.4	N/A
New Zealand*	**2009**	**55-65 years**		24.0
		65-74 years	N/A	19.7
		75 years and over		18.1
Australia*	**2004-06**	**65-74 years**		21.8
		75 years and over	N/A	17.9

(Slade et al., 2007, Health Canada, 2010, Haisman et al., 2010, O'Sullivan et al., 2011)

4.7.3.3 Dental caries

Comparison of the mean DMFT among TILDA oral health sample with other countries studies, is as follows in Table 4-47.

*Table 4-47: Mean DMFT by age group, country and examination year (*Dentate sample).*

Country	Years of examination	Age group	Mean DMFT	
			Whole sample	Dentate only
Ireland	**2014-15 TILDA oral health sample**	**50-64 years**	20.1	19.6
		65-74 years	23.6	22.5
		75 years and over	26.2	24.2
New Zealand*	**2009**	**55-64 years**		21.7
		65-74 years	N/A	24.2
		75 years and over		24.8
Australia*	**2004-06**	**55-64 years**		21.7
		65-74 years	N/A	23.2
		75 years and over		24.6

(Slade et al., 2007, Haisman et al., 2010)

It suggests that among dentate adults, for those aged 65-74 years, the TILDA oral health sample (2014-15) had a lower mean DMFT as compared to Australia (2004-06) and New Zealand (2009). But for dentate adults aged 75 years and over, the TILDA oral health assessment sample (2014-15) had nearly similar mean DMFT to Australia and New Zealand. When these findings are compared with Table 4-46, it can be stated that for age group 75 years and over, TILDA oral health sample had similar mean DMFT along with a lower mean number of teeth than Australia and New Zealand. It would be reasonable to expect that the mean DMFT values in Australia and New Zealand, will have fallen further because TILDA oral health study was done 9 to 6 years later than these countries.

4.7.4 Socioeconomic status and oral health trends

4.7.4.1 National comparisons

Table 4-48 shows, in 2014-15, among adults aged 65 years and over, a higher proportion of adults with a medical card were edentate than adults without a medical card (22.1% vs 8.1%) and this trend was similar in previous Irish oral health surveys

Table 4-48: Percentage of edentate adults aged 65 years and over, in Ireland by gender, year of examination and medical card possession (Base-edentate and dentate).

Years of survey	**Medical card holders**			**Non-Medical holders**		
	M	**F**	**Total**	**M**	**F**	**Total**
2014-15	17.9%	25.2%	22.1%	6.8%	9.5%	8.1%
2000-02	40.1%	49.2%	45.6%	23.9%	35.2%	29.4%
1989-90	48.2%	72.2%	62.2%	17.0%	42.9%	30.8%

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

Table 4-48 shows despite falling levels of edentulism, over time there has been an increase in the difference between two groups (with medical card vs without medical card). Over these years, this fall in gender difference was greater among non-medical card holders (23.2%) than medical card holders (16.7%) from 1989-90 to 2014-15.

Table 4-49 shows that in 2014-15 adults aged 65 years and over, with medical card had a lower mean number of teeth than adults without medical card (12.2 vs 17.4) and this trend was similar in previous two Irish oral health surveys. Table 4-49 also shows that the gender difference in relation to the mean number of teeth, in both groups (with medical card and without medical card) was reduced over time in Ireland and in 2014-15, it had almost disappeared.

Table 4-49: Mean number of teeth per person among adults aged 65 years and over, in Ireland by gender, year of examination and medical card status (Base-edentate and dentate).

Years of examination	Mean number of teeth					
	Medical card			No medical card		
	M	F	Total	M	F	Total
2014-15	12.3	12.1	12.2	17.5	17.3	17.4
2000-02	8.1	6.6	7.2	13.3	9.8	11.6
1989-90	8.3	3.1	5.3	11.9	7.7	9.9

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

Table 4-50 shows that in 2014-15, adults aged 65 years and over, with a medical card had a higher mean DMFT than adults without medical card (25.4 vs 23.2) and this trend was similar in the previous Irish oral health surveys of 1989-90 and 2000-02.

Table 4-50: Mean DMFT-c among adults aged 65 years and over, in Ireland by year of examination and medical card status (Base-edentate and dentate).

Year of examination	DMFT-c	
	Medical card	No medical card
2014-15	25.4	23.2
2000-02	26.7	24.4
1989-90	28.3	25.9

(Whelton et al., 2007, O'Mullane and Whelton, 1992)

This table also shows that the difference in mean DMFT-c between the two groups (with medical card and without medical card) had slightly reduced over time in Ireland. These changes over time in edentulism, mean number of teeth and mean DMFT, among adults with and without a medical card, are probably a reflection of the services available to the medical card holders.

4.7.4.2 International comparisons

This section will report the comparisons of edentulism, the mean number of teeth, the proportion of adults with 21 or more teeth and mean DMFT, in relation to economic status, education level, area of residence and ethnic groups in different countries. Although some countries reported these variations in different age groups and others reported in the whole sample. Some countries calculated mean number of teeth and 21 or more teeth among the dentate sample only (Australia, New Zealand and the UK) and others calculated the mean number of teeth in both the dentate and edentate sample (Ireland). Different countries used different measures of socioeconomic status, nonetheless despite all these methodological differences, trends can be identified.

Despite the reported variations in the available data, Table 4-51 shows that in all these countries, in adults with poor economic status, more were edentate, they had a lower mean number of teeth and more of those adults had less than 21 teeth when compared with adults of better economic status (except FNOH Canada). For example, in 2014-15, in Ireland fewer adults in the highest income quantile were edentate (5.4% vs 14.6%), they had a higher mean number of teeth (21.1 vs 15.6) and higher proportion of them had 21 or more teeth (67.0% vs 38.7%) than adults in the lowest income quantile ($P < 0.0001$ when Chi-square analysis was done between income quantiles and edentulism and between income quantile and proportion of adults with 21 and more teeth). Similarly, in Australia (2004-06), in adults who were eligible for public dental care, more were edentate (17.1% vs 2.7%), they had a lower mean number of teeth (5.2 vs 8.7) and a lower proportion of them had 21 or more teeth (72.9% vs 93.3%) compared with adults who were not eligible for public dental care.

Table 4-51 shows that in adults with a higher level of education, fewer were edentate (with exception of FNOH), they had a higher mean number of teeth and a higher proportion of those had 21 or more teeth. However, in the First Nation adults in Canada, more of those with more than higher school education were edentate (7.6% vs 5.7%) than adults with high school and less education (Table 4-51). Table 4-51 also shows that adults living in capital cities and urban areas had lower levels of edentulism, had a higher mean number of teeth and a higher proportion of them had 21 or more teeth than adults living in rural areas.

The effect of socioeconomic variables on edentulism, mean number of teeth and 21 or more teeth was similar in all reported countries with the exception of the FNOH (Table 4-51), despite all the methodological and sample variation reported above. Adults with better socioeconomic status had lower levels of edentulism, had on average more teeth and a higher proportion of them had 21 or more teeth compared with adults with poor socioeconomic status.

*Table 4-51: Edentulism, mean number of teeth per person and proportion of adults with 21 or more teeth by socioeconomic status, country and examination year (*Dentate sample).*

Country and year of examination	Socioeconomic Variables	Categories of Socioeconomic Variables	Edentulism	Mean number of teeth	≥ 21 teeth
Ireland 2014-15	**Education**	**Primary**	20.3%	13.0	27.8%
		Secondary	9.4%	17.6	47.8%
		Third level/higher	5.7%	20.4	63.0%
	Medical card possession	**No medical card**	4.9%	20.3	61.4%
		Medical card	17.6%	14.2	33.4%
	Area of residence	**Dublin/ Co. Dublin**	6.9%	19.3	58.2%
		Other towns and cities	9.7%	17.9	49.9%
		Rural	11.9%	17.0	45.7%
	Income quantile	**1**	14.6%	15.6	38.7%
		2	13.2%	16.0	41.7%
		3	8.9%	17.5	47.8%
		4	6.4%	19.0	54.5%
		5	5.4%	21.1	67.0%
UK* 2009	**Occupational status**	**Managerial and professional occupations**	2%	26.6	92%
		Intermediate occupations	5%	25.3	85%
		Routine and manual occupations	10%	24.7	79%
Canada FNOH 2009-10	**Income level**	**< $20000**	5.8%	23.0	78.4%
		≥ $20000	6.9%	22.9	74.4%
	Education level	**High school or less**	5.7%	23.3	77.5%
		More than high school	7.6%	24.7	90.3%
	Area of residence	**Urban community**	5.9%	23.6	80.4%
		Non-Urban community	7.9%	22.8	75.1%
Australia* 2004-06	**Level of schooling**	**Year 9/less**	21.9%	10.0	66%
		Year 10/more	4.1%	5.6	91.4%
	Indigenous Identity	**Indigenous**	7.9%	7.4	89.6%
		Non-indigenous	6.4%	6.1	88.6%
	Residential location	**Capital city**	5.0%	6.8	86%
		Other areas	9.0%	5.7	90%
	Eligibility for public dental care	**Eligible**	17.1%	5.2	72.9%
		Ineligible	2.7%	8.7	93.3%

(Slade et al., 2007, Health Canada, 2010, Haisman et al., 2010, O'Sullivan et al., 2011, The First Nations Information Governance Centre, 2012)

Table 4-52 shows the variations in mean DMFT associated with economic status, education level, area of residence and ethnic groups in different countries. Despite the methodological and sample variations, the same trend can be identified from this table.

*Table 4-52: Mean DMFT among different countries by socioeconomic status, education and ethnic group (*Dentate sample).*

Country and examination years	Socioeconomic Variables	Categories of Socioeconomic Variables	Age group	Mean DMFT
Ireland 2014-15	**Medical card possession**	**No medical card**	**50 years and over**	21.1
		Medical card		24.1
	Education	**Primary**		24.5
		Secondary		22.3
		Third level/higher		21.3
	Area of residence	**Dublin/ Co. Dublin**		22.0
		Other towns and cities		22.1
		Rural		22.6
	Income quantile	**1**		23.3
		2		23.3
		3		22.6
		4		21.7
		5		20.8
Canada CHMS 2007-09	**Highest household education**	**Less than degree/diploma**	**All**	11.9
		Equal to degree/diploma		10.3
	Origin	**Aboriginal**	**All**	12
		Non-aboriginal		10.6
	Insurance	**Public insurance**	**All**	13.4
		Private insurance		10.3
Canada FNOH 2009-10	**Income level**	**< $20000**	**All**	13.3
		≥ $20000		13.9
	Education level	**High school or less**	**All**	13.2
		More than high school		13.7
	Area of residence	**Urban community**	**All**	13.0
		Non-Urban community		15.3
Australia* 2004-06	**Level of schooling**	**Year 9/less**	**All**	17.2
		Year 10/more		12.3
	Eligibility for public dental care	**Eligible**	**All**	15.8
		Ineligible		11.8
	Indigenous Identity	**Indigenous**	**All**	14.8
			35-54 years	15.8
			55-74 years	23.3
			75 years and over	N/A
		Non-indigenous	**All**	12.8
			35-54 years	14.3
			55-74 years	22.2
			75 years and over	24.4
	Residential location	**Capital city**	**All**	12.3
			35-54 years	14.4
			55-74 years	21.9
			75 years and over	24.1
		Other areas	**All**	13.8
			35-54 years	15.1
			55-74 years	22.7
			75 years and over	24.8
New Zealand*	**Ethnic groups**	**Maori**	**All**	12.3
		Pacific		9.6
		Asian		6.8
		European /others		15.0

(Slade et al., 2007, Whelton et al., 2007, Health Canada, 2010, Haisman et al., 2010, The First Nations Information Governance Centre, 2012)

Table 4-52 shows that adults with poor economic status had higher mean DMFT values. The exception to this trend was in adults from the First Nation Oral Health Survey (FNOHS) in Canada, those with less than $20,000 income had a very slightly lower mean DMFT (13.3) compared with adults with $20,000 or more income (13.9). It can also be seen that adults with lower levels of education had a higher mean DMFT value compared with adults with higher level of education (except adults of FNOHS, those with high school or less education had a lower mean DMFT (13.2) while adults with more than high school education had a mean DMFT of 13.7). It also shows that levels of education, access to private health insurance were closely related to economic status and so with mean DMFT values. As income levels in urban areas also tend to be higher than in rural areas a similar trend was seen in caries prevalence as with education level.

Mean DMFT also varied among different population groups in each country. For example, among CHMS aboriginal adults had a higher mean DMFT than non-aboriginal (12 vs 10.6) and in Australia, overall the indigenous adults had a higher mean DMFT than non-indigenous adults (14.8 vs 12.8) and this difference was similar in all older age groups. Interestingly in New Zealand, the European population group had the highest mean DMFT (15.0) compared with the other ethnic groups with the Pacific and Asian groups who had much lower values (9.6 and 6.8). This suggests an effect of cultural habits on dental caries prevalence.

This section concluded that over time (from 2004-06 to 2014-15) the negative effect of poor socioeconomic status on edentulism, mean number of teeth and mean DMFT, did not change although different studies reported different variables to represent socioeconomic status.

4.7.5 Conclusions of the discussion section

The above findings suggest that there has been a considerable improvement in the retention of teeth among community-dwelling adults of age 50 years and over in Ireland as compared to previous Irish surveys. However, tooth loss was still common among older adults posing a challenge for our health services. Over time there were considerable improvements in tooth retention, decayed teeth, root caries and periodontal health among adults aged 65 years and over in Ireland and the trend in gender difference was similar (Table 4-34, Table 4-36, Table 4-37, Table 4-38, Table 4-40, Table 4-42, and Table 4-43). In respect of treatment needs, over time in Ireland, the need for treatment for dental caries did not change, as decayed teeth were very uncommon among both males and females in all the surveys reported (Table 4-41). However, the need for periodontal treatment, changed from more complex to simple treatments as the proportion of adults and the mean number of sextants per person with deep pockets reduced while tooth retention increased from 2000-02 to 1014-15 (Table 4-41, Table 4-43 and Table 4-44). The improvements in tooth retention seen in these data also suggest a challenging situation for oral health policymakers, to support more complicated oral health treatment needs among older adults in Ireland.

Along with other health conditions, oral health has also been strongly related to different socioeconomic factors. This section also demonstrated that in Ireland over time there have been also improvements in tooth retention, dental caries, and periodontal health according to economic status also but still these improvements were less in adults with poor economic status than adults with good economic status (Table 4-48, Table 4-49 and Table 4-50). This suggests that adults with poor economic status were a high-risk group for oral health care and should be prioritised in oral health policy.

Ireland appears to have followed the international trends of improvements in the oral health of older adults and the oral health status of adults aged 50 years and above, is reasonably comparable with other developed countries like the UK, the USA, Australia and New Zealand (Table 4-51 and Table 4-52). Furthermore, this section also reported that in Ireland in 2014-15, the trends of oral health status according to socioeconomic status were similar to most of the international trends.

Retention of natural teeth in a healthy condition into old age is highly desirable from an oral health and general health viewpoint. The trends described above are very positive and reflect the positive impacts of previous oral health policies in Ireland. They also indicate a likely requirement for more complex oral health care (restorative) than previously and that may be challenging for frail elderly people, those with dementia and other chronic systemic diseases. In addition, more of the older people will be living in their own homes and in supported living situations with fewer living in nursing homes, which will make the delivery of services more demanding. These findings should provide a valuable resource for oral health policy and planning of oral health services for older people in Ireland.

5 Results and discussion of self-reported oral health and its relationship with objectively measured oral health

This section of the results will cover the self-reported data on teeth and dentures, oral health status, difficulties with mouth, teeth or dentures, frequency of dental visits and dental care provider, (see self-reported questions in Appendix 1) of the TILDA Wave 3 oral health assessment (OHA) sample (n=2504) by age and gender. The comparisons between self-reported oral health and objectively measured oral health status of the same cohort and comparisons between the self-reported oral health status of two samples, the OHA sample and the TILDA Wave 3 sample (n=6687) will also be reported.

5.1 Self-reported oral health

In TILDA Wave 3, the respondents were asked five oral health-related questions in the computer-assisted personal interview (CAPI), which was carried out in the respondents' home by trained interviewers. The question about the self-assessed denture treatment need was asked during the clinical examination when the denture wearing status was noted, and if dentures were present the respondent was asked if they were happy with their dentures or they needed their dentures replaced or repaired; the dentist's opinion was also recorded. So self-assessed denture treatment need was recorded only among the OHA sample. All the questions and the results of these questions follow here (Appendix 1).

5.1.1 Self-reported status of teeth and dentures

Question: Which best describes the teeth you have? (Appendix 1, PH 507)

1. *I have all my own natural teeth – none missing*
2. *I have my own teeth, no dentures – but some missing*
3. *I have dentures as well as some of my own teeth*
4. *I have full dentures*
5. *I have no teeth or dentures*

Table 5-1 indicates that self-reported having complete dentures (Note- respondents reported, 'have full dentures', option 4 of Question PH 507) comprised 9.8% of the sample and 89.9% self-reported having one or more teeth present. The proportion of people who reported having complete dentures was almost the same as the objectively measured prevalence of edentulism (9.9%) described in Chapter 4. Very few (n=5, 0.2%) respondents answered that they had neither teeth nor dentures and 8.6% of the sample reported that they had no missing teeth.

Table 5-1: Self-reported status of teeth and dentures, among the oral health assessment sample of TILDA Wave 3 (Base-edentate and dentate, n=2504).

	Own teeth & no missing teeth	Own teeth & some missing	Own teeth & Dentures	Complete dentures	No teeth no dentures	Do not Know	Total
n	214	1102	934	246	5	3	2504
%	8.6%	44.0%	37.3%	9.8%	0.2%	0.1%	100%

As reported in Table 5-1, 9.8% of the sample self-reported having complete upper and lower dentures but 9.1% were recorded as wearing complete upper and lower dentures in the clinical examination (see Table 4-5). This difference in self-reported (9.8%) having complete dentures and objectively measured wearing of complete dentures (9.1%) may be due to people who had complete dentures but did not wear them.

Chi-square analysis showed that there was a statistically significant difference, in presence of teeth and dentures, among different age groups ($p < 0.001$). Table 5-2 shows that the percentage of adults with no missing teeth was higher in the age group 50-64 years compared to the adults in age group 75 years and over. The percentage of adults with teeth and dentures also increased between those aged 50-64 years to those aged 65-74 years. Interestingly, from those aged 65-74 years to those aged 75 years and over, the proportion of adults with their own teeth and dentures only increased among males. These results are consistent with the objectively measured data in Table 4-6.

Table 5-2 also demonstrates a gender difference was present in relation to self-reported status of teeth and dentures. In all three age groups, a higher proportion of females had 'own teeth and no missing teeth' and 'complete dentures' than males. The very low percentages of males (1.2%) and females (2.5%) with complete dentures in those aged 50-64 years is striking. If, as expected, a large proportion of this cohort will not progress to edentulism then it signals a step-change in the oral health of older adults in Ireland compared to the previous generation.

The gender difference in the self-reported having complete dentures (more females reported that they had complete dentures than males) resembled the objectively measured gender difference in edentulism; among all adults aged 50 years and over, more females were edentate than males in all three age groups (Chapter 4, Table 4-3).

Table 5-2: Self-reported status of teeth and dentures, among the oral health assessment sample of TILDA Wave 3 by age group and gender (Base-edentate and dentate, n=2504).

	Own teeth & no missing teeth		Own teeth & some missing		Own teeth & dentures		Complete Dentures		No teeth no dentures		Do not know		
Age groups	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**Total**
50-64 years	51 4.2%	102 8.4%	292 23.9%	376 30.9%	151 12.4%	198 16.3%	15 1.2%	30 2.5%	1 0.1%	0 0%	1 0.1%	1 0.1%	1218
65-74 years	21 2.3%	28 3.1%	171 18.7%	167 18.2%	188 20.5%	225 24.6%	41 4.5%	72 7.9%	1 0.1%	1 0.1%	0 0%	1 0.1%	916
75 years & over	2 0.5%	10 2.7%	52 14.1%	44 11.9%	98 26.5%	74 20.0%	35 9.5%	53 14.3%	0 0%	2 0.5%	0 0.0%	0 0.0%	370
Total	74 3%	140 5.6%	515 20.6%	587 23.4%	437 17.5%	497 19.8%	91 3.6%	155 6.2%	2 0.1%	3 0.1%	1 0.0%	2 0.1%	2504

5.1.2 Self-reported oral health status

Question: Would you say your dental health (mouth, teeth or dentures) is? (Appendix 1, PH 508)

1. *Excellent*
2. *Very good*
3. *Good*
4. *Fair*
5. *Poor*

Table 5-3 shows that 82.1% of those aged 50 years and over reported their oral health status as 'Excellent', 'Very good' or 'Good' and only 3.4% reported their oral health as 'Poor'.

Table 5-3: Self-reported oral health status of oral health assessment sample of TILDA Wave 3 aged 50 years and older (Base-edentate and dentate, n =2504).

Oral health status	**Excellent**	**Very good**	**Good**	**Fair**	**Poor**	**Total**
n	290	754	1011	363	86	2504
%	11.58%	30.1%	40.4%	14.5%	3.4%	100%

Table 5-4 shows that overall 31.8% of males and 38.6% of females self-reported their oral health as 'Very good' or 'Good'.

Table 5-4: Self-reported oral health status of the oral health assessment sample of TILDA Wave 3 by gender and age group (Base-edentate and dentate, n= 2504).

Oral health	**Excellent**		**Very good**		**Good**		**Fair**		**Poor**		**Total**
Age groups	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	
50-64 years	39 3.2%	106 8.7%	148 12.2%	231 18.9%	205 16.8%	261 21.4%	95 7.8%	82 6.7%	24 2.0%	27 2.2%	1218
65-74 years	45 4.9%	66 7.2%	113 12.3%	152 16.6%	190 20.7%	194 21.2%	66 7.2%	68 7.4%	8 0.9%	14 1.5%	916
75 years & over	13 3.5%	21 5.7%	57 15.4%	53 14.3%	84 22.7%	77 20.8%	24 6.5%	28 7.6%	9 2.4%	4 1.1%	370
Total	97 3.9%	193 7.7%	318 12.7%	436 17.4%	479 19.1%	532 21.2%	185 7.4%	178 7.1%	41 1.6%	45 1.8%	2504

A higher proportion of adults in the group aged 50-64 years self-reported their oral health as 'Excellent' and 'Very good' compared with those aged 75 years and over. It also shows that in the two younger age groups, more females reported having 'Excellent', 'Very good' and 'Good' oral health compared to males in the same age group. In those aged 75 years and over, this gender difference was reduced or was slightly reversed (Table 5-4).

5.1.3 Self-reported difficulties with mouth, teeth or dentures

The respondents were asked the following question in the computer-assisted interview,

Question: "In the past 6 months, have any problems with mouth, teeth or dentures caused you to have any of the following? (Appendix 1, PH 509)

1. *Difficulty eating food*
2. *Difficulty speaking clearly*
3. *Problems with smiling, laughing and showing teeth without embarrassment*
4. *Problems with emotional stability, for example, becoming more easily upset than usual*
5. *Problems enjoying the company of other people such as family, friends, or neighbours*
6. *None of these [code maximum 5 out of 6 possible responses]"*

Table 5-5 shows that 94.1% of adults self-reported that they did not have any difficulties with their mouth, teeth or dentures. It is important to remember when looking at Table 5-5 that respondents could answer Yes/No to each option. While 147 people self-reported at least one difficulty, the most common self-reported difficulty was eating difficulty (n=98), followed by smiling difficulty (n=51) (Appendix 1).

Table 5-5: Self-reported difficulties with mouth, teeth or dentures among oral health assessment sample of TILDA Wave 3 (Base-edentate and dentate, n= 2504).

Any difficulty with mouth, teeth or dentures		Eating Difficulty	Speaking Difficulty	Smiling Difficulty	Emotional Instability	Enjoyment problems
n (%)		**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Yes	147 (5.9%)	98 (3.9%)	23 (0.9%)	51 (2.0%)	8 (0.3%)	11 (0.4%)
No	2357 (94.1%)	2406 (96.1%)	2481 (99.1%)	2453 (97.9%)	2496 (99.7%)	2493 (99.6%)

As shown in Table 5-5, 147 respondents self-reported having difficulty with mouth, teeth or dentures. Out of those, three respondents did not self-report any type of difficulty from the first 5 options. It is notable that the number of respondents self-reporting any difficulty with their mouth, teeth or dentures were small and some of the numbers in the individual categories were very small and for this reason caution is required in their interpretation.

Table 5-6 shows that out of 5.9% with difficulties, 4.6% had only one problem, 0.8% had two problems and less than 0.5% adults had more than two problems with their mouth, teeth or dentures in the previous 6 months.

Table 5-6: Self-reported number of difficulties with mouth, teeth or dentures per person among oral health assessment sample of TILDA Wave 3 (Base-edentate and dentate, n =2504).

	No difficulty	One difficulty	Two Difficulties	Three difficulties	Four difficulties	Five Difficulties	Total
n	2360	114	20	6	1	3	2504
%	94.3%	4.6%	0.8%	0.2%	0.1%	0.1%	100%

Table 5-7 indicates that of those who reported difficulties with mouth, teeth or dentures, the highest number of difficulties reported in all age groups was eating difficulty followed by smiling and speaking. Those aged 50-64 years self-reported the highest number of eating and smiling difficulties compared to other age groups. It is also notable that adults in the 75 years an over age group reported very few difficulties with their mouth, teeth or dentures except eating difficulty.

Table 5-7: Self-reported difficulties with mouth, teeth or dentures among oral health assessment sample of TILDA Wave 3 by age group (Base-edentate and dentate, n =2504).

Age group	Eating Difficulty	Speaking Difficulty	Smiling Difficulty	Emotional Instability	Enjoyment Problems
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**
50-64 years	44 (3.6%)	13 (1.1%)	34 (2.8%)	7 (0.6%)	8 (0.7%)
65-74 years	41 (4.5%)	8 (0.9%)	14 (1.5%)	1 (0.1%)	3 (0.3%)
75 years & over	13 (3.5%)	2 (0.5%)	3 (0.8%)	0 (0.0%)	0 (0.0%)
Total	98 (3.9%)	23 (0.9%)	51 (2.04%)	8 (0.3%)	11 (0.4%)

Table 5-8 shows no statistically significant difference between males and females with respect to each type of difficulty (p> 0.05).

Table 5-8: Self-reported difficulties with mouth, teeth or dentures among oral health assessment sample of TILDA Wave 3 by gender (Base-edentate and dentate, n =2504).

Gender	Eating Difficulty	Speaking difficulty	Smiling Difficulty	Emotional instability	Enjoyment Problems	Total
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n**
Male	47 (4.2%)	13 (1.2%)	20 (1.8%)	4 (0.4%)	5 (0.5%)	1120
Female	51 (3.7%)	10 (0.7%)	31 (2.2%)	4 (0.3%)	6 (0.4%)	1384

Table 5-9 shows that the proportion in the dentate sample (n=2255) that reported any difficulty with their mouth, teeth or dentures was the same as in the total sample (edentate and dentate, n=2504).

During the oral health examination, each of the respondents who was wearing any type of denture (complete or partial, upper, lower and upper and lower) was questioned about their satisfaction with their dentures by asking, *"Are you happy with your dentures and do you think they need to be replaced or repaired?"* The opinion of the dentist about denture treatment need was also recorded and is reported in the next section of comparison between self-reported oral health and objectively measured oral health (Section 5.2).

Table 5-9: Percentage of adults with self-reported any difficulty with mouth, teeth or dentures among oral health assessment sample of TILDA Wave 3 (Base-edentate and dentate, n=2504 and Base-dentate, n=2255).

Any difficulty mouth, teeth or denture	**Base - Edentate and dentate**	**Base – Dentate**
	n (%)	**n (%)**
n	2360 (94.3%)	2127 (94.3%)
Yes	144 (5.7%)	128 (5.7%)
Total	**2504**	**2255**

Table 5-10 shows that 53.4% of adults reported that they did not need treatment related to dentures whereas 46.6% reported that they had a denture treatment need. The highest proportion (25%) self-reported that they needed upper denture treatment (complete or partial) only, and only 2.3% reported the need for lower denture treatment.

Table 5-10: Number and percentage of adults by self-reported denture treatment need (repair or replacement) for any type of dentures (complete or partial) (Base-edentate and dentate, n =2504).

Prosthetic need – respondent's opinion	**Upper and Lower**		**Upper only**		**Lower only**		**No denture treatment need**		**Total**	
	n	%	n	%	n	%	n	%	n	%
	483	19.3%	626	25%	57	2.3%	1338	53.4%	2504	100%

It might have been expected that there would be fewer reports of difficulty with the mouth, teeth or dentures in the dentate group but as the proportion edentate was low and many of the dentate group were wearing partial dentures, this result is not surprising. These results suggest that the respondents also differentiated between eating, speaking, smiling, emotional instability and enjoyment and the need for replacement of dentures (as in Table 5-9 and Table 5-10) only 5.7% reported any such difficulty.

5.1.4 Self-reported frequency of dental visits

Question: Over the last few years how often have you visited the dentist? (Appendix 1, PH 510)

1. *More frequently than every 2 years*
2. *Less frequently than every 2 years*
3. *Never*

Table 5-11 shows that a higher proportion (64.9%) of dentate adults aged 50 years and over, self-reported visiting a dentist more frequently than every 2 years and just 3.9% self-reported never visiting a dentist.

Table 5-11: Self-reported frequency of dental visits among the oral health assessment sample of TILDA Wave 3, aged 50 years and older (Base-dentate, n =2255).

	More frequently than every 2 years	Less frequently than every 2 years	Never	Refused to answer	Total
n	1463	704	87	1	2255
%	64.9%	31.2%	3.9%	0.04%	100%

Chi-square analysis showed that there was a statistically significant difference in the frequency of dental visits (p<0.001) by age group. Table 5-12 shows that overall the frequency of dental visits was greater in those aged 50-64 years compared to those aged 75 years and over. There was also a difference (p< 0.001) between males and females whether they had a dental visit more or less frequently than every 2 years.

Table 5-12: Self-reported frequency of dental visits among the oral health assessment sample of TILDA Wave 3 by age group and gender (Base-dentate, n =2255).

Frequency of dental visits		**More frequently than every 2 years**		**Less frequently than every 2 years**		**Never**		**Total**
Age groups		**M**	**F**	**M**	**F**	**M**	**F**	
50-64 years	**n**	494	277	167	197	13	22	1170
	%	42.2%	23.7%	14.3%	16.8%	1.1%	1.8%	
65-74 years	**n**	301	225	111	142	11	19	809
	%	37.2%	27.8%	13.7%	17.6%	1.4%	2.3%	
75 years & over	**n**	80	86	39	48	9	14	276
	%	28.9%	31.2%	14.1%	17.4%	3.3%	5.1%	
Total	**n**	875	588	317	387	33	55	2255
	%	38.8%	26.1%	14.1%	17.2%	1.5%	2.4%	

In older age groups, the proportion of dentate adults who never visited a dentist was greater in both males and females. This change in the frequency of dental visits may be because of decreased mobility and activity levels with age, resulting in access to care becoming more difficult or because edentate people do not see any need to visit a dentist.

5.1.5 Self-reported dental care provider

Question: *If you needed a routine visit for dental care, which one of the following would you attend? (Appendix 1, PH 511)*

1. *A general dental practice as a private patient [with or without PRSI reimbursement]*
2. *A general dental practice through the Medical Card Scheme*
3. *A HSE dentist at the local clinic*
4. *A Dental Hospital (either UCC or Trinity College Dublin)*
5. *A dental technician*

Table 5-13 shows that 95.9% of these adults reported that they visited general dentists (as private patients or with a medical card) and 2.2% visited a dental technician. A very small number of adults visited HSE dentists, a dental hospital or a dental technician.

Table 5-13: Self-reported dental care provider among the oral health assessment sample of TILDA Wave 3 (Base-edentate and dentate, n =2504).

	General dentist as a private patient	**General dentist With MC**	**HSE dentist**	**Dental hospital**	**Dental Technician**	**Do not know**	**Total**
n	1888	512	19	15	54	16	2504
%	75.4%	20.5%	0.8%	0.6%	2.2%	0.6%	100%

Table 5-14 also shows that overall the proportion of adults who visited a general dentist as a private patient was lower in the older age groups and the proportion who visited a general dentist with a medical card was higher in the older age groups.

This finding suggests that either there were more people in the older age groups who met the income criteria for eligibility for a full medical card (adults with very low incomes are eligible for a full medical card which covers dental care whereas adults aged 70 years and older whose income is above the threshold receive a GP visit card only) or it could be that the type of treatment required by the older age group is covered by the DTSS (Dental Treatment Service Scheme). Gender difference was present in relation to self-reported dental visits (Table 5-14). Overall a higher proportion of women than men reported visiting a general dentist as a private patient and with a medical card, though this trend was reversed in those aged 75 years and older. Although among OHA sample (n= 2504), 40.0% of adults had a medical card but only 20.5% reported visiting a general dentist with a medical card.

Table 5-14: Self-reported dental visits of the oral health assessment sample of TILDA Wave 3 by age group and gender (Base-edentate and dentate, n =2504).

Dental care provider	General dentist as private		General dentist with MC		HSE dentist		Dental Hospital		Dental technician		Do not Know		Total
Age group	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	
50-64 years	431 35.4%	602 49.4%	69 5.7%	86 7.1%	4 0.3%	3 0.3%	4 0.3%	6 0.5%	1 0.1%	8 0.7%	2 0.2%	2 0.2%	1218 48.6%
64-74 years	304 33.2%	336 36.7%	98 10.7%	131 14.3%	5 0.6%	3 0.3%	3 0.3%	1 0.1%	9 0.9%	20 2.2%	3 0.3%	3 0.3%	916 36.6%
75 years & over	111 30%	104 28.1%	66 17.8%	62 16.8%	2 0.5%	2 0.5%	0 0.0%	1 0.3%	6 1.6%	10 2.7%	2 0.5%	4 1.1%	370 14.8%

5.2 Self-reported oral health compared with objectively measured oral health status

This section covers the relationship of self-reported oral health status with objectively measured oral health status. Here the self-reported oral health of the sample (according to five self-reported questions) is compared with the objectively measured mean number of teeth, mean number of sound untreated natural teeth (SUNT), mean DMFT, proportion of adults with less than 10 and 10 or more tooth contacts and Community Periodontal Index of Treatment Need CPITN (maximum values per person). The clinically measured need for dentures is also compared with self-reported need for dentures.

5.2.1 Objectively measured oral health by self-reported status of teeth and dentures

Table 5-15 shows that in the OHA sample (n= 2504) the self-reported figure for edentulism (10.0%) (having complete denture and no teeth or dentures) was comparable with the edentate figure from the clinical examination (9.9%), where the adults with at least one natural tooth present were recorded as dentate. The slight discrepancy between self-reported and objectively measure edentulism could be because those adults who had a few retained teeth or roots and self-reported being edentate, while on clinical examination were not edentate.

Table 5-15: Number of edentate respondents, self-reported and objectively measured by age group and gender (Base-edentate and dentate, n= 2504).

Age group	50-64 years		65-74 years		75 years and over		Total
Gender	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**n (%)**
OHA	15	33	36	71	39	55	249 (9.9%)
Self-reported	16	30	42	73	35	55	251 (10.0%)

The findings of the self-reported status of teeth and dentures among the OHA sample (aged 50 years and over) of TILDA Wave 3, were different from TILDA Wave 3 cohort aged 54 years and over, reported by Sheehan and colleagues (Sheehan et al., 2017). In the TILDA Wave 3 OHA sample (n=2504), 9.8% self-reported that they had complete dentures and 8.6% reported that they had their own teeth and none missing. Whereas, in the TILDA Wave 3, sample aged 54 years and over (n= 6,425), 17% self-reported that they had complete dentures and 7.5% reported that they had own teeth and no dentures (Sheehan et al., 2017). Table 5-16 clearly indicates the limitations of self-reported presence of natural teeth and dentures, because some adults who reported that they had complete dentures, had some teeth and tooth contacts when clinically examined. Adults in the 'do not know' category also had a higher mean number of teeth and mean tooth contacts than adults with self-reported teeth and dentures.

Table 5-16: Mean number of teeth and mean DMFT by self-reported status of teeth and dentures (Base-edentate and dentate, n =2504).

How is your oral health	Own teeth & no missing	Own teeth & some missing	Own teeth & dentures	Complete Dentures	No-teeth no dentures	Do not know	Total
Mean number of teeth	**26.2**	**23.0**	**14.4**	**0.8**	**5.6**	**17.3**	**17.8**
Mean SUNT	**14.7**	**12.6**	**7.4**	**0.4**	**3.4**	**7**	**9.6**
Mean DMFT	**17.2**	**19.3**	**24.5**	**31.6**	**28.6**	**25**	**22.3**
Mean contacts	**15.8**	**12.4**	**5.8**	**3.4**	**8**	**16**	**9.9**

Table 5-17 shows that there were only small differences between self-reported denture wearing and objectively measured denture wearing in all age groups.

Table 5-17: Comparison of self-reported denture wearing with objectively measured denture wearing by age group (Base-edentate and dentate, n =2504).

Age groups		**Not wearing a denture**		**Any type of denture wearing C/C, C/P, C/ P/P, P/, /P, P/C,**		**Total**
		Objectively measured	**Self-reported**	**Objectively measured**	**Self-reported**	**n**
50-64 years	**n**	838	822	380	396	1218
	%	68.8%	67.5%	31.2%	32.5%	
65-74 years	**n**	392	389	524	527	916
	%	42.8%	42.5%	57.2%	57.2%	
75 years & over	**n**	100	110	270	260	370
	%	27.0%	29.7%	73%	70.3%	
Total	**n**	1330	1321	1174	1183	1504
	%	53.2%	52.8%	46.8%	47.2%	

Table 5-18 shows that in the clinical examination the dentist considered that 55.8% of the sample had some type of denture treatment need, either repair or replacement of dentures (complete or partial) whereas, the 46.6% of respondents self-reported problems with their dentures and the need for repair and replacement.

Table 5-18: The percentage of adults with denture treatment need for any type of dentures (complete or partial) by the dentist's opinion and self-reported need (Base-edentate and dentate, n =2504).

Denture repair or replacement need	**Upper and Lower**	**Upper only**	**Lower only**	**no denture treatment need**	**Total**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n**
Dentist's opinion	601 (24.0%)	193 (7.7%)	604 (24.1%)	1106 (44.2%)	2504
Self-reported need	483 (19.3%)	626 (25%)	57 (2.3%)	1338 (53.4%)	2504

The divergence between the dentist's opinion and the respondents' is especially noticeable in the need for, 'Upper only' or 'Lower only' dentures. Self-reported need for an upper denture only (partial and complete), was more than three times that determined by the dentist (25% vs 7.7%). The self-reported need for a lower denture only (partial and complete), showed the opposite trend; ten times lower self-reported need compared to the assessment by the examining dentist (2.3% vs 24.1%) (see table 5-18).

These results suggest that some adults did not prioritise having a lower denture and probably would not seek out treatment for a partial or complete lower denture. A secondary qualitative analysis is required to probe the reasons behind this difference between subjective and objective denture treatment need. These findings also suggest that self-reported oral health analysis could be helpful in the evaluation of edentulism and denture wearing but may not be accurate in assessing treatment need for dentures.

5.2.2 Objectively measured oral health by self-reported oral health status

Descriptive statistics in Table 5-19 show respondents self-reported their oral health status in relation to objectively measured, mean number of teeth and mean DMFT.

Table 5-19: Mean number of teeth, mean SUNT and mean DMFT by self-reported oral health status (Base-edentate and dentate, n= 2504)

How is your oral health?	Excellent	Very good	Good	Fair	Poor
Mean number of teeth	19.9	19.1	16.9	16.6	16.7
Mean SUNT	10.6	10.3	9.2	8.8	8.8
Mean DMFT	21.3	21.7	22.7	23.1	23.1

Adults with lower levels of self-reported oral health (‘Fair’ and ‘Poor’) had lower mean numbers of teeth and higher mean DMFT when compared with adults with ‘Excellent’ and ‘Very good’ oral health. For example, adults with ‘Excellent’ self-reported oral health had a mean of 19.9 teeth and a mean DMFT of 21.3, as compared with adults with ‘Poor’ self-reported oral health who had a mean of 16.7 teeth and mean DMFT of 23.1. From self-reported ‘Excellent’ to ‘Poor’ oral health, the difference in the mean number of teeth (3.2 teeth) was reflected in the differing DMFT (1.8).

Chi-square analysis was done to examine the relationship between self-reported oral health status and 10 or more contacts. Table 5-20 shows there was a statistically significant difference in the percentage of dentate adults with 10 or more tooth contacts by self-reported oral health status (p<0.001).

Table 5-20: Percentage of dentate adults with less than 10, and 10 or more tooth contacts by self-reported oral health status (Base-dentate, n=2255, p<0.001).

Tooth Contacts	Excellent n (%)	Very good n (%)	Good n (%)	Fair n (%)	Poor n (%)	Total n
<10 Contacts	54 (21.3%)	228 (33.6%)	444 (49.3%)	196 (57.7%)	53 (63.9%)	975
≥10 Contacts	199 (78.7%)	450 (66.4%)	457 (50.7%)	144 (42.4%)	30 (36.1%)	1280
Total	253	678	901	340	83	2255

Table 5-21 shows that there was a statistically significant difference between the percentage of adults with the different CPITN scores (healthy, bleeding, calculus, shallow and deep pockets) by self-reported oral health status (p=0.021), among the dentate sample (n= 2255). The highest proportion of adults with a CPITN score of healthy reported their oral health as 'Excellent' (14.5%) or 'Very good' (30.5%) and very few adults who reported 'Poor' oral health had a CPITN score of healthy (1.5%). However, 78% of those who had a CPITN score of bleeding also reported their oral health as 'Excellent', 'Very good' or 'Good' and 21.5% reported it as 'Fair' or 'Poor' which suggests a poor relationship between self-reported oral health and objectively measured periodontal health. It also suggests that the adults who had a periodontal treatment need were unaware of it.

Overall, a higher proportion of dentate adults with self-reported oral health of 'Excellent' 'Very good' and 'Good' had worse CPITN scores (shallow and deep pockets) and only 45% of those with a maximum CPITN score of 'Healthy', self-reported having 'Excellent' or 'Very good' oral health (Table 5-21). Furthermore, a higher proportion of adults who self-reported their oral health as 'Excellent' had shallow pockets (11.7%) and deep pockets (5.5%) compared with adults who self-reported their oral health as 'Poor' (shallow pockets 3.8% and deep pockets 3.1%).

Table 5-21: The percentage of dentate adults with maximum CPITN score of healthy, bleeding, calculus, shallow and deep pockets by self-reported oral health status (Base-dentate, n= 2255, p= 0.021).

CPITN Maximum value	**Self-reported oral health**					**Total**
	Excellent n (%)	**Very good n (%)**	**Good n (%)**	**Fair n (%)**	**Poor n (%)**	**n**
Healthy	19 (14.5%)	40 (30.5%)	49 (37.4%)	21 (16.0%)	2 (1.5%)	131
Bleeding	11 (13.9%)	16 (20.3%)	35 (44.3%)	12 (15.2%)	5 (6.3%)	79
Calculus	77 (10.8%)	230 (32.2%)	290 (40.6%)	91 (12.8%)	26 (3.6%)	714
Shallow pockets (3.5-5.5mm)	134 (11.7%)	356 (31.1%)	434 (37.9%)	178 (15.6%)	43 (3.8%)	1145
Deep pockets (≥6mm)	7 (5.5%)	23 (17.9%)	67 (52.3%)	27 (21.1%)	4 (3.1%)	128
Missing Sextant	5 (8.6%)	13 (22.4%)	26 (44.8%)	11 (19.0%)	3 (5.2%)	58
Total	253 (11.2%)	678 (30.1%)	901 (39.9%)	340 (15.1%)	83 (3.7%)	2255

For all the CPITN codes the highest proportion of respondents self-reported having 'Good' oral health. These findings indicate that periodontal health status did not influence how these adults rated their oral health and it suggests that other factors affected how they reported their oral health status.

5.2.3 Objectively measured oral health by self-reported difficulties with mouth, teeth or dentures

Table 5-22 shows the mean number of teeth, mean SUNT, and mean DMFT by self-reported difficulties with mouth, teeth or dentures. There was a trend that adults who self-reported not having any difficulty with their mouth, teeth or dentures had a higher mean number of teeth, mean SUNT and lower mean DMFT than those who reported having any difficulty. This trend was seen with any type of difficulty such as eating, speaking, smiling, enjoyment except 'Emotional instability'. It must be remembered that the numbers self-reporting any difficulty, were small and so these may not be clinically significant differences. Chi-square analysis reported that there was a statistically significant difference (p<0.001) for the proportion of adults with 10 or more tooth contacts by self-reported any difficulties with mouth, teeth or dentures among the dentate sample (n= 2255).

Table 5-22: Mean number of teeth, mean SUNT, mean DMFT by self-reported difficulties with mouth, teeth or dentures (Base-edentate and dentate, n =2504).

Difficulty with teeth	Eating Difficulty		Speaking difficulty		Smiling Difficulty		Emotional Instability		Enjoyment Problems		Any Difficulty	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Mean number of teeth	14.5	18.0	11.0	17.9	16.7	17.9	19.0	17.9	16.9	17.9	15.2	18.0
Mean SUNT	7.8	9.7	5.9	9.6	8.8	9.6	12.3	9.6	8.6	9.6	8.0	9.7
Mean DMFT	24.1	22.2	26.1	22.3	23.0	22.3	19.6	22.3	23.4	22.3	23.9	22.2

Table 5-23 shows that overall a higher percentage of dentate adults with 'Any difficulty' had less than 10 tooth contacts. The 'Eating', 'Speaking' and 'Smiling difficulty' had a statistically significant relationship with less than 10, or 10 or more tooth contacts (p<0.001). However, 'Emotional instability' and 'Enjoyment problems' did not have any significant relationship with less than 10 or 10 or more tooth contacts among dentate adults (P > 0.05) (Table 5-23).

Table 5-23: Percentage of dentate adults with less than 10 and 10 or more tooth contacts by self-reported difficulties with mouth, teeth or dentures (Base-dentate, n =2255).

<10/≥ 10 tooth Contacts	Eating difficulty	Speaking Difficulty	Smiling Difficulty	Emotional instability	Enjoyment Problems	Any Difficulty
<10 Contacts	64.7%	78.9%	71.4%	42.9%	50.0%	64.6%
≥10 Contacts	35.3%	21.1%	28.6%	57.1%	50.0%	35.4%
Total n (%)	98 (3.91%)	23 (0.92%)	51 (2.04%)	8 (0.32%)	11 (0.44%)	128 (5.7%)

Table 5-24 shows the descriptive statistics of adults with and without any difficulty with mouth, teeth or dentures by categories of CPITN score. No further analysis was done in relation to CPITN score among adults with and without any difficulty because the number of adults with any difficulty was very small in the different categories of CPITN score.

Table 5-24: Percentage of dentate adults with maximum CPITN score of healthy, bleeding, calculus, shallow and deep pockets by self-reported any difficulty with mouth, teeth or dentures (Base-dentate, n =2255).

CPITN Maximum value	**Any difficulty**		**Total n**
	No (%)	**Yes (%)**	
Healthy	119 (90.8%)	12 (9.2%)	131
Bleeding	72 (91.1%)	7 (8.9%)	79
Calculus	675 (94.5%)	39 (5.5%)	714
Shallow pockets (3.5-5.5mm)	1088 (95.0%)	57 (5.0%)	1145
Deep pockets (≥6mm)	119 (92.9%)	9 (7.1%)	128
Missing sextant	54 (93.1%)	4 (6.9%)	58
Total	2127	128	2255

5.2.4 Objectively measured oral health by self-reported frequency of dental visits

Table 2-25 shows that dentate adults who visited the dentist more than every 2 years had a higher mean number of teeth, mean SUNT and mean number of tooth contacts and lower mean DMFT than those who visited the dentist less frequently than every 2 years or who never visited the dentist.

Table 5-25: Mean number of teeth, mean SUNT, mean DMFT and mean tooth contacts by self-reported frequency of dental visits (Base-dentate, n =2255).

	Frequency of dental visits (n=2255)			
	More frequently than every 2 years (n=1463)	Less frequently than every 2 years (n=704)	never (n=87)	Refused to answer (n=1)
Mean number of teeth	20.9	18.3	14.2	22
Mean SUNT	10.8	10.5	9.3	11
Mean DMFT	21.4	22.8	27.4	21
Mean number of contacts	10.8	8.6	5.3	8

As shown in Table 5-26, the Chi-square analysis reported that there was a statistically significant difference in maximum CPITN score by frequency of dental visits among the dentate sample (p=0.002).

Table 5-26: Percentage of dentate adults with maximum CPITN score of healthy, bleeding, calculus, shallow and deep pockets by self-reported frequency of dental visits (Base-dentate, n=2255, p= 0.002).

CPITN	Frequency of dental visits			
	More than every 2 years n (%)	Less than every 2 years n (%)	Never n (%)	Total
Healthy	98 (6.7%)	29 (4.1%)	4 (4.6%)	131
Bleeding	52 (3.6%)	25 (3.6%)	2 (2.3%)	79
Calculus	473 (32.3%)	213 (30.3%)	28 (32.2%)	714
Shallow pockets (3.5-5.5mm)	732 (50.0%)	371 (52.7%)	42 (48.3%)	1145
Deep pockets (≥6mm)	75 (5.1%)	50 (7.1%)	3 (3.6%)	128
Missing Sextant	33 (2.5%)	16 (2.3%)	9 (10.3%)	58
Total	1463 (64.9%)	704 (31.2%)	87 (3.9%)	2255

Table 5-26 also reports that a higher proportion of dentate adults who visited the dentist more than every two years had a maximum CPITN score of 'Healthy' than those who visited less frequently than every 2 years (6.7% vs 4.1%). Whereas there was no marked difference in the percentage of adults with deep and shallow pockets who visited the dentist less frequently than every two years (52.7% and 7.1%) when compared with adults who visited the dentist more than every two years (50.0% and 5.1%). A lower percentage of adults who never visited dentist had shallow pockets (48.3%) along with the highest percentage of missing sextants (10.3%).

The explanation for this finding may be that the adults who never or rarely visited a dentist had a lower number of retained teeth and fewer shallow pockets than those who did attend a dentist, though it must be remembered that the numbers in these categories were small. These findings suggest the self-reported frequency of dental visits was a good indicator of tooth contacts and the mean number of teeth but not a good indicator of periodontal health among the OHA sample.

Apart from the relationship between self-reported dental visits and objectively measured oral health status, the relationship between self-reported dental visits and self-reported oral health was also evaluated by chi-square test.

Table 5-27: Percentage of adults with self-reported oral health status by self-reported frequency of dental visits (Base-edentate and dentate, n =2504, p<0.001).

	Frequency of dental visits (n=2255)			
	More frequently than every 2 years (n=1463)	**Less frequently than every 2 years (n=704)**	**never (n=87)**	**Refused to answer (n=1)**
Mean number of teeth	20.9	18.3	14.2	22
Mean SUNT	10.8	10.5	9.3	11
Mean DMFT	21.4	22.8	27.4	21
Mean number of contacts	10.8	8.6	5.3	8

Table 5-27 shows that the self-reported oral health status was also a statistically significant different by self-reported frequency of dental visits. A higher proportion of adults who visited a dentist more frequently than every 2 years, had self-reported oral health status of 'Excellent', 'Very good, and 'Good' compared with those who visited a dentist less frequently than every 2 years or never. Whereas, a higher proportion of adults with self-reported oral health, 'poor' visited the dentist less than every two years (48.8%). These findings suggest that the self-reported frequency of dental visits was associated with both objectively measured oral health (number of teeth and tooth contacts) and self-reported oral health status.

5.2.5 Objectively measured oral health by self-reported dental care provider

Table 5-28 shows that adults who visited a general dentist as a private patient had a higher mean number of teeth, mean SUNT and mean tooth contacts and lower mean DMFT than adults who visited any other place for dental treatment.

Table 5-28 also shows that that adults with a medical card had a very similar profile whether they attended a general dentist as a medical card patient or a HSE dentist, though the number attending a HSE dentist was very small. One reason could be that the adults with medical card had basic treatment options under the DTSS scheme. The adults who visited a dental technician had very few teeth and highest DMFT, which makes sense as these were most likely to be adults with either complete dentures or partial dentures and few teeth.

Table 5-28: Mean number of teeth, mean SUNT, mean DMFT (Base-edentate and dentate, n= 2504) and mean tooth contacts (Base- dentate, n=2255) by the self-reported dental care provider.

Self-reported dental care provider	General dentist as private patient (n=1888)	General dentist With MC (n=502)	HSE dentist (n=19)	Dental Hospital (n=15)	Dental Technician (n=54)	Do not know (n=16)
Mean of teeth	19.6	13.8	14.1	13	2.1	10
Mean SUNT	10.4	7.7	7.9	4.9	1.2	5.8
Mean DMFT	21.4	24.2	23.8	26.9	30.7	26.1
Mean no of Contacts	10.6	7.1	6.1	9.5	4.7	10

5.3 Comparison of self-reported oral health between OHA and TILDA sample

This section reports on the comparisons of the self-reported oral health between the OHA sample (n=2504) and TILDA Wave 3 sample (n= 6687) according to the five self-reported oral health questions (Appendix 1).

5.3.1 Self- reported status of teeth and dentures

In 2017, Sheehan and colleagues reported on the self-reported oral health questions for the adults aged 54 years and older in the TILDA Wave 3 sample (n= 6425, observations n= 6415 and missing n=10), whereas the OHA sample data reported here are for both those aged 50 years or older and 54 years and older.

Table 5-29 shows that the TILDA Wave 3 sample had a higher proportion of edentate adults as compared to the OHA sample which is probably due to the differences in the samples as discussed in chapter 4 (Table 4-1). The OHA sample had more people with third-level education, living in Dublin or Co Dublin and more of them were with better general health (Table 4-1 in chapter 4).

Table 5-29: Comparison of self-reported edentulism between the OHA sample of 50 years and over (n= 2504), OHA sample of 54 years and over (n= 2432), TILDA Wave 3 sample of 50 years and over (n= 6687) and TILDA sample of 54 years and over (n= 6425, observations n= 6415 and missing n= 10).

Self-reported edentulism	Edentate n (%)	Dentate n (%)	Total n
Oral Health Assessment sample (50 years and over)	251 (10.0%)	2253 (90.0%)	2504
Oral Health Assessment sample (54 years and over)	246 (10.1%)	2186 (89.9%)	2432
TILDA Wave 3 sample (50 years and over)	1118 (16.8%)	5569 (83.3%)	6687
TILDA Wave 3 sample (54 years and over)	1114 (17.4%)	5301 (82.6%)	6415

In 2014, the Intellectual Disability Supplement to The Irish Longitudinal Study on Ageing (IDS-TILDA) of the nationally-representative sample of adults with intellectual disabilities also reported that in Ireland the self-reported edentulism prevalence in that group was more than double that in the general population of adults (34.1% vs 14.9%) (Mac Giolla Phadraig et al., 2015).

Table 5-30: Comparison of self-reported status of teeth and dentures between OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

Self-reported teeth and denture status	Own teeth & no missing teeth	Own teeth & some missing	Own teeth & dentures	Complete dentures	No teeth no dentures	Do not know	Total n
Oral Health Assessment sample	214 (8.6%)	1102 (44.0%)	934 (37.3%)	246 (9.8%)	5 (0.2%)	3 (0.1%)	2504
TILDA Wave 3 sample	530 (7.9%)	2586 (38.7%)	2443 (36.5%)	1060 (15.9%)	58 (0.9%)	10 (0.1%)	6687

In all the following tables, the comparisons are made between the whole TILDA Wave 3 sample (n=6687) and the OHA sample (n=2504). Table 5-30 shows that the TILDA Wave 3 sample had more adults who self-reported having complete dentures (15.9% vs 9.8%), fewer adults with their own teeth and some missing, (38.7% vs 44.0%) than the OHA sample.

Mac Giolla Phadraig and colleagues reported that in IDS-TILDA, 61.1% of edentate adults with intellectual disabilities were not wearing dentures which contrasts with 0.9% of the TILDA Wave 3 sample and 0.2% of the OHA sample (Mac Giolla Phadraig et al., 2015).

5.3.2 Self-reported oral health status

Table 5-31 shows there was no marked difference between the OHA sample and TILDA Wave 3 sample in relation to self-reported oral health, despite the difference in the prevalence of edentulism described above (see Table 5-29 and Table 5-30). This suggests that higher levels of edentulism in the TILDA Wave 3 sample did not affect how people self-reported their oral health status.

Table 5-31: Comparison of self-reported oral health status between OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

Self-reported oral health	Excellent n (%)	Very good n (%)	Good n (%)	Fair n (%)	Poor n (%)	Total n
OHA sample	290 (11.5%)	754 (30.1%)	1011 (40.5%)	363 (14.5%)	86 (3.4%)	2504
TILDA Sample	743 (11.1%)	1895 (28.3%)	2798 (41.8%)	973 (14.6%)	278 (4.2%)	6687

5.3.3 Self-reported difficulties with mouth, teeth or dentures

Table 5-32 shows the proportion of adults with self-reported difficulties with mouth, teeth or dentures was the same in both the OHA sample and the TILDA sample; these findings were similar to those reported in Table 5-31.

Table 5-32: Comparison of self-reported difficulties with mouth, teeth or dentures, between OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

Samples	Any difficulty with mouth, teeth or dentures		Total
	Yes n (%)	No n (%)	n
OHA sample	147 (5.9%)	2357 (94.1%)	2504
TILDA sample	392 (5.9%)	6295 (94.1%)	6687

5.3.4 Frequency of dental visits

The comparisons shown in Table 5-33 indicate that a higher proportion of the OHA sample visited a dentist more frequently than every 2 years as compared to the TILDA Wave 3 sample. The possible reason may be that the OHA sample adults were younger, there were more adults with higher education and with better general health as compared to TILDA sample, as reported in Table 4.1.

Table 5-33: Comparison of self-reported frequency of dental visits, between OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

Frequency of dental visits	More frequently than every 2 years n (%)	Less frequently than every 2 years n (%)	Never n (%)	Refused to answer n (%)	Total n
Oral Health Assessment sample	1506 (60.1%)	820 (32.8%)	177 (7.1%)	1 (0%)	2504
TILDA sample	3440 (51.4%)	2470 (36.9%)	767 (11.5%)	10 (0.1%)	6687

5.3.5 Self-reported dental care provider and possession of medical card

Table 5-34 shows that in the OHA sample, more adults visited a general dentist as a private patient, and fewer visited a general dentist with a medical card than in the TILDA Wave 3 sample.

Table 5-34: Comparison of self-reported dental care provider, between the OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

Self-reported dental care provider	General dentist as private patient n (%)	General dentist with MC n (%)	HSE dentist n (%)	Dental hospital n (%)	Dental Technician n (%)	Do not Know n (%)	Total n
Oral Health Assessment sample	1888 (75.4%)	512 (20.5%)	19 (0.8%)	15 (0.6%)	54 (2.2%)	16 (0.6%)	2504
TILDA sample	4570 (68.3%)	1718 (25.7%)	84 (1.3%)	38 (0.6%)	197 (3.0%)	80 (1.2%)	6687

Table 5-35 also indicates that fewer adults had a medical card in the OHA sample than TILDA sample (40.0% vs 47.9%). A comparison of possession of the medical card and visiting a general dentist with the medical card showed that in both samples, only 50% of adults with the medical card used it to visit a general dentist. For example, in the OHA sample, 40.0% had the medical card yet only 20.5% used it to visit a general dentist (Table 5-34 and Table 5-35).

Table 5-35: Comparison of self-reported possession of the medical card, between the OHA sample (n=2504) and TILDA Wave 3 sample (n=6687).

	MC Yes n (%)	MC No n (%)	Don't know n (%)	Total n
Oral Health Assessment sample	1002 (40.0%)	1502 (60.0%)	1 (0.0%)	2504
TILDA sample	3207 (47.9%)	3470 (51.9%)	100 (0.2%)	6687

These findings suggest that approximately half of adults with the medical card were either unaware of their entitlement to dental care with the medical card or they were unable to access the care they needed with the medical card.

Despite the differences in some characteristics of the two samples, there were similarities between the samples in self-reporting of oral health status, difficulties with mouth, teeth or dentures and access to dental care. It is also notable that in both samples access to dental care through the medical card was low. These similarities between the two samples were perhaps because of actual similarities between the samples or because of the nature of self-reported questions. For example, the specific question on self-reported edentulism and frequency of dental visits showed differences between the two samples whereas the broad self-reported questions on oral health status were answered similarly in both groups. For example, the answers to a broad question such as, "How is your oral health?" can easily vary by self-perception of an individual; an individual with a few remaining teeth might have no problem with their mouth and have reported their oral health as good, which may contrast to their objectively measured oral health status. Further research is required to determine the factors affecting the self-reporting of oral health status in order to improve their validity.

5.4 Discussion of relationship between self-reported oral health and objectively measured oral health

In oral health surveys, the objective approach for the assessment of oral health status and treatment needs of a population is used to provide an evidence-base for oral health policies. Although the objective approach in epidemiological studies is a more targeted and accurate method of oral health evaluation, it is more expensive, time-consuming and somewhat invasive in nature. Most respondents are willing to self-report their oral health status, however, it has been shown in this study to not correspond with objective assessment in many respects.

Subjective assessments of health may be biased by self-beliefs and ideas, so it is important to estimate the validity of the subjective assessment, such as in the self-reported oral health status. Along with above-reported reasons, a subjective approach may also be compromised by missing data and by the oral health literacy level of respondents (Little and Rubin, 2002, Fox-Wasylyshyn and El-Masri, 2005, Firmino et al., 2018). Determination of the relationship between subjective and objective methods of oral health assessment can provide a method of improving the accuracy of self-reported oral health status. It may also help to modify methods such as the self-reported questionnaire to increase the construct and content in the validity of the subjective assessment of oral health. Improved validity of a subjective approach in oral health assessment may also help to assess the treatment needs among the population. This may be because this approach better reflects the self-perceived needs of a population, which are as important as objective needs because they are more likely to become the demand for dental care services. An evaluation of the interrelationship between subjective and objective data could help to improve the value of subjective reporting against objective measurements.

In this research, among the oral health assessment (OHA) sample (n= 2504), the evaluation of the interrelationship between subjective and objective methods of oral health assessment was more important because of the cohort age. As the adults in this study were 50 years and older, the subjective method of oral health assessment is likely to have been influenced by the cognitive, physical and systemic health of the sample along with other factors (socioeconomic, ideas, beliefs, self-perception) affecting the subjective oral health evaluation (Atchison et al., 1993, Jones et al., 2001, Liu et al., 2010, Yamamoto et al., 2012, Farmer et al., 2017). For example, Jones and colleagues reported that self-reported oral health was biased by age, gender and education (Jones et al., 2001). Atchison and colleagues reported that apart from the difficulty in assessing self-reported oral health, self-perception also plays an important role in the evaluation of self-reported oral health. Clinically defined oral health or disease status is different from an individual's own perception of oral health which accounts for social, functional and behaviour factors (Atchison et al., 1993).

There may be an argument for both the subjective and objective assessment of oral health status in order to improve oral health status. For example, subjective oral health assessment is important to evaluate self-perceived needs. But the results in this study which showed a poor relationship between periodontal status and self-reported oral health status which would support the need for people to be better informed about periodontal disease which may then become demand for dental care to prevent periodontal destruction. It also supports the objective assessment of periodontal treatment need, is more accurate as compared to the subjective assessment.

The second aim of this aspect of the research was to compare the self-reported oral health status, difficulties with mouth, teeth or dentures, and frequency and place of dental care provider, with the clinically measured number of teeth, DMFT, and maximum CPITN score in the same sample. Chi-square analysis and non-parametric tests (Kruskal-Wallis test) were carried out to explore these associations. The findings of this research revealed that objectively measured number of teeth and tooth contacts were statistically significantly different ($p<0.001$) according to self-reported status of teeth and dentures, oral health status (excellent, very good, good, fair and poor), self-reported difficulties with the mouth, teeth or dentures and self-reported frequency and place of dental visits. These comparisons of self-reported and objectively measured oral health were done to investigate whether self-reported oral health can be used instead of objectively measured oral health for large population-based studies and what is the accuracy of the self-reported oral health data in relation to objectively measured oral health data in a sample of older adults? These comparisons between self-reported and objectively measured oral health were also explored to obtain an insight into the validity of the structure of self-reported questions, as a representation of actual oral health of older adults.

Five self-reported questions and their relationship with objectively measured oral health of same cohort, and comparisons with other studies in this aspect are as follows

Question: *Which best describes the teeth you have?* (Appendix 1, PH 507)

1. *I have all my own natural teeth – none missing*
2. *I have my own teeth, no dentures – but some missing.*
3. *I have dentures as well as some of my own teeth*
4. *I have full dentures*
5. *I have no teeth or dentures*

This question was asked in the previous waves of the TILDA study and in the SLAN (Survey of Lifestyle, Attitude and nutrition in Ireland) studies and so provides an opportunity for comparison with the previous waves of TILDA and other studies such as SLAN (The Economic and Social Research Institute Ireland, 2007). This question was asked in the computer-assisted personal interview (CAPI) (Kearney et al., 2011).

Similar to the studies of Liu and colleagues in 2010 and Pitiphat and colleagues in 2002, this study also found that adults were able to self-assess the status of teeth and dentures (Pitiphat et al., 2002, Liu et al., 2010). Furthermore, similar to the Scandinavian study of Palmqvist and colleagues in 1991, which reported good agreement between self-reported and clinically present removable dentures, this study also found that adults with self-reported, 'teeth and dentures' had fewer teeth than those who either self-reported having no missing teeth or having most of their own teeth and few missing (Table 5-16) (Palmqvist et al., 1991). These findings indicate that adults in this research had a good understanding of the presence of natural teeth and denture wearing when compared with the objectively recorded presence of teeth and denture wearing. A few adults who reported having full dentures (n=23) and no teeth and no dentures (n=2) were found to have one or more teeth present (dentate) by clinical examination (Table 5-16). These were probably those adults who might have had only 1 or 2 teeth remaining. It was further calculated that there were a few adults (n=22) who were edentate and reported themselves as dentate in OHA sample.

The proportion of respondents who self-reported having complete dentures in the OHA sample was lower (9.9%) than the proportion that self-reported having complete dentures in the full TILDA Wave 3 cohort aged 50 years and over (16.8%, n=6687) and aged 54 years and over (17.4%, n=6425) (Sheehan et al., 2017). Perhaps one reason for this difference between the two samples was the exclusion of very old adults and those with physical disabilities or cognitive decline from the OHA sample, who did not come to the TILDA health assessment centre for the health assessment.

Question*: Are you happy with your dentures and do you think they need to be replaced or repaired?*

This question was asked at the time of clinical examination, to estimate self-reported denture treatment need (complete or partial) from the OHA sample.

This study found that there was a statistically significant ($p<0.001$) difference between self-reported and clinically examined denture treatment need. Overall, 9.2% fewer respondents self-reported the need for denture repair or replacement (46.6%) as compared to clinically assessed denture treatment need (55.8 %) (Table 5-18). A much lower proportion of adults self-reported a treatment need for lower dentures only and a higher proportion of adults self-reported a treatment need for upper dentures only, when compared with clinically assessed treatment need (see Table 5-18). In the OHA sample significantly fewer respondents were aware of their denture treatment need and they were not aware of their need for lower dentures only or for both upper and lower dentures (Table 5-18). There are likely to be several reasons for this divergence in self-reported and clinically examined denture treatment need, one may be the respondent's opinion about the difficulty of wearing a lower complete denture. Apart from this, a higher proportion of adults might have reported upper denture need because of aesthetic concerns. These findings indicate the limitations of self-reporting denture treatment need and the priorities associated with the self-reported evaluation of denture treatment need. Further research is required to evaluate the reasons for this difference.

Question: *Would you say your dental health (mouth, teeth or dentures) is?* (Appendix 1, PH 508)

1. *Excellent*
2. *Very good*
3. *Good*
4. *Fair*
5. *Poor*

This question was asked in the computer-assisted personal interview (CAPI). It came from Wave 3 of the English Longitudinal Study of Adults (ELSA) (English Longitudinal Study of Ageing, 2011).

In this research, self-reported oral health status (excellent, very good, good, fair and poor) had a statistically significant relationship ($p<0.05$) with the objectively measured number of teeth (Kruskal-Wallis test) and 10 or more tooth contacts (Chi-square test). The mean DMFT was also different by self-reported oral health status. These results were similar to the studies of Douglass and colleagues in 1991, Pitiphat and colleagues in 2002, Liu and colleagues in 2010 and Vered and Sgan-Cohen in 2003 (Douglass et al., 1991, Pitiphat et al., 2002, Vered and Sgan-Cohen, 2003, Liu et al., 2010). Adults in this study who self-reported their oral health as 'Excellent', and 'Very good' had a higher mean number of teeth and more of this group had 10 or more tooth contacts than adults who self-reported their oral health 'Fair' and 'Poor' (Table 5-19 and Table 5-20). There was very little difference in the mean number of teeth between adults who self-reported their oral health as, 'Good' (16.9), 'Fair' (16.6) and 'Poor' (16.7) (Table 5-19).

Unlike other studies, in this study the self-reported questionnaire did not ask about the number of teeth so it was not possible to estimate whether the numbers of teeth were over or underestimated, such as in two Scandinavian studies, in which an overestimation of the self-reported number of teeth was reported (Könönen et al., 1986, Palmqvist et al., 1991). In this study, self-reported oral health status was only compared with the objectively measured number of teeth and tooth contacts.

In 1998, Robinson and colleagues reported that adults had moderate sensitivity for the self-reported presence of dental caries (58%) (Robinson et al., 1998). In this study, the adults with clinically examined higher mean number of decayed teeth, self-reported their oral health as ' Poor' (mean decayed teeth 1.6), and 'Fair' (mean decayed teeth 0.8), whereas adults with clinically examined lower mean number of decayed teeth reported their oral health as, 'Excellent' (mean decayed teeth 0.3), 'Very good' (mean decayed teeth 0.3), and 'Good' (mean decayed teeth 0.4). The findings of Robinson and colleagues and this study were similar despite the methodological variations; Robinson and colleagues specifically asked about dental caries from respondents whereas, in this study, a broad question was asked about self-reported oral health status that was then compared with mean DMFT score and mean decayed teeth. In this study, clinically examined dental caries was also found to vary with self-reported oral health status (Table 5-19).

This study also found that despite the statistically significant difference of the self-reported oral health status by CPITN score, the self-reported oral health status was not indicative of clinically examined periodontal health and treatment needs (Table 5-21). Most of the adults were unable to accurately self-report their periodontal health and periodontal treatment need in terms of self-reported oral health status and adults overestimated their self-reported oral health in relation to objectively measured CPITN scores. So this research found that the self-reported oral health status was not a good indicator of objectively measured periodontal health (Table 5-21). Similar to the studies of Tervonen and Knuuttila in 1988, Nagarajan and Pushpanjali in 2008 and Gilbert and Nuttall in 1999, in this study most of those adults who had periodontal disease were unaware of it (Tervonen and Knuuttila, 1988, Gilbert and Nuttall, 1999, Nagarajan and Pushpanjali, 2008).

Question: *In the past 6 months, have any problems with mouth, teeth or dentures caused you to have any of the following?* (Appendix 1, PH 509)

1. *Difficulty eating food*
2. *Difficulty speaking clearly*
3. *Problems with smiling, laughing and showing teeth without embarrassment*
4. *Problems with emotional stability, for example, becoming more easily upset than usual*
5. *Problems enjoying the company of other people such as family, friends, or neighbours*

6. *None of these [code maximum 5 out of 6 possible responses]*

This question was asked in the computer-assisted personal interview (CAPI). It came from Wave 3 of the English Longitudinal Study of Adults (ELSA) (English Longitudinal Study of Ageing, 2011).

The low prevalence of self-reported problems (5.7%) with mouth, teeth or dentures was probably the most striking finding from this question (Table 5-5). These findings were not much different from the findings of the English Longitudinal Study of Ageing (ELSA study) of adults 50 years and over, which reported that overall 8.6% adults (n= 557) (among dentate adults 7.9%, n=422) had at least one difficulty with mouth, teeth or dentures and the most common was eating difficulty 6.2% (n= 407) (Tsakos et al., 2011). Furthermore, among the dentate sample, there was no statistically significant relationship (P>0.05) between self-reported difficulties with mouth, teeth or dentures and objectively measured periodontal health (by maximum CPITN score per person). The adults who reported no difficulties with mouth, teeth or dentures had the highest CPITN scores of, “Healthy”, “Bleeding”, “Calculus”, “Shallow”, and “Deep pockets” (Table 5-24). This suggests that self-reported difficulties with mouth, teeth or denture were not a good indicator of clinically examined periodontal health status.

During analysis, an issue arose in relation to this question (PH 509), which asked if respondents had any type of difficulty with their mouth, teeth or dentures. However, 147 also answered, “None of these” as “No”, so instead of giving 5 out of 6 options which covered the type of problem they had, they answered 6 out of 6 options. This suggests that respondents were unable to understand this question properly or there could be a training issue for interviewers, as this question was asked in CAPI (Computer Assisted Personal Interview). It is suggested to modify this question in next waves or interviewers should be trained with regard to this question, so that respondents can understand it easily. This issue also indicated, how question design is also among one of the factors affecting self-reported data.

Question: *Over the last few years, how often have you visited the dentist?* (Appendix 1, PH 510). This question was asked in the computer-assisted personal interview (CAPI).

1. *More frequently than every 2 years*
2. *Less frequently than every 2 years*
3. *Never*

Question: *If you needed a routine visit for dental care, which one of the following would you attend?* (Appendix 1, PH 511). This question was asked in the computer-assisted personal interview (CAPI).

1. *A general dental practice as a private patient [with or without PRSI reimbursement]*
2. *A general dental practice through the Medical Card Scheme*
3. *A HSE dentist at the local clinic*
4. *A Dental Hospital (either UCC or Trinity College Dublin)*
5. *A dental technician*

The adults who reported visiting a dentist more frequently than every two years and a general dentist as a private patient had a higher mean number of teeth and lower mean DMFT than their counterparts (Table 5-25 and Table 5-28). These findings were similar to those reported in other studies that both self-reported oral health and clinically examined oral health were associated with frequency of dental care utilization (Robinson et al., 1998, Arcury et al., 2012, Adunola et al., 2019). However, this study was different from the study of the Jang and colleagues, who reported among adults aged 60 years and over, that poor oral health was associated with increased frequency of dental visits (Jang et al., 2014). These studies further evaluated the role of other co-factors (socioeconomic, physical and mental health) on the association of oral health (subjective or objective) and frequency of dental visits. Whereas, in this study, only the association of self-reported frequency of dental visits with oral health status (subjective and objective) was evaluated (see Table 5-25 and Table 5-27).

The difference between Jang and colleagues study and this study could be because this study did not include other cofactors associated with the relationship between self-reported frequency of visits and objective oral health (number of teeth, tooth contact and DMFT) as done by other studies (Jang et al., 2014). It could also be because of the better general health of OHA sample than participants of other studies.

The adults who were financially strong (visited a general dentist as a private patient) had a higher mean number of teeth and lower mean DMFT which also indicates the negative impact of poor economic status on oral health status. It can be concluded that among dentate adults in this study, self-reported frequency of dental visits was a good indicator of clinically assessed oral health status and regular dental visits had a positive effect on the mean number of teeth, and tooth contacts though the direction of this relationship needs further research (Table 5-28). These findings of the relationship of self-reported frequency of dental visits and economic status with mean number of teeth were very similar to findings of Adult Dental Health survey in the UK and previous Irish Oral Health Surveys (O'Mullane and Whelton, 1992, Whelton et al., 2007, Fuller et al., 2011).

These findings suggest the self-reported frequency of dental visits was a good indicator of tooth contacts and the mean number of teeth but not a good indicator of periodontal health among the OHA sample (Table 5-26). So, it appears that the self-reported frequency of dental visits was not a good indicator of clinically assessed periodontal health and regular self-reported dental visits did not influence the clinically recorded periodontal status.

In this research, there was no direct question about self-reported treatment needs (except denture treatment need as reported in Table 5-17), such as in the study of Farmer and colleagues in 2017. Nonetheless, the self-reported treatment needs of this research sample could be estimated by self-reported oral health status and difficulties with mouth, teeth or dentures as a proxy for treatment needs. For example, it might be expected that adults who reported ‘Poor’ and ‘Fair’ oral health and difficulties with mouth, teeth or dentures would have more restorative treatment needs than adults with ‘Excellent’ self-reported oral health status. Despite the methodological variations, the results in this study were similar to those in the study by Farmer and colleagues in 2017, who reported moderate agreement between self-reported and objectively measured restorative treatment need (Farmer et al., 2017). In this study, the clinically estimated restorative treatment need (by mean number of teeth and mean DMFT) was also a reflection of self-reported restorative treatment need (using self-reported oral health status as a proxy). The adults with self-reported oral health of ‘Fair’ and ‘Poor’ and self-reported difficulty with mouth, teeth or dentures had a lower objectively measured mean number of teeth, and higher mean DMFT, which suggests that this group might have more restorative treatment need.

This study has also reported that the frequency of dental visits was also a good indicator of normative restorative treatment need, using a lower mean number of teeth, fewer tooth contacts and higher mean DMFT as a proxy for treatment need. This was because the adults who visited more frequently had a higher mean number of teeth, a higher number of tooth contacts and lower mean DMFT which suggests less normative treatment need. These findings were similar to findings of Adunola and colleagues, Arcury and colleagues and Robinson and colleagues (Robinson et al., 1998, Arcury et al., 2012, Adunola et al., 2019).

The comparison of self-reported oral health status with objectively measured periodontal treatment need by CPITN suggested that the self-reported oral health status was not a good indicator of periodontal health and therefore periodontal treatment need, which was also the same as reported by Farmer and colleagues in 2017 (Farmer et al., 2017). It is important to remember that above reported comparisons of this study did not include self-reported dental treatment needs, but included estimated treatment needs calculated by self-reported oral health.

This research also found that subjective oral health assessment may be valuable as an indicator of the demand for treatment not for the need for treatment. For example, most of the respondents had clinically assessed need for lower denture (partial or complete) but their demand for upper denture (partial or complete) was higher than their assessed need for lower denture (Table 5-18). Similarly, periodontal health treatment need was higher as reported by CPITN scores but adults did not report for periodontal treatment need by reporting their oral health as good or excellent (Table 5-21). A possible reason is that periodontal problems are not symptomatic unless very severe and a person may remain unaware of such problems and associated periodontal treatment need. Whereas, other issues such as tooth loss, dental caries and denture discomfort are more noticeable, causing pain, food trapping and difficulties with chewing certain foods.

Among the strengths of the study is that few respondents 'refused to answer' or had 'missing data' (n<10) in the self-reported evaluation of oral health. This makes the results of this study more reliable for comparisons of self-reported oral health with objectively measured oral health and increases its usefulness from the perspective of a longitudinal study. Other studies have reported a significant amount of self-reported data (missing group may have the best oral health or very poor oral health) (Little and Rubin, 2002, Fox-Wasylyshyn and El-Masri, 2005, Taylor et al., 2007, Morgan et al., 2008). In such studies, to avoid bias due to missing data further data analysis techniques, such as deletion and imputation, were required to draw final conclusions about self-reported results (Little and Rubin, 2002, Fox-Wasylyshyn and El-Masri, 2005).

While it was not among the aims of this study, there were no self-reported questions directly related to restorative and periodontal treatment needs (except denture treatment need). Restorative and periodontal treatment needs were estimated by self-reported oral health status as a proxy and were related with clinically examined missing teeth, mean DMFT and CPITN score. Though given the low levels of untreated caries and deep pockets, the levels of self-reported treatment needs might be low. Nonetheless, it would be important to explore whether subjects themselves might identify other priorities related to treatment need, such as aesthetic concerns. Farmer and colleagues asked specific questions in relation to different types of unmet dental treatments to check the validity of self-reported treatment needs against objectively measured treatment needs and found that their questions had overall 78% specificity but low 56% sensitivity. Their study did report 78% sensitivity for the question about the need for restorations but 25% sensitivity for preventive-diagnostics and 29% for periodontal treatments (Farmer et al., 2017).

Cohort age has been reported as an important factor influencing self-reported oral health status (Jones et al., 2001). The exclusion of very old adults and adults with physical disabilities in this study, who did not come for a health assessment in TCD, was also a limitation in the evaluation of the association between self-reported oral health status and objectively measured oral health status. As reported by Liu and colleagues and other studies, older adults tended to overestimate their oral health status (Jones et al., 2001, Sheiham et al., 2002, Sheiham, 2005, Liu et al., 2010). The comparison of the TILDA Wave 3 sample with oral health assessment sample (in the previous section) has already reported that the oral health assessment sample was younger, more educated and had more dentate adults than TILDA Wave 3 sample. All of these factors are likely to have had a bearing on how respondents self-reported their oral health status (Table 4.1).

5.5 Conclusions

From this study it can be concluded that the unstructured and non-specific, self-reported questions to evaluate oral health status cannot fully replace objectively measured oral health and can only provide a general idea regarding the oral health of older adults. Only edentulism and denture wearing were accurately estimated by respondents themselves. Knowing about edentulism accurately using self-reported data is important in epidemiological studies as it reduces the resources required for a clinical epidemiological survey. For example, in the Australian oral health survey of 2004-06, the New Zealand oral health survey of 2009 and the Adult Dental Health survey of the UK in 2009, the adults who self-reported that they were edentate were excluded from clinical examination (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011).

Further study is required to design specific questions for certain oral health indicators and evaluating their validity with objectively measured oral health indicators. For example, for gingival health and bleeding, specific questions might be more valid when compared to clinically examined periodontal health instead of just asking about oral health status and relating it with clinically examined periodontal health. Similarly, specific self-reported questions about different types of treatment needs, such as fillings, extraction and replacement of missing teeth might be more valid compared to clinically examined dental treatment needs. A more representative sample selection in future waves by the participation of the TILDA cohort living at home and in residential care centres would be more informative as it will demonstrate the validity of the self-reported oral health evaluation among the oldest group as well as those with cognitive and physical disabilities. These suggestions will improve the validity of self-reported oral health status and treatment needs and may potentially provide a simpler way of oral health evaluation of large population-based studies used in oral health policymaking.

For the wellbeing of adults, subjective oral health needs are as important as objective needs, although may be different from objective needs. Subjective needs are more likely to be expressed as demand for dental care whereas objective needs may not translate into demand. This research found that self-assessment of oral health status and treatment needs may provide a better insight into the demand (perceived need) for dental treatment but cannot replace the objective assessment of oral health and treatment needs. As reported in the results section, the participants demand for replacement or repair of upper dentures was higher and for lower denture was less than the calculated needs by dentist. Similarly, the self-reported oral health was not influenced by the periodontal treatment need and demand for periodontal treatment was not related with periodontal treatment need recorded by dentist. The difference between demands and needs could be one of the reasons that the adults who need the care most, access it least as reported by Inverse Care Law (Marmot, 2018).

It is recommended to continue with the objective assessment of oral health and treatment needs because this study found that subjective data cannot give accurate information about oral health status and treatment need. Objective assessment of oral health status and treatment need is important to assess the success of dental care available through oral health policy though assessment of subjective needs will inform the likely demand for dental care.

6 Results and discussion of oral health and its relationship with systemic health conditions

6.1 Introduction

Different studies have reported the inter-relationship between oral health and systemic health conditions but this area still needs further research to establish the nature of these relationships; in particular, whether they are associations or causal (Seymour, 2007). Among the links between oral health and systemic health conditions, the most frequently evaluated are those between oral health and diabetes, cardiovascular disease, osteoporosis and cognition. This is because of common risk factors and pathophysiological links between these systemic health conditions and oral health, as reported in the literature review section 2.6 (chapter 2). This section of the research will report the methods, results and discussion on the findings from this research about the relationship between oral health and four systemic health conditions reported above.

6.2 Methods

The TILDA study has gathered extensive data on the systemic health conditions in a nationally representative sample of adults aged 50 years and over, living in Ireland. Among the systemic health conditions, this research evaluated the relationship of diabetes, atherosclerotic cardiovascular disease (ACD), osteoporosis and cognition with the number of teeth and periodontal health. The number of teeth and periodontal health were chosen as there were numerous previous publications that used these parameters. In this study, the distribution of the number of teeth and its transformations did not fulfil the normality assumptions and linear regression had a poor model fit (R=0.01). So, the number of teeth was categorised into three categories (edentate, 1-19 teeth, 20 or more teeth) to evaluate if these systemic health conditions were a risk indicator for the number of teeth. These categories were used because these covered both edentate adults, adults with less than 20 teeth and adults with 20 or more teeth which is the recommended target for retention of teeth among older adults by WHO (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004). Similarly, for periodontal health evaluation, this research used CPITN, which has 5 categories, but for the purpose of analysis, these categories were merged into 3 groups, healthy (CPITN score 0), bleeding and calculus (CPITN score 1 and 2), and periodontal pockets (CPITN score 3 and 4). The grouping of CPITN score was done, as linear regression could not be done because the dependent variable (CPITN) was categorical.

Multinomial regression analysis was used to obtain relative risk ratios (RRR) because both the dependent variables, number of teeth and periodontal health were categorical. To evaluate the independent relationship of the number of teeth and periodontal health with each of the above-mentioned systemic health conditions, each of these systemic health conditions was separately evaluated in four different regression models as reported in this section. The TILDA data provided extensive information about health, socioeconomic and demographic status of respondents. Along with each of the systemic health conditions, the relationship of other cofactors (age, gender, BMI, smoking, education, area of residence) was also evaluated with number of teeth and periodontal health. The criteria used to classify the different systemic health conditions are described below.

6.2.1 Diabetes

The prevalence of diabetes is rapidly increasing in the developed world and it is a leading cause of disability and mortality worldwide (Murray et al., 2012, Wang et al., 2016). It affects 8.3% of adults worldwide and was estimated to increase by 55% by 2030 (Whiting et al., 2011). As reported in the literature review chapter, some studies also reported a bi-directional relationship between diabetes and periodontal disease (Mealey and Oates, 2006, Chapple and Genco, 2013). In this research adults with diabetes were classified as (i) those with self-reported diabetes (doctor diagnosed) in TILDA Wave 1 or Wave 3 or (ii) with self-reported use of diabetes medications (oral hypoglycaemic or insulin) or (iii) adults who self-reported that they had either Type 1 and Type 2 diabetes or (iv) adults with an objectively measured glycosylated haemoglobin (HbA1c) ≥ 48nmol/mol in Wave1 (undiagnosed diabetes and no self-reported data on diabetes, diabetes medication or type of diabetes). The American Diabetic Association provides a cut off value of HbA1c ≥ 48nmol/mol, as undiagnosed diabetes. HbA1c provides an individual average of glycaemic control over the previous 8-12 weeks and is the accepted method of diagnosis of diabetes and prediabetes (American Diabetes Association, 2016).

Using the criteria below, among the OHA sample (n=2504), 21.4% (n= 536) of adults were calculated to have diabetes (Table 6-1). Two multinomial and one logistic regression analyses were used to answer three research questions about the relationship of diabetes with number of teeth and periodontal health.

1. Was diabetes a risk indicator (before and after controlling for other cofactors) for being edentate and having 1-19 teeth relative to have 20 or more teeth?
2. Was diabetes a risk indicator (before and after controlling for other cofactors) for having a CPITN score of bleeding or calculus and shallow or deep pockets relative to have healthy periodontium?

3. Were the number of teeth (before and after controlling for other cofactors) a risk indicator for having diabetes?

Table 6-1: Criteria used to classify adults with diabetes in OHA sample (n= 2504).

Diabetes	**Self-reported**	Self-reported diabetes in TILDA Wave 1 or Wave 3.
		Self-reported Type-1 or Type-2 diabetes in TILDA Wave 1 or Wave 3.
		Taking diabetic medications (oral hypoglycaemic or insulin) Wave 1 or Wave 3.
	Objectively measured	HbA1c ≥ 48nmol/mol in Wave 1 and no self-reported diabetes or no use of diabetic medications (oral hypoglycaemic or insulin) in Wave 1 or Wave 3.
No diabetes		No self-reported diabetes in Wave 3 or Wave 1, no data of taking diabetic medications and HbA1c <48nmol/mol in Wave 1.

6.2.2 Heart disease

Among the TILDA-CAPI questions, there was no direct question about ACD (atherosclerotic cardiovascular disease) (Whelan and Savva, 2013). The rationale for choosing "Atherosclerotic cardiovascular disease (ACD)" for this analysis was that there is a pathophysiological link between certain oral health conditions (periodontal health and tooth loss) and ACD (Iwai, 2009, Kebschull et al., 2010, Tonetti and Dyke, 2013). The studies reported in the literature review section also evaluated the relationship between ACD and periodontal health (Saremi et al., 2005, Holmlund et al., 2006, Al-Emadi et al., 2006, Bahekar et al., 2007, Humphrey et al., 2008, Dietrich et al., 2008, Kebschull et al., 2010) and ACD and tooth loss (Cabrera et al., 2005, Holmlund et al., 2010, Polzer et al., 2012, Schwahn et al., 2013, Wiener and Sambamoorthi, 2014). (for details see Chapter 2, section 2.6.3).

In order to calculate the adults with atherosclerotic cardiovascular disease (ACD), those included had self-reported conditions related to atherosclerotic cardiovascular disease (ACD) (stroke, heart attack, mini-stroke and angina) and had an increased objectively measured pulse wave velocity (PWV). In TILDA Wave 3, the average of two PWV measurements between the carotid and femoral arteries was obtained using a Vicorder®, which is the gold standard, non-invasive method of measuring arterial stiffness. The European Society of Hypertension and the European Society of

Cardiology suggest that PWV of >12 m/s is indicative of asymptomatic organ damage affecting the heart, brain, kidney, eye or peripheral arteries (Mancia et al., 2013). So, this value of PWV > 12 m/s was used as indicative of atherosclerotic ACD. The criteria used to categorise adults with atherosclerotic cardiovascular disease were as follows.

Table 6-2: Criteria used to classify adults with atherosclerotic cardiovascular disease in the OHA sample (n= 2504).

Atherosclerotic cardiovascular disease Yes	**Self-reported**	Stroke - Wave 1 or Wave 3
		Mini stroke - Wave 1 or Wave 3
		Angina - Wave 1 or Wave 3
		Heart attack - Wave 1 or Wave 3
	Objectively measured	Pulse wave velocity >12m/s in Wave 3
No atherosclerotic heart disease		None of the above self- reported and pulse wave velocity <12m/s

Adults who self-reported any of the above conditions in TILDA Wave 1 or Wave 3 and those with objectively measured pulse wave velocity >12m/s as per European Society of Hypertension and European Society of Cardiology, were classified to have atherosclerotic heart disease (Mancia et al., 2013). By these criteria, among the TILDA Wave 3 OHA sample (n=2504), 30.4% (n= 760) had the conditions suggestive (reported/recorded) of ACD (Table 6-2).

Two multinomial regression analyses were used to answer the two research questions for the relationship of ACD with number of teeth and periodontal health.

1. Was ACD a risk indicator (before and after controlling for other cofactors) for having CPITN score of bleeding or calculus and shallow or deep pockets relative to have healthy periodontium?
2. Was ACD a risk indicator (before and after controlling for other cofactors) for being edentate and having 1-19 teeth relative to have 20 or more teeth?

6.2.3 Osteoporosis

In the TILDA health assessment, the osteoporosis was assessed using quantitative ultrasound of the calcaneus or heel bone (Achilles Heel Ultrasound, Lunar, Madison, USA). This device measures the broadband ultrasound attenuation (BUA) and the speed of sound (SOS) and t-score. The stiffness index is calculated using the BUA and SOS and is a better predictor of fracture risk than

BUA or SOS alone, however, it is important to mention that it is not diagnostic (Schott et al., 1995).

Table 6-3: Criteria used to classify adults with osteoporosis in OHA sample (n=2504).

Osteoporosis	**Self-reported**	Osteoporosis - Wave 3 or Wave 1
	Objectively measured	WHO recommended T-score <-2.5
		Bone stiffness index ≤ 65%
No osteoporosis		No self-reported osteoporosis in Wave 3 and Wave 1, T-score> -2.5 and bone stiffness index > 65%

An individual is considered to have osteoporosis, osteopenia or normal bone density if the stiffness index is ≤65%, 66-86%, or >86% respectively (Varenna et al., 2005). Similarly, the WHO recommended T-score calculation is that the individual is healthy (T-score is >-1), having osteopenia (T-score is between -1 and -2.5) and osteoporosis (T-score is < -2.5) (WHO Scientific Group on the Prevention and Management of Osteoporosis, 2003). In this research, the criteria used to classify the adults with osteoporosis can be seen in Table 6-3.

Among the OHA sample (n=2504), 20.4% (n=511) of adults met the criteria of having osteoporosis. Two multinomial and one logistic regression analysis were used to answer the three research questions for the relationship of osteoporosis with number of teeth and periodontal health.

1. Was osteoporosis a risk indicator (before and after controlling for other cofactors) for being edentate and having 1-19 teeth relative to have 20 or more teeth?
2. Was osteoporosis a risk indicator (before and after controlling for other cofactors) for having CPITN score of bleeding or calculus and shallow or deep pockets relative to have healthy periodontium?
3. Was number of teeth (before and after controlling for other cofactors) a risk indicator for having osteoporosis?

6.2.4 Cognition

A global cognitive ability test, the Montreal Cognitive Assessment score (MoCA) from the TILDA Wave 3 health assessment data, was used to evaluate the relationship of cognition with number of teeth and periodontal health among the OHA sample (n=2504). This test assesses function across multiple domains of cognition including memory recall, visuospatial ability, executive function, attention, language, and orientation to time/place. The test is frequently used in clinical practice and has a maximum score of 30 (Nasreddine et al., 2005). MoCA score was used as a continuous predictor (independent) variable in the regression model. Two multinomial analyses were done to answer two research questions for the relationship of cognition with the number of teeth and periodontal health.

1. Was a decrease in MoCA score a risk indicator (before and after controlling for other cofactors) for having CPITN score of bleeding or calculus and shallow or deep pockets relative to have healthy periodontium?
2. Was a decrease in MoCA score a risk indicator (before and after controlling for other cofactors) for being edentate and having 1-19 teeth relative to have 20 or more teeth?

6.2.5 Other Cofactors

Along with each of the systemic health conditions, other cofactors (predictors) included as categorical variables were, age group (3 categories, 50-64 years, 65-74 years and 75 years and over), gender (male and females), BMI (3 categories, normal 18.5 to 24.9, overweight 25.0-29.9 and obese ≥ 30.0), smoker (3 categories, never, former and current), education (3 categories, primary or no education, secondary, and third-level or higher) and area of residence (3 categories, Dublin city or county, another town or city and rural area).

6.3 Results

This section will report descriptive statistics of predictor variables by the categories of factor variables (periodontal health and number of teeth), results of multinomial regression with each of systemic health condition individually, results of logistic regression analysis of diabetes and osteoporosis as factor variables and discussion related to these results.

6.3.1 Descriptive statistics of predictor variables by the categories of factor variables

As reported in methods section the respondents were categorised into three categories by maximum CPITN score: Healthy periodontium (CPITN score 0), bleeding/calculus (CPITN score 1 and 2), and periodontal pockets (CPITN score 3 and 4). The relationship of periodontal health with systemic health conditions along with other socioeconomic factors, was evaluated among dentate sample only (n= 2255). However, the adults with maximum CPITN score of, “X” were also omitted from the sample as these did not have sufficient numbers of teeth to carry out the CPITN assessment. So, the final sample for this analysis was of, n= 2197 dentate adults. Table 6-4 reports descriptive statistics of the independent variables by categories of the dependent variable, periodontal health.

For multinomial regression analysis, respondents were categorised into 3 categories according to the number of teeth; (i) edentate, (ii) with 1-19 teeth and (iii) with ≥ 20 teeth as reported in methods. This was done as the distribution of the number of teeth and its transformations did not fulfil the normality assumptions, so it was not possible to keep the number of teeth as a continuous dependent variable in the regression model. The relationship of number of teeth with systemic health conditions, along with different socioeconomic factors, was evaluated among the full OHA sample (Edentate/dentate, n= 2504). The prevalence and descriptive statistics of predictor variables by number of teeth categories (factor variable) are reported in Table 6-5.

Table 6-4: Prevalence and descriptive statistics of predictor variables by periodontal health categories (Base-dentate, n=2197 and excluded, n=58).

Predictor Variables	**Descriptive statistics of predictor variables by categories of periodontal health (n=2197)**			
	Healthy (CPITN score 0) (n= 131)	**Bleeding & calculus (CPITN score 1 and 2) (n= 793)**	**Shallow & deep pockets (CPITN score 3 and 4) (n= 1273)**	**Chi-Square P value**
Age group				P<0.001
50-64 years	61 (5.3%)	379 (32.7%)	719 (62.0%)	
65-74 years	47 (6.0%)	301 (38.5%)	434 (55.5%)	
75 years and over	23 (9.0%)	113 (44.1%)	120 (46.9%)	
Gender				P<0.001
Male	45 (4.6%)	317 (32.2%)	623 (63.3%)	
Female	86 (7.1%)	476 (39.3%)	650 (53.6%)	
BMI				P=0.007
Normal weight	49 (6.8%)	297 (40.9%)	380 (52.3%)	
Overweight	53 (5.5%)	325 (33.7%)	587 (60.8%)	
Obese	29 (5.7%)	171 (33.8%)	306 (60.5%)	
Smoker				P=0.001
No smoker	63 (5.8 %)	425 (39.2%)	596 (55.0 %)	
Former smoker	60 (6.6 %)	318 (34.7%)	538 (58.7 %)	
Current smoker	8 (4.1 %)	50 (25.4%)	139 (70.6 %)	
Education				P= 0.729
Primary	19 (5.2%)	140 (38.4%)	206 (56.4%)	
Secondary	52 (5.9%)	309 (34.8%)	526 (59.3%)	
Third level/higher	60 (6.4%)	344 (36.4%)	541(57.3%)	
Locality				P<0.001
Dublin/Co-Dublin	53 (8.6 %)	277 (44.9%)	287 (46.5%)	
Another town/city	26 (4.5 %)	196 (33.7%)	359 (61.8%)	
Rural area	52 (5.2 %)	320 (32.0%)	627 (62.8%)	
Diabetes				P=0.185
No diabetes	100 (5.7%)	646 (37.0%)	1000 (57.7%)	
Diabetic	31 (6.9%)	147 (32.6%)	273 (60.5%)	
Atherosclerotic cardiovascular disease				P=0.018
No	85(5.4%)	552(35.0%)	942 (59.7 %)	
Yes	46 (7.4%)	241 (39.00%)	331 (53.6 %)	
Osteoporosis				P=0.016
No	100 (5.7%)	618 (34.9%)	1051 (59.4 %)	
Yes	31 (7.2%)	175 (40.9%)	222 (51.9%)	

Table 6-5: Prevalence and descriptive statistics of predictor variables by number of teeth categories (Base-edentate and dentate, n=2504).

Predictor Variables	**Descriptive statistics of predictor variables by categories of number of teeth (n= 2504)**			
	Edentate (n= 249)	**1-19 teeth (n= 895)**	**20 or more teeth (n 1360)**	**Chi-square P values**
Age group				P<0.001
50-64 years	48 (3.9%)	292 (24.0%)	878 (72.1%)	
65-74 years	107 (11.7%)	422 (46.1%)	387 (42.3%)	
75 years and over	94 (25.4%)	181 (48.9%)	95 (25.7 %)	
Gender				P=0.001
Male	90 (8.0%)	439(39.2 %)	591 (52.8%)	
Female	159 (11.5%)	456 (33.0%)	769 (55.6%)	
BMI				P=0.004
Normal weight	80 (9.8%)	255 (31.2%)	482 (35.44%)	
Overweight	101 (9.2%)	410 (37.3%)	588 (53.5%)	
Obese	68 (11.6%)	230 (39.1%)	290 (49.3%)	
Smoker				P<0.001
Never	105 (8.7%)	386 (32.1%)	713 (59.2%)	
Former smoker	117 (10.9 %)	413 (38.6%)	541 (50.5%)	
Current smoker	27 (11.8 %)	96 (41.9%)	106 (46.3%)	
Education				P<0.001
Primary	97 (20.3%)	228 (47.7 %)	153 (32.0 %)	
Secondary	94 (9.4%)	385 (38.4 %)	523 (52.2 %)	
Third level/higher	58 (5.7%)	282 (27.6 %)	683 (66.8 %)	
Area of residence				P<0.001
Dublin/Co-Dublin	47 (6.9 %)	224 (32.9%)	409 (60.2%)	
Another town/city	64 (9.7 %)	230 (34.8%)	367 (55.5%)	
Rural area	138 (11.9%)	441 (37.9%)	584 (50.2%)	
Diabetes				P<0.001
No diabetes	181 (9.2 %)	676 (34.4%)	1,111 (56.5%)	
Diabetic	68 (12.7 %)	219 (40.9%)	249 (46.5%)	
Atherosclerotic heart disease				P<0.001
No	152 (61.04 %)	540 (60.34 %)	1,052 (77.35 %)	
Yes	97 (12.8 %)	355 (46.7 %)	308 (40.5 %)	
Osteoporosis				P<0.001
No	173 (8.7%)	693 (34.8 %)	1,127 (56.6%)	
Yes	76 (14.9%)	202 (39.5 %)	233 (45.6 %)	

6.3.2 Periodontal health and number of teeth relationship with diabetes

According to criteria reported in Table 6-1, among the OHA sample (n= 2504), 21.4% adults (n= 536) were calculated to have diabetes (Table 6-1).

Table 6-6: Multinomial regression analysis of diabetes and other factors associated with periodontal health categories (Base-dentate, n= 2197). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with bleeding & calculus (n= 793) and shallow & deep pockets (n= 1273) compared to healthy periodontium (n= 131) as base.**			
	Bleeding & calculus		**Shallow & deep pockets**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of diabetes with periodontal health conditions	0.73 (0.47-1.14)	0.169	0.88 (0.58 - 1.35)	0.557
After controlling for other cofactors				
Diabetes (No diabetes)				
Yes	0.74 (0.48 -1.16)	0.189	0.89 (0.58 - 1.37)	0.597
Age group (50-64 years)				
65-74 years	0.99 (0.65 -1.50)	0.960	0.79 (0.53 - 1.19)	0.266
75 years and over	0.76 (0.44 - 1.31)	0.318	0.48 (0.28 - 0.82)	0.007
Gender (Male)				
Female	0.75 (0.50 - 1.11)	0.151	0.54 (0.37 - 0.80)	0.002
BMI (Normal weight)				
Overweight	0.95 (0.62 - 1.46)	0.820	1.24 (0.81 - 1.89)	0.315
Obese	0.95 (0.57 - 1.57)	0.832	1.21 (0.73 - 1.98)	0.461
Smoker (Non-smoker)				
Former smoker	0.75 (0.51 - 1.10)	0.139	0.85 (0.58 - 1.25)	0.411
Current smoker	0.84 (0.38 - 1.89)	0.679	1.57 (0.72 - 3.40)	0.254
Education (Primary)				
Secondary	0.79 (0.45 - 1.40)	0.420	0.89 (0.51 - 1.57)	0.689
Third level/higher	0.77 (0.43 - 1.36)	0.363	0.88 (0.50 - 1.55)	0.663
Locality (Dublin/Co-Dublin)				
Another town/city	1.44 (0.87 - 2.39)	0.159	2.42 (1.47 - 3.98)	0.001
Rural area	1.13 (0.74 - 1.72)	0.578	2.02 (1.33 - 3.05)	0.001

Regression analysis in Table 6-6 shows that diabetes did not have a statistically significant relationship with the periodontal health categories before and after controlling for other cofactors (age, gender, BMI, smoking, education, area of residence). Among other cofactors, being female (p = 0.002, RRR = 0.54, CI=0.37-80) and age 75 years and over (p=0.007, RRR= 0.48, CI= 0.28-0.82) decreased while living in another city/town (p = 0.001, RRR = 2.42, CI=1.47-3.98) and in a rural area (p = 0.001, RRR = 2.02, CI=1.33-3.05) increased the risk of having shallow and deep pockets compared to have healthy periodontium.

Table 6-7 shows that diabetes was a risk indicator for being edentate and having 1-19 teeth. Adults with diabetes were at higher risk of being edentate (p = 0.001, RRR = 1.68, CI=1.23-2.29) and having 1-19 teeth (p < 0.001, RRR = 1.45, CI=1.18-1.78) teeth relative to have 20 or more teeth. After controlling for other cofactors; age, gender, BMI, smoking, education and area of residence, adults with diabetes were also at higher risk of being edentate (p = 0.010, RRR = 1.58, CI=1.12-2.23) and have 1-19 teeth (p = 0.005, RRR = 1.38, CI=1.10-1.73) relative to having 20 or more teeth.

Table 6-7 also shows that among other cofactors, old age, obesity, living in a rural area, smoking, increased the relative risk of being edentate and having 1-19 teeth relative to have 20 or more teeth. Increase in the education level decreased the risk of being edentate and having 1-19 teeth. However, being overweight did not increase the risk of being edentate (p= 0.831) but increased the risk of having 1-19 teeth (p = 0.034, RRR= 1.27, CI=1.01-1.58) compared to having 20 or more teeth. Being a female, increased the risk of being edentate (p <0.001, RRR=2.16, CI =1.57-2.97) but did not increase the risk of having 1-19 teeth (p=0.568) relative to have 20 or more teeth. Among all cofactors, the age group 75 years and over was highly associated with edentulism (p <0.001, RRR = 28.42, CI=18.02-44.82) and having 1-19 teeth (p <0.001, RRR=7.35, CI=5.42-9.97) compared to have 20 or more teeth.

Table 6-7: Multinomial regression analysis of diabetes and other factors associated with number of teeth categories (Base-edentate and dentate, n=2504). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with edentulism (n=249) and 1-19 teeth (n=895) compared to (base) 20 or more teeth possession (n=1360)**			
	Edentate		**1-19 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of diabetes with number of teeth	1.68 (1.23- 2.29)	0.001	1.45 (1.18-1.78)	<0.001
After controlling for other cofactors Diabetes (No diabetes)				
Yes	1.58 (1.12- 2.23)	0.010	1.38 (1.10 – 1.73)	0.005
Age group (50-64 years)				
65-74 years	5.38 (3.67 - 7.89)	<0.001	3.43 (2.79 - 4.20)	<0.001
75 years and over	28.42 (18.02-44.82)	<0.001	7.35 (5.42 - 9.97)	<0.001
Gender (Male)				
Female	2.16 (1.57 - 2.97)	<0.001	1.06 (0.86 - 1.28)	0.568
BMI (Normal weight)				
Overweight	1.04 (0.73 – 1.48)	0.831	1.27 (1.01 - 1.58)	0.034
Obese	1.53 (1.02 - 2.28)	0.040	1.51 (1.17 - 1.95)	0.002
Smoker (Non-smoker)				
Former smoker	1.99 (1.44 - 2.76)	<0.001	1.50 (1.23 - 1.82)	<0.001
Current smokers	3.34 (1.97- 5.66)	<0.001	2.27 (1.64 3.16)	<0.001
Education (Primary)				
Secondary	0.36 (0.25 - 0.52)	<0.001	0.64 (0.49 - 0.83)	0.001
Third level/higher	0.18 (0.12 - 0.27)	<0.001	0.37 (0.29 - 0.49)	<0.001
Locality (Dublin/Co-Dublin)				
Another town/city	1.95 (1.26 - 2.03)	0.003	1.27 (0.99 - 1.64)	0.064
Rural area	3.60 (2.43 - 5.35)	<0.001	1.83 (1.45 - 2.30)	<0.001

Studies have reported a bidirectional relationship between oral health and diabetes. An evaluation was done to determine if either the number of teeth increased the risk of having diabetes. Logistic regression analysis was carried out by keeping diabetes as the dependent variable and the independent variables were number of teeth (continuous variable), age group, gender, BMI, smoking, education and area of residence (categorical variables).

Table 6-8: Logistic regression analysis of factors associated with diabetes (Base-edentate and dentate, n=2504). OR is odds ratio.

Predictor Variables (Reference value)	**Factors associated with diabetes (n= 536) compared to no diabetes (n= 1968). Total n= 2504. Model p=0.0001**	
	OR (95% CI)	**P value**
Relationship of number of teeth with diabetes	0.98 (0.97 - 0.99)	<0.001
After controlling for other factors Number of teeth with diabetes	0.98 (0.97 - 0.10)	<0.001
Age group (50-64 years)		
50-74 years	0.99 (0.79 - 1.23)	0.899
75 years and over	1.22 (0.90 - 1.67)	0.200
Gender (Male)		
Female	0.87 (0.71 - 1.06)	0.165
BMI (Normal weight)		
Overweight	1.03 (0.81 - 1.30)	0.816
Obese	1.48 (1.14 - 1.92)	0.003
Smoker (Non-smoker)		
Former smoker	1.06 (0.86 - 1.30)	0.597
Current smoker	1.17 (0.83 - 1.66)	0.373
Education (Primary)		
Secondary	0.94 (0.72 - 1.23)	0.658
Third level/higher	1.12 (0.84 - 1.46)	0.471
Locality (Dublin/Co-Dublin)		
Another town/city	1.08 (0.83 - 1.41)	0.557
Rural area	0.93 (0.73 - 1.18)	0.527

Table 6-8 shows that number of teeth was a risk indicator (OR = 0.98, CI=0.97-0.99) for diabetes and a one-unit increase in the number of teeth reduced the risk of being diabetic. This relationship was also present after controlling for other cofactors (age, gender, BMI, smoking, area of residence and education level). Among other cofactors, being obese increased the risk of having diabetes (p=0.003, OR=1.48, CI=1.14-1.92). It was further evaluated that periodontal health status did not influence being diabetic.

6.3.3 Periodontal health and number of teeth relationship with atherosclerotic cardiovascular disease

Using the criteria reported in Table 6-2, among the TILDA Wave 3 OHA sample (n=2504), 30.4% (n=760) adults had any condition suggestive of atherosclerotic cardiovascular disease (ACD).

Table 6-9: Multinomial regression analysis of ACD and other factors associated with periodontal health categories (Base-dentate, n=2197). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with Bleeding & calculus (n= 793) and Shallow & deep pockets (n= 1273)) compared to (base) Healthy periodontium (n= 131)**			
	Bleeding & calculus		**Shallow & deep pockets**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of ACD with periodontal health.	0.81 (0.57 - 1.19)	0.280	1.65 (1.44 - 1.95)	0.026
After controlling for other factors				
ACD (No)				
ACD Yes	0.80 (0.51 - 1.23)	0.308	0.68 (0.44 - 1.05)	0.790
Age group (50-64 years)				
65-74 years	1.04(0.68 - 1.61)	0.852	0.87 (0.57 - 1.32)	0.509
75 years and over	0.83 (0.46 - 1.50)	0.545	0.58 (0.32 - 1.04)	0.066
Gender (Male)				
Female	0.73 (0.48 - 1.09)	0.122	0.51 (0.35 - 0.76)	0.001
BMI (Normal weight)				
Overweight	0.95 (0.62 - 1.46)	0.824	1.24 (0.82 - 1.90)	0.310
Obese	0.93 (0.56 - 1.54)	0.780	1.21 (0.74 - 1.98)	0.459
Smoker (Non-smoker)				
Former smoker	0.75 (0.51 - 1.10)	0.139	0.86 (0.59 - 1.26)	0.438
Current smoker	0.86 (0.38 - 1.92)	0.708	1.63 (0.75 - 3.55)	0.217
Education (Primary)				
Secondary	0.78 (0.44 - 1.39)	0.404	0.88 (0.50 - 1.55)	0.656
Third level/higher	0.76 (0.43 - 1.35)	0.352	0.88 (0.50 - 1.57)	0.647
Locality (Dublin/Co-Dublin)				
Another town/city	1.43 (0.86 - 2.37)	0.170	2.39 (1.45 - 3.93)	0.001
Rural area	1.12 (0.74 - 1.72)	0.587	2.00 (1.32 - 3.03)	0.001

Table 6-9 reports the relationship of periodontal health with ACD and other cofactors, among the dentate sample. Multinomial regression analysis reported that ACD was not associated with bleeding and calculus (p=0.280) but it increased the risk (predictor) for shallow and deep pockets (RRR= 1.65, CI=1.44-1.95).

After controlling for other cofactors in the model (age, gender, smoking, BMI, education and area of residence), there was no relationship of ACD with bleeding and calculus (p= 0.308) or with shallow and deep pockets (p= 0.790). Among other cofactors, age, BMI, smoking, education, did not have a statistically significant relationship with any periodontal health condition. However, being a female (p = 0.001, RRR =0.51, CI=0.35-0.76), living in another town/city (p = 0.001, RRR = 2.39, CI=1.45-3.93), and in rural area (p = 0.001, RRR= 2.00, CI=1.32-3.03) increased the relative risk of having shallow or deep pockets compared to healthy periodontium (Table 6-9).

Table 6-10: Multinomial regression analysis of ACD and other factors associated with number of teeth categories among OHA sample (Base-edentate and dentate, n=2504). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Adults with edentulism (n=249) and less than 20 teeth (n= 895) compared to (base) 20 or more teeth (n= 1360)**			
	Edentate		**1-19 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P value**
Relationship of ACD with number of teeth	2.18 (1.64 - 2.90)	<0.001	2.25 (1.87 - 2.70)	<0.001
After controlling for other cofactors. (No ACD)				
ACD Yes	1.01 (0.73 - 1.42)	0.934	1.33 (1.07 - 1.65)	0.009
Age group (50-64 years)				
65-74 years	5.36 (3.64 - 7.90)	<0.001	3.21 (2.61 - 3.96)	<0.001
75 years and over	28.63 (17.75 - 46.19)	<0.001	6.51 (4.72- 8.97)	<0.001
Gender (Male)				
Female	2.12 (1.54 - 2.93)	<0.001	1.09 (0.90 - 1.34)	0.362
BMI (Normal weight)				
Overweight	1.05 (0.74 - 1.49)	0.792	1.27 (1.02 - 1.58)	0.033
Obese	1.57 (1.05 - 2.34)	0.027	1.54 (1.20 - 1.99)	0.001
Smoker (Non-smoker)				
Former smoker	1.99 (1.45 - 2.76)	<0.001	1.48 (1.22 - 1.81)	<0.001
Current smoker	3.36 (1.98 - 5.69)	<0.001	2.23 (1.61 - 3.10)	<0.001
Education (Primary)				
Secondary	0.36 (0.25 - 0.52)	<0.001	0.64 (0.50-0.83)	0.001
Third level/higher	0.18 (0.12 - 0.27)	<0.001	0.38 (0.29 - 0.49)	<0.001
Locality (Dublin/Co-Dublin)				
Another town/city	1.96 (1.27 - 3.05)	0.0003	1.29 (1.00 - 1.66)	0.051
Rural area	3.58 (2.41 - 5.32)	<0.001	1.83 (1.46 - 2.30)	<0.001

Table 6-10 shows that atherosclerotic cardiovascular disease (ACD) had a statistically significant relationship with edentulism and having 1-19 teeth. The adults with ACD, were at a higher relative risk of being edentate (RRR 2.18, CI=1.64-2.90) and having 1-19 teeth (RRR 2.25, CI=1.87-2.70) as compared to having 20 or more teeth. However, after controlling for other variables in the model, having ACD was not a risk indicator for being edentate (p = 0.934). But adults with ACD were at a higher relative risk of having 1-19 teeth (p=0.009, RRR 1.33, CI=1.07-1.65) compared to having 20 or more teeth.

It was further evaluated that even after controlling for diabetes along with other cofactors, the significant relationship was present between ACD and edentulism and 1-19 teeth. The regression model in Table 6-10 also suggested that older age, obesity, being a current or former smoker and living away from Dublin or Co Dublin increased the risk of being edentate and have 1-19 teeth compared to have 20 or more teeth. However, being overweight was not a risk indicator for edentulism (p = 0.792) but increased the risk of having 1-19 teeth (p = 0.033, RRR = 1.27, CI=1.02-1.58) compared to have 20 or more teeth. Being a female, only increased the risk of being edentate (p<0.001, RRR = 2.12, CI=1.54-2.93) but had no relationship with having 1-19 teeth (p = 0.362) relative to 20 or more teeth. Increase in the education level decreased the risk of being edentate and having 1-19 teeth (Table 6-10).

6.3.4 Periodontal health and number of teeth relationship with osteoporosis

Among the OHA sample (n=2504), 20.4% (n=511) of adults met the criteria for being classified as having osteoporosis (self-reported or objectively measured) (Table 6-3).

Table 6-11 shows the relationship of periodontal health (dependent variable) with osteoporosis (independent variable) before and after controlling for other cofactors of age, gender, smoking, BMI, education and area of residence. It shows that osteoporosis did not have a statistically significant relationship (before and after controlling for other cofactors) with periodontal health. However, being female and living in another town/city increased the risk of having shallow and deep pockets.

Table 6-11: Multinomial regression analysis of osteoporosis and other factors associated with periodontal health categories (Base-dentate, n=2197). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with Bleeding & calculus (n=793) and Shallow & deep pockets (n=1273)) compared to (base) Healthy periodontium (n=131)**			
	Bleeding & calculus		**Shallow & deep pockets**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of osteoporosis with periodontal health	0.91 (0.59 - 1.41)	0.684	0.68 (0.44 -1.05)	0.079
After controlling for other factors				
Osteoporosis (No)				
Yes	0.97 (0.61 - 1.56)	0.911	0.90 (0.57 - 1.43)	0.663
Age group (50-64 years)				
65-74 years	0.99 (0.65 - 1.51)	0.961	0.80 (0.53 - 1.21)	0.290
75 years and over	0.74 (0.43 - 1.28)	0.288	0.48 (0.28 - 0.83)	0.008
Gender (Male)				
Female	0.76 (0.50 - 1.14)	0.186	0.55 (0.37 - 0.83)	0.004
BMI (Normal weight)				
Overweight	0.95 (0.62 - 1.46)	0.804	1.23 (0.80 - 1.88)	0.344
Obese	0.92 (0.55 - 1.53)	0.746	1.18 (0.71 - 1.94)	0.525
Smoker (Non-smoker)				
Former smoker	0.74 (0.50 - 1.09)	0.132	0.85 (0.58 - 1.24)	0.400
Current smoker	0.84 (0.37 - 1.87)	0.662	1.57 (0.72 - 3.40)	0.256
Education (Primary)				
Secondary	0.79 (0.45 - 1.40)	0.415	0.89 (0.51 - 1.56)	0.679
Third level/higher	0.76 (0.43 - 1.35)	0.353	0.88 (0.50 - 1.54)	0.644
Locality (Dublin/Co-Dublin)				
Another town/city	1.44 (0.87 - 2.39)	0.161	2.42 (1.47 - 3.99)	0.001
Rural area	1.13 (0.74 - 1.72)	0.570	2.02 (1.33 - 3.06)	0.001

Table 6-12 shows that there was a statistically significant ($p<0.001$) relationship between number of teeth and osteoporosis.

Table 6-12: Multinomial regression analysis of osteoporosis and other factors associated with number of teeth categories (Base-edentate and dentate, n=2504). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Adults with edentulism (n=249) and 1-19 teeth (n=895) compared to (base) 20 or more teeth (n=1360)**			
	Edentate		**Less than 20 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of osteoporosis with number of teeth	2.13 (1.57- 2.89)	<0.001	1.41 (1.14 - 1.74)	<0.001
After controlling for other cofactors Osteoporosis (No)				
Osteoporosis yes	1.30 (0.90 - 1.88)	0.159	1.30 (1.02 - 1.67)	0.034
Age group (50-64 years)				
65-74 years	5.26 (3.58 - 7.71)	<0.001	3.35 (2.73 - 4.11)	<0.001
75 years and over	27.98 (17.67 - 44.35)	<0.001	7.22 (5.32 - 9.81)	<0.001
Gender (Male)				
Female	2.00 (1.43 - 2.80)	<0.001	0.99 (0.81 - 1.21)	0.919
BMI (Normal weight)				
Overweight	1.08 (0.76 - 1.54)	0.675	1.31 (1.05 - 1.63)	0.017
Obese	1.64 (1.10 - 2.46)	0.016	1.61 (1.25 - 2.09)	<0.001
Smoker (Non-smoker)				
Former smoker	2.02 (1.46 - 2.79)	<0.001	1.51 (1.24 - 1.84)	<0.001
Current smoker	3.37 (1.99 – 5.71)	<0.001	2.27 (1.64 - 3.15)	<0.001
Education (Primary)				
Secondary	0.36 (0.25 - 0.52)	<0.001	0.63 (0.49 - 0.82)	0.001
Third level/higher	0.18 (0.12 - 0.27)	<0.001	0.38 (0.29 - 0.49)	<0.001
Locality (Dublin/Co-Dublin)				
Another town/city	1.95 (1.26 - 3.02)	<0.001	1.26 (0.98 - 1.63)	0.071
Rural area	3.56 (2.40 - 5.29)	<0.001	1.81 (1.44 - 2.28)	<0.001

Table 6-12 shows osteoporosis was a risk indicator for being edentate ($p < 0.001$, RRR = 2.13, CI= 1.57-2.89) and having 1-19 teeth (p= 0.001, RRR 1.41, CI=1.14-1.74) compared to having 20 or more teeth. However, after controlling for other variables (age, gender, BMI, smoking, education and area of residence) in the model, the adults with osteoporosis were only at higher risk of having 1-19 teeth (p= 0.034, RRR 1.30, CI=1.02-1.67) relative to have 20 or more teeth. There was no relationship between osteoporosis and being edentate (p= 0.159) relative to have 20 or more teeth, after controlling for other cofactors (age, gender, BMI, smoking, education and area of residence) (Table 6-12).

Table 6-12 also shows that among other cofactors, age group, obesity, smoking (current and former), education level and living in a rural area had significant relationship with number of teeth. However, being female ($p<0.001$, RRR = 2.00, CI=1.43-2.80) and living in another town/city only increased the risk of being edentate ($p<0.001$, RRR = 1.95, CI=1.26-3.02) and were not significantly related with having 1-19 teeth when compared with having 20 or more teeth. Being overweight increased the risk of having 1-19 teeth ($p = 0.017$, RRR =1.31, CI=1.05-1.63) and was not a risk indicator for being edentate ($p= 0.675$) compared to have 20 or more teeth.

Further evaluation was carried out as to whether number of teeth was a risk indicator for osteoporosis. Logistic regression analysis was carried out by keeping osteoporosis as the dependent variable and the independent variables were number of teeth (continuous variable), age group, gender, smoking, BMI, area of residence and education level (categorical variables). It was found that with a one-unit increase in the number of teeth, the risk of having osteoporosis decreased by 0.97 (OR = 0.97, CI=0.96-0.98). Table 6-13 shows that this relationship was also present (OR = 0.99, CI=0.97-1.0) after controlling for other cofactors (age, gender, BMI, smoking, education and area of residence). Among other cofactors, increase in age, being female and BMI, increased the risk of having osteoporosis. However, there was no significant relationship between smoking and osteoporosis. It was further evaluated that periodontal health did not influence osteoporosis.

Table 6-13: Logistic regression analysis of factors associated with osteoporosis (Base-edentate and dentate, n=2504). OR is odds ratio.

Predictor Variables (Reference value)	**Factors associated with osteoporosis (n=511) compared to no osteoporosis (n=1993) Total n=2504, Model p=0.0001**	
	OR (95% CI)	**P value**
Relationship of number of teeth with osteoporosis		
Number of teeth as continuous variable in predictors	0.97 (0.96 - 0.98)	<0.001
After controlling for other factors relationship of number with osteoporosis		
Number of teeth	0.99 (0.97 - 1.0)	0.023
Age group (50-64 years)		
65-74 years	1.82 (1.41 - 2.33)	<0.001
75 years and over	2.74 (1.95 - 3.83)	<0.001
Gender (Male)		
Female	6.14 (4.70 - 8.02)	<0.001
BMI (Normal weight)		
Overweight	0.52 (0 .41 - 0.66)	<0.001
Obese	0.39 (0.28 - 0.51)	<0.001
Smoker (Non-smoker)		
Former smoker	0.92 (0.73 - 1.15)	0.456
Current smoker	1.17 (0.80 - 1.71)	0.412
Education (Primary)		
Secondary	0.94 (0.70 - 1.27)	0.087
Third level/higher	0.76 (0.56 - 1.04)	0.084
Locality (Dublin/Co-Dublin)		
Another town/city	1.29 (0.97 - 1.71)	0.086
Rural area	1.09 (0.84 -1.42)	0.535

6.3.5 Periodontal health and number of teeth relationship with cognition

As reported above, this research used the MoCA score as a continuous variable to analyse the relationship of the periodontal health and number of teeth with cognition. Table 6-14 shows there was no significant relationship (P> 0.05) between periodontal health and cognition, even after controlling for other cofactors of age, gender, BMI, smoking, education and area of residence. MoCA score was not a risk indicator for having bleeding and calculus and shallow and deep pockets compared to have healthy periodontium, in the OHA dentate sample.

Table 6-14: Multinomial regression analysis of MoCA score and other factors associated with periodontal health categories (Base-dentate, n=2197). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with Bleeding & calculus (n= 793) and Shallow & deep pockets (n= 1273) compared to (base) Healthy periodontium (n= 131)**			
	Bleeding & calculus		**Shallow & deep pockets**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of MoCA score with periodontal health	1.00 (0.93 - 1.05)	0.764	0.98 (0.92 - 1.04)	0.486
After controlling for other cofactors				
MoCA score as continuous variable	0.97 (0.93 - 1.07)	0.911	0.98 (0.92 - 1.05)	0.536
Age group (50-64 years)				
65-74 years	0.99 (0.65 - 1.51)	0.959	0.79 (0.52 - 1.17)	0.252
75 years and over	0.73 (0.42 - 1.27)	0.270	0.45 (0.26 - 0.79)	0.005
Gender (Male)				
Female	0.75 (0.50 - 1.12)	0.155	0.54 (0.37 - 0.80)	0.002
BMI (Normal weight)				
Overweight	0.95 (0.62 - 1.46)	0.816	1.24 (0.81 - 1.88)	0.331
Obese	0.92 (0.55 - 1.52)	0.741	1.18 (0.72 - 1.94)	0.519
Smoker (Non-smoker)				
Former smoker	0.75 (0.51 - 1.10)	0.141	0.86 (0.59 - 1.26)	0.435
Current smoker	0.84 (0.38 - 1.88)	0.673	1.56 (0.72 - 3.39)	0.259
Education (Primary)				
Secondary	0.80 (0.45 - 1.44)	0.460	0.92 (0.52 - 1.64)	0.782
Third level/higher	0.78 (0.43 - 1.41)	0.407	0.93 (0.52 - 1.67)	0.812
Locality (Dublin/Co Dublin)				
Another /city	1.44 (0.87 - 2.40)	0.156	2.39 (1.45 - 3.94)	0.001
Rural area	1.14 (0.74 - 1.73)	0.556	1.99 (1.32 - 3.02)	0.001

Multinomial regression analysis in Table 6-15 shows that the number of teeth had a significant relationship with cognition. The increase in MoCA score decreased the risk of being edentate (RRR= 0.84, CI=0.81-0.88) and having 1-19 teeth (RRR = 0.88, CI=0.86-0.91), relative to have 20 or more teeth. Table 6-15 also shows that after controlling for other cofactors (age, gender, BMI, smoking, education and area of residence), there was also a statistically significant relationship between edentulism and cognition (p= 0.006, RRR= 0.94, CI=0.89-0.98) and between 1-19 teeth and cognition (p<0.001, RRR= 0.94, CI=0.91-0.97).

Table 6-15: Multinomial regression analysis of MoCA score and other factors associated with number of teeth categories (Base-edentate and dentate, n=2504). RRR is relative risk ratio.

Predictor Variables (Reference value)	Factors associated with edentulism (n=249) and less than 20 teeth (n=895) compared to (base) 20 or more teeth possession (n=1360)			
	Edentate		**Less than 20 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Relationship of MoCA score with number of teeth	0.84 (0.81 - 0.88)	<0.001	0.88 (0.86 - 0.91)	<0.001
After controlling for other factors- MoCA score	0.94 (0.89 - 0.98)	0.006	0.94 (0.91 - 0.97)	<0.001
Age group (50-64 years)				
65-74 years	5.23 (3.56 - 7.66)	<0.001	3.35 (2.73 - 4.10)	<0.001
75 years and over	26.36 (16.62 - 41.82)	<0.001	6.89 (5.06 - 9.38)	<0.001
Gender (Male)				
Female	2.12 (1.54 - 2.92)	<0.001	1.05 (0.86 - 1.27)	0.650
BMI (Normal weight)				
Overweight	1.02 (0.72 - 1.46)	0.906	1.25 (1.00 - 1.56)	0.052
Obese	1.52 (1.02 - 2.27)	0.040	1.50 (1.16 - 1.94)	0.002
Smoker (Non-smoker)				
Former smoker	2.06 (1.49 - 2.85)	<0.001	1.53 (0.26 - 1.87)	<0.001
Current smoker	3.39 (2.00 - 5.75)	<0.001	2.29 (1.64 - 3.18)	<0.001
Education (Primary)				
Secondary	0.37 (0.27 - 0.58)	<0.001	0.70 (0.53 - 0.91)	0.007
Third level/higher	0.21 (0.14 - 0.32)	<0.001	0.43 (0.33 - 0.57)	<0.001
Locality (Dublin/Co Dublin)				
Another town/city	1.89 (1.22 - 2.94)	0.005	1.25 (0.97 - 1.61)	0.087
Rural area	3.48 (2.34 - 5.17)	<0.001	1.79 (1.43 - 2.26)	<0.001

6.3.6 Conclusions

The above reported results demonstrate that among dentate adults in the OHA sample, there was no statistically significant relationship of periodontal health with diabetes, osteoporosis and cognition, before and after controlling for cofactors of age, gender, BMI, smoking, education and area of residence (Table 6-6, Table 6-11 and Table 6-14). However, this research found ACD was a risk indicator for shallow and deep pockets relative to healthy periodontium. But after controlling for the other cofactors of age, gender, BMI, smoking, education, area of residence, there was no relationship between ACD and periodontal health (Table 6-9).

In relation to edentulism the above reported results suggested that in the OHA sample, diabetes (RRR = 1.58, CI=1.12-2.23) and cognition (RRR = 0.94, CI=0.89-0.98) were risk indicators for being edentate relative to having 20 or more teeth, before and after controlling for other cofactors; age, gender, BMI, smoking, education and area of residence (Table 6-7 and Table 6-15). But ACD and osteoporosis were only risk indicators for being edentate relative to have 20 or more teeth before controlling for other cofactors. There was no relationship between ACD and edentulism and osteoporosis and edentulism after controlling for other cofactors; age, gender, BMI, smoking, education and area of residence (Table 6-10 and Table 6-12). This research also found that, diabetes (RRR =1.38, CI=1.10-1.73), ACD (RRR 1.33, CI=1.07-1.65), osteoporosis (RRR=1.30, CI=1.02-1.67) and cognition (RRR = 0.88, CI=0.86-0.91) were individual risk indicators for having 1-19 teeth relative to have 20 or more teeth, before and after controlling for other cofactors of; age, gender, BMI, smoking, education and area of residence (Table 6-7, Table 6-10, Table 6-12 and Table 6-15).

This research further evaluated a bidirectional relationship of number of teeth with diabetes and osteoporosis. As reported above, not only were diabetes and osteoporosis individual risk indicators for number of teeth (Table 6-7 and Table 6-12), the increase in number of teeth was indicative of decreased risk of being diabetic (OR=0.98, CI=0.97-0.99) and similarly the increase in number of teeth was indicative of decrease risk of osteoporosis (OR=0.98, CI=0.97-0.99), after controlling for age, gender, BMI, smoking, education and area of residence (Table 6-8 and Table 6-13).

One limitation of this study is that adults who were classified as having any of four of the above reported systemic disease might have more than one systemic health condition. For example, adults who were classified as having ACD might also have had osteoporosis or poor cognition, and tooth loss or poor periodontal could have been because of the latter two conditions rather than ACD. For this reason, a final regression analysis was done to evaluate the relationship of periodontal health and number of teeth after controlling for all four systemic health conditions along with other cofactors of age, gender, BMI, smoking, education level and area of residence. Among all four systemic health conditions, edentulism was found to have the strongest statistically significant relationship with diabetes (p=0.011, RRR=1.57, CI=1.11-2.23), followed by cognition (p=0.010, RRR=0.94, CI=0.90-0.99), after controlling for osteoporosis, heart disease, age, gender, education level, area of residence, BMI and smoking. However, there was no statistically significant relationship between edentulism and osteoporosis (p=0.097) and ACD (p=0.874) after controlling for diabetes, cognition, age, gender, education level, area of residence, BMI and smoking (Table 6-16).

Table 6-16: Multinomial regression analysis of diabetes, ACD, osteoporosis, cognition and other factors associated with number of teeth categories (Base-edentate and dentate, n=2504). RRR is relative risk ratio.

Predictor Variables (Reference value)	**Factors associated with edentulism (n=249) and 1-19 teeth (n=895) compared to (base) 20 or more teeth possession (n=1360)**			
	Edentate		**1-19 teeth**	
	RRR (95% CI)	**P value**	**RRR (95% CI)**	**P Value**
Diabetes (No)				
Yes	1.57 (1.11 - 2.23)	0.011	1.37 (1.09 - 1.72)	0.007
ACD (No)				
Yes	0.97 (0.69 - 1.37)	0.874	1.28 (1.03 - 1.59)	0.024
Osteoporosis (No)				
Yes	1.37 (0.95 - 1.99)	0.097	1.32 (1.03 - 1.69)	0.027
Decrease in Cognition	0.94 (0.90 - 0.99)	0.010	0.95 (0.92 - 0.98)	0.001
Age group (50-64 years)				
65-74 years	5.10 (3.45 - 7.54)	<0.001	3.09 (2.50 - 3.81)	<0.001
75 years and over	24.90 (15.25- 40.65)	<0.001	5.85 (4.22 - 8.11)	<0.001
Gender (Male)				
Female	1.97 (1.40 - 2.77)	<0.001	1.02 (0.84 - 1.25)	0.829
BMI (Normal weight)				
Overweight	1.05 (0.74 - 1.51)	0.780	1.28 (1.02 - 1.60)	0.031
Obese	1.54 (1.03 - 2.32)	0.036	1.52 (1.17 - 1.97)	0.002
Smoker (Non-smoker)				
Former smoker	2.04 (1.47 - 2.83)	<0.001	1.51 (1.24 - 1.84)	<0.001
Current smokers	3.28 (1.93 - 5.57)	<0.001	2.20 (1.58 - 3.07)	<0.001
Education (Primary)				
Secondary	0.40 (0.27 - 0.58)	<0.001	0.70 (0.53 - 0.91)	0.008
Third level/higher	0.21 (0.14 – 0.32)	<0.001	0.43 (0.33 - 0.57)	<0.001
Locality (Dublin/Co-Dublin)				
Another town/city	1.85 (1.19 – 2.87)	0.007	1.25 (0.97 - 1.61)	0.092
Rural area	3.49 (2.35 – 5.20)	<0.001	1.81 (1.44 - 2.28)	<0.001

Diabetes, heart disease, osteoporosis and cognition had a statistically significant relationship (p<0.05) with having 1-19 teeth relative to have 20 or more teeth, after controlling for age, gender, education level, area of residence, BMI and smoking. Diabetes was the strongest (RRR=1.37, CI= (1.09 - 1.72) risk indicator for having 1-19 teeth relative to have 20 or more teeth, followed by osteoporosis (RRR 1.32, CI=1.03-1.69), heart disease (RRR=1.28, CI=1.03-1.59) and cognition (RRR=0.95, CI=0.92-0.98) after controlling for cofactors of age, gender, education level, area of residence, BMI and smoking (Table 6-16).

This research found that overall systemic health conditions (diabetes, ACD, osteoporosis and cognition) had a statistically significant relationship with number of teeth and did not have a statistically significant relationship with periodontal health, except ACD was a risk indicator for shallow and deep periodontal pockets but after controlling for other cofactors; age, gender, education level, area of residence, BMI and smoking, there was no relationship between ACD and periodontal health categories .

6.4 Discussion

Some previous studies have reported evidence of a relationship between oral health and certain systemic health conditions, and WHO has also highlighted the importance of oral health for the prevention of chronic systemic diseases (Petersen and Yamamoto, 2005). This relationship of oral health with systemic health conditions may be more apparent in older adults. Chronic diseases are common as people age; apart from the pathophysiological links and common risk factors between chronic diseases and oral health status, the medicines used to manage different chronic diseases can lead to poor oral health because of hypo-salivation. On the other hand, edentulism has also been associated with poor systemic health because of improper nutritional intake (Shlossman et al., 1990, Walls et al., 2000).

The TILDA study has collected both subjective (SCQ and CAPI) and objective (health assessment) data about systemic health conditions of community-dwelling adults aged 50 years and over, in Ireland. This study provided a timely opportunity to investigate any relationship of objective oral health conditions and systemic health conditions among the TILDA Wave 3 sample who went through an oral health assessment.

In this research, access was available to self-reported (subjective) and objective data on systemic health conditions (diabetes, ACD, osteoporosis and cognition). The use of objective systemic health data along with the self-reported data reduced the chances of any undiagnosed systemic condition among respondents and therefore helped to determine the relationship between oral health conditions and reported systemic health conditions.

As reported in the methods (section 6.2) that the longitudinal subjective and objective data from TILDA Wave 1 and Wave 3 were used to classify the OHA sample (n=2504) adults with any of four systemic health conditions (diabetes, ACD, osteoporosis and cognition) and objective oral health data of TILDA Wave 3, was used for the analysis of any relationship between oral health and systemic diseases. Each of these four systemic health conditions was then individually evaluated for a relationship with number of teeth and periodontal health by multinomial and logistic regression models. This section will report the comparisons of results of the relationship between oral health and systemic health conditions in this research, with other studies of this type. The strengths and limitations of this study will also be reported.

6.4.1 Oral health and diabetes

It is important to note that in this research, among the adults who were classified being diabetic (n=536) only 10 respondents were reported as having Type 1 diabetes, all the rest of the respondents had Type 2 diabetes. For this reason, it was not possible to evaluate the relationship of Type 1 and Type 2 diabetes separately with oral health. The term 'Diabetes' as used in this research includes all respondents with Type 2 diabetes and the 10 with Type 1 diabetes. The possible reason for the small number of adults with Type 1 diabetes is the age range of the respondents, as with age the Type 2 diabetes becomes more common.

The literature has provided strong evidence about the relationship between diabetes and periodontal disease and has also reported, diabetes as a risk factor for gingivitis and periodontal disease (Papapanou, 1996, Mealey and Oates, 2006, Lalla and Papapanou, 2011). This study evaluated the relationship between diabetes and periodontal health categories; healthy, bleeding and calculus, and shallow and deep pockets (Table 6-6). Unlike studies of Karjalainen and Knuuttila, Sbordone and colleagues, Cutler and colleagues and Salvi and colleagues, this study did not record gingivitis separately and relate it with diabetes (Karjalainen and Knuuttila, 1996, Sbordone et al., 1998, Cutler et al., 1999, Salvi et al., 2005). But if the periodontal health category of 'Bleeding and calculus' is considered in this study as a proxy for gingivitis, no relationship was found between diabetes and 'Bleeding and calculus', among OHA sample of TILDA Wave 3.

Many studies have reported the relationship between any type of diabetes and periodontal disease despite the methodological variations in the recording of periodontal disease (Baelum and Papapanou, 1996). For example, most of the studies used clinical examinations to record pocket depth or attachment loss and some used radiographs to measure attachment loss and alveolar bone loss to diagnose periodontitis (Nelson et al., 1990, Taylor et al., 1998). There is also evidence to support the association of Type-2 diabetes with the prevalence and severity of periodontitis (Nelson et al., 1990, Taylor et al., 1998, Chapple and Genco, 2013). Studies have further reported the relationship of Type 2 diabetes with the incidence and progression of periodontitis (Nelson et al., 1990, Taylor et al., 1998). Unlike these above reported studies, this study did not find a relationship between diabetes and periodontal disease (Table 6-6). It may be possible to further evaluate the relationship of diabetes with the incidence and progression of periodontal disease by a follow-up study in the next wave of the TILDA.

It has been 20 years since the first studies reported that poor periodontal health was a risk factor for diabetes by increasing the inflammatory markers in circulation (Demmer et al., 2008, Chapple and Genco, 2013). Periodontal health has also been reported as a risk factor for the incidence of diabetes in non-diabetic adults with periodontitis (Demmer et al., 2008). The findings of this study were different from the finding of a systematic review in 2013, by Taylor and colleagues, who reported, "There was enough evidence to support the diabetes effects on periodontitis but the effect of increased inflammatory factors from periodontitis on diabetes was still speculative." They further suggested that the longitudinal clinical studies were required to answer this question conclusively (Taylor et al., 2013). This study did not even find that diabetes was a risk indicator for periodontal disease and vice versa.

The literature has also reported that glycaemic control plays important role in this relationship of diabetes and the severity of periodontal disease (Safkan-Seppala and Ainamo, 1992, Seppala and Ainamo, 1994, Taylor et al., 1998, Tsai et al., 2002, Al-Emadi et al., 2006, Kaur et al., 2009, Chapple and Genco, 2013, David and Famili 2017). For example, in 1992 and in 1994, Safkan-Seppala and Ainamo reported that adults with poorly controlled Type-1 diabetes had more the interproximal clinical attachment loss and alveolar bone loss (by radiographic evaluation and by site by site evaluation of attachment loss and alveolar bone loss) than adults with well-controlled Type-1 diabetes (Safkan-Seppala and Ainamo, 1992, Seppala and Ainamo, 1994). In 2002, a study by Tsai and colleagues reported that poorly controlled diabetes (OR=2.90, 95% CI=1.40-6.03) was more related to periodontitis than well-controlled diabetes (OR=1.56, 95% CI=0.90-2.68) (Tsai et al., 2002).

Similar to the studies of Tsai and colleagues and David and Familli, well-controlled glycaemic levels could be among one of the reasons, that this study did not find that diabetes was a risk indicator for periodontal health and vice versa (Tsai et al., 2002, David and Famili 2017). This may be because this study used the objective evaluation of diabetes by HbA1c level, from TILDA Wave 1 (reported in the methods section of this chapter) and not from TILDA Wave 3, as no objective data of HbA1c level was available from TILDA Wave 3, by the time of writing. Most of the Wave 3 data on diabetes prevalence was from self-reporting of diabetes and being on diabetic medications. It is presumed that the respondents who were aware of being diabetic and were on diabetes medication might have well-controlled glycaemic levels. Another reason could be, as reported in Chapter 5, that 64.9% of the dentate sample visited the dentist more than every 2 years. So, adults who visited a dentist regularly might have reduced level of severe periodontal disease. Differences in the methods, sample characteristics (dietary habits, oral hygiene habits, access to care, genetic and cultural factors) and other cofactors used in this study and other studies, may be among other reasons for not finding any relationship between diabetes and periodontal health in this research (Nelson et al., 1990, Papapanou, 1996, Taylor et al., 1998).

Although there was a limited evidence-base in the literature about the inverse relationship between diabetes and number of teeth as reported by Taylor and colleagues, this study found that a statistically significant relationship was present between number of teeth and diabetes, this relationship was also present after controlling for age, gender, BMI, smoking, area of residence and education level. In this study, after controlling for other cofactors; age, gender, BMI, smoking, education and area of residence, adults with diabetes were at higher risk of being edentate (p=0.010, RRR = 1.58, CI=1.12-2.23) and having 1-19 teeth (p = 0.005, RRR=1.38, CI=1.10-1.73) teeth relative to have 20 or more teeth (see Table 6-7) (Taylor et al., 2004). The clinical significance of this relationship needs further investigations because as reported by Haworth and colleagues, the reason for tooth loss in older adults is difficult to determine (Haworth et al., 2018). Similar findings were reported from a cross-sectional evaluation of the relationship between self-reported data on tooth loss and self-reported diabetes, among adults aged 54 years and over in the TILDA Wave 3 sample (Sheehan et al., 2017). They reported, “The adults with self-reported no teeth were more likely to have been diagnosed with diabetes (13%) than those with their own teeth (8%), but after controlling for age the difference was only significant for those in the 65 to 74 age group (17% versus 11%)” (Sheehan et al., 2017).

These findings were similar to the studies of Kapp and colleagues and Kaur and colleagues, those also found a relationship between diabetes and tooth loss (Taylor et al., 2004, Kapp et al., 2007, Kaur et al., 2009). But this study’s findings were different in relation to respondents’ age. The studies of Kapp and colleagues, Taylor and colleagues and Demmer and colleagues reported that this association between diabetes and tooth loss was more pronounced among younger adults after controlling for other covariates, but this study found that this relationship was stronger among adults aged 75 years and older (for edentate p<0.001 (RRR=28.4, CI=18.02-44.82) and for 1-19 teeth p<0.001, (RRR=7.35, CI=5.42-9.97) than in adults aged 50-64 years (for edentate P<0.001 (RRR=5.38, CI=3.67-7.89) and for 1-19 teeth p<0.001, (RRR=3.43, CI=2.79-4.20) and diabetes was a risk indicator for being edentate and having 1-19 teeth relative to having 20 or more teeth (Table 6-7) (Taylor et al., 2004, Kapp et al., 2007, Demmer et al., 2008). One reason for this difference in the age-related relationship of diabetes with tooth loss, might be the difference in cut off points used for number of teeth. For example, Kapp and colleagues compared 1-5 missing teeth and 6 or more missing teeth with no missing teeth and found that the relationship between tooth loss and diabetes was stronger in those aged 18-44 years than in those aged 45-64 years. However, there was no relationship between tooth loss and diabetes among adults aged 65 years and over (Kapp et al., 2007). Other reasons could be the sample size in different age groups and other cofactors used in this relationship were different from other studies. For example, the Kaur and colleagues study used two age groups, 22-59 years and 50-88 years, and found that the relationship between Type 1 diabetes and tooth loss was statistically significant (p<0.0001), but the relationship between Type 2 diabetes and tooth loss was statistically significant only for females (OR=1.60, 95% CI=1.10-2.33) (Kaur et al., 2009).

Unlike the findings of relationship between periodontal health and diabetes, this study found that relationship between diabetes and number of teeth was bidirectional, not only was diabetes a risk indicator for being edentate and having 1-19 teeth relative to have 20 or more teeth, the increase in the number of teeth was also a weak risk indicator for diabetes (OR=0.98, CI=0.97-0.99), after controlling for other cofactors of age, gender, BMI, smoking, education level and area of residence (Table 6-7 and Table 6-8). But among other cofactors, only obesity had a statistically significant relationship with diabetes and increased the risk of being diabetic (p=0.003, OR= 1.48, CI=1.14-1.92).

The relationship between tooth loss and diabetes could be another reason for not finding any direct relationship between periodontal health and diabetes. This may be because most of the periodontal disease involved teeth might have been extracted and the remaining teeth might be less vulnerable to periodontal disease. Periodontal disease being a cause of tooth loss is important among other reasons behind the relationship between tooth loss and diabetes. It may be an indirect relationship between periodontal disease and diabetes manifest through tooth loss, although the causes of tooth loss are difficult to determine accurately (Haworth et al., 2018).
This study also found that the strongest relationship was present between number of teeth and diabetes compared to that between the other systemic health condition (ACD, osteoporosis and

cognition) and number of teeth, even after controlling for age, gender, BMI, smoking, area of residence and education level.

6.4.2 Oral health and atherosclerotic cardiovascular disease (ACD)

The term atherosclerotic cardiovascular disease (ACD) covers a wide range of diseases of the heart and vascular system (Mendis et al., 2011, Abubakar et al., 2015). As reported in Table 6.2, this research used the criteria of having had a stroke, mini-stroke, angina, heart attack and measurement of pulse wave velocity >12m/s as indicative of ACD among the OHA sample. The combination of both subjective and objective methods of ACD evaluation and relating it with objective oral health status is valuable because it will also include the adults with undiagnosed ACD rather than just subjective reporting. As the adults who self-reported that they had conditions suggestive of ACD were being clinically diagnosed so they were aware of these.

Studies have reported three mechanisms behind the association of periodontal health and tooth loss with ACD; inflammatory, infection and diet and nutrition (Iwai, 2009, Kebschull et al., 2010). Many studies have reported the relationship of periodontitis with ACD and ACD related mortality, although the methods of recording atherosclerotic cardio vascular diseases varied among studies (Saremi et al., 2005, Holmlund et al., 2006, Al-Emadi et al., 2006, Bahekar et al., 2007, Humphrey et al., 2008, Dietrich et al., 2008, Kebschull et al., 2010). Some authors suggested that the underlying known cofactors such as smoking, obesity, diabetes and socioeconomic status play some role in this association (Berenson et al., 1998, McGill et al., 2000, Kebschull et al., 2010). While others studies reported the role of unknown factors such as genetic tendencies in periodontal or ACD diseases playing an important role in this relationship (Schaefer et al., 2009, Kebschull et al., 2010). Similar to these reported studies, this study also found that that there was a relationship of periodontal health with ACD, as there was increased risk of shallow and deep pockets in adults with ACD (p=0.026, RRR= 1.65. CI=1.44-1.95), but after controlling for other cofactors of age, gender, smoking, BMI, education level and area of residence there was no relationship between periodontal health and ACD (Table 6-9).

This study did not evaluate whether the periodontal health was a risk factor for ACD like many studies in literature review section which reported that periodontitis was an individual risk factor for ACD (Bahekar et al., 2007, Humphrey et al., 2008, Tonetti and Dyke, 2013). Most of the studies which reported the effect of periodontal disease on ACD also reported that periodontal disease was present before ACD (Tonetti and Dyke, 2013). This study evaluated that that ACD was a risk indicator for having shallow or deep periodontal pockets, but this relationship was not present with other cofactors. It may be that the age of this sample played some role, as there was no relationship between periodontal health and ACD after controlling for age and other cofactors, which needs secondary analysis. As reported by Dietrich and colleagues, there was less association between periodontitis and coronary artery disease among adults aged more than 60 years (Dietrich et al., 2008). Saremi and colleagues reported that periodontal disease was a strong predictor of mortality from ischaemic heart disease in Pima Indians with type 2 diabetes (Saremi et al., 2005). While no relationship between periodontal health and ACD was found after controlling for diabetes in this sample (Saremi et al., 2005). Another reason for no relationship between periodontal health and ACD in the presence of other cofactors could be that there were fewer adults with more severe periodontal disease in this study's sample (n=128 dentate adults with deep pockets). The second possible reason for not seeing relationship between periodontal health and ACD could be fewer retained teeth in older age groups.

Several studies have reported the relationship of tooth loss and ACD, and have reported tooth loss being an additional risk factor for ACD (Polzer et al., 2012, Schwahn et al., 2013). This finding may be either due to tooth loss, being a present or past maker of periodontal disease (inflammatory theory) which itself has been reported a risk for ACD and a cause of tooth loss. It could be because of improper nutritional intake due to the presence of few teeth (nutritional theory) which could be a reason of ACD (Iwai, 2009, Kebschull et al., 2010).

The literature has reported that tooth loss increased the risk of CVD and CVD mortality. Although different studies used different methods and included different types of CVD, but most of these included atherosclerotic cardiovascular diseases. So term 'Atherosclerotic cardiovascular disease' used in this study and term 'Cardiovascular disease' used in other reviewed studies are synonymous. For example, Cabrera and colleagues in a 24-year cohort study of women (included self-reported and clinical assessment of missing teeth and self-reported and clinically examined stroke and myocardial infarction history from hospital registers), reported that missing teeth was a risk factor for CVD mortality (RR=1.46, 95% CI=1.15-1.85 per 10 missing teeth) and all-cause mortality (RR=1.36, 95% CI=1.18-1.58) independent of socioeconomic status (Cabrera et al., 2005). Holmlund and colleagues, reported a linear inverse relationship between the self-reported number of teeth and carotid arteries with plaques (OR= 0.85, CI=0.82-0.98, p=0.016) after adjusting the covariates of age, sex, smoking, BMI, blood pressure, waist/hip ratio, blood glucose, triglycerides, cholesterol, C-reactive protein, leukocyte count, blood pressure and Framingham risk score (Holmlund and Lind, 2012). Wiener and Sambamoorth by self-reported assessment of missing teeth and cardiovascular disease, also reported an increased risk for cardiovascular disease (OR=1.85, 95%CI=1.71-2.01) among the participants who had all of their teeth missing (Wiener and Sambamoorthi, 2014). Similarly, Polzer and colleagues by a systematic review and meta-analysis reported that tooth loss was related to CVD mortality, but less evidence was present in relation to tooth loss and all-cause mortality and Schwahn and colleagues reported that 9 or more missing un-replaced teeth were associated with CVD related mortality (Polzer et al., 2012, Schwahn et al., 2013).

Similar to these studies, this study also found a statistically significant relationship of edentulism ($p<0.001$, RRR= 2.18, CI=1.64-2.90) and 1-19 teeth ($p<0.001$, RRR=2.25, CI=1.87-2.70) with ACD. This relationship between 1-19 teeth and ACD was also present after controlling for other cofactors of, age, gender, smoking, BMI, area of residence and education level. But there was no relationship between edentulism and ACD after controlling for above-reported cofactors (Table 6-10). These above-reported studies also found that tooth loss was a risk factor for ACD. In this research, ACD was a risk indicator for having fewer teeth (1-19) compared to have 20 or more teeth, without controlling for other cofactors. But ACD was not a risk indicator for being edentate after controlling for other cofactors (Table 6-10). So this study does not support the finding by Watt and colleagues of a relationship between edentulism and ACD (Watt et al., 2012).

Although in this study, a significant relationship was found between fewer retained teeth (1-19) and ACD and it was found that ACD was a risk indicator for 1-19 retained teeth, it is difficult to make conclusive comments about this relationship because it is difficult to determine the cause of both tooth loss and ACD among older adults. Both tooth loss and ACD could be because of some underlying factors other than the relationship between each other. For example, tooth loss could be due to caries and periodontal disease affected by lack of access to dental care, lifestyle and dietary factors or because of other systemic health conditions such as cognitive decline and osteoporosis. Whereas ACD could be because of arterial stiffness with age, genetic factors, lifestyle and dietary factors. Further well-controlled longitudinal studies are required in this context to draw final conclusions about this relationship of tooth loss and ACD.

6.4.3 Oral health and osteoporosis

Periodontal disease, tooth loss and osteoporosis are major chronic health issues affecting adults aged 50 years and over (National Institutes of Health, 2000). Studies have reported a relationship between periodontal disease, tooth loss and osteoporosis, although the methods used to measure them and the samples in different studies were different, as reported in the literature review section (section 2.6.4). In this study adults with osteoporosis were classified by both subjective and objective assessment as reported in Table 6-3.

The literature has reported inconsistent findings of the relationship between osteoporosis and periodontal disease. However, different studies also used different hypotheses for the evaluation of this relationship. For example, some studies evaluated osteoporosis as a risk indicator for periodontal disease (Tezal et al., 2000, Inagaki et al., 2001, Yoshihara et al., 2004). While others reported that periodontal health was a risk indicator for osteoporosis especially in postmenopausal women (Taguchi et al., 1995). In contrast to the above reported studies, in this research, no relationship was found between periodontal health and osteoporosis, and osteoporosis was not a risk indicator for periodontal health either in absence or presence of other cofactors, age, gender, BMI, smoking area of residence and education level (Table 6-11). Similar to this study, Tezal and colleagues in 2000 and Kribbs in 1990, also did not report any statistically significant association between periodontal measurements (attachment loss and probing depths) and osteoporosis (Kribbs, 1990, Tezal et al., 2000). Although the results of this study and those of Kribbs and Tezal and colleagues, were similar, the latter two studies evaluated this relationship among postmenopausal women whereas in this study both men and women with osteoporosis were included in the sample.

Another reason for the variation in evidence about a relationship between periodontal disease and osteoporosis may be that the different studies used different methods for osteoporosis evaluation. For example, some used a history of self-reported fractures and others used DXA scan of different bones. In 2001, Parfitt stated, “The skeleton is heterogenic, different regions being related to each another but yet have some degree of independence in relation to bone density, bone turnover and bone remodelling,” (Parfitt, 2001). This might have affected the evaluation of the relationship between periodontal disease and osteoporosis and was one of the reasons for inconsistent findings in this relationship.

This study did not find any relationship between periodontal health and osteoporosis, while other oral health factors associated with periodontal health such as number of teeth were not controlled in the regression model. Whereas Muhammad and colleagues found a significant relationship between periodontal health and osteoporosis even after controlling for plaque score and Yoshihara and colleagues found a statistically significant weak relationship among adults aged 70 years and older who had 20 or more teeth. They postulated that their sample, because they were 70+ years and had 20+ teeth, may have been “Periodontitis resistant” (Mohammad et al., 2003, Yoshihara et al., 2004). Yoshihara and colleagues also measured attachment loss over time to evaluate periodontal health but in this study only pockets depths were measured. The OHA sample had a much wider age range than the Yoshihara and colleagues’ sample, this may have also influenced the lack of relationship between periodontal health and osteoporosis in the OHA sample.

Maestre and colleagues who did a systematic review of 35 studies reported that there was a positive relationship between periodontitis and osteoporosis in the majority of studies, despite the methodological variations (Martinez-Maestre et al., 2010). It is suggested that well-controlled studies should be done for further evaluation of the relationship between systemic osteoporosis, alveolar osteoporosis and periodontal disease.

A positive relationship between tooth loss and osteoporosis among males and females has also been reported and it has been suggested that systemic bone loss in osteoporosis contributes towards tooth loss (Yoshihara et al., 2005, Nicopoulou-Karayianni et al., 2009). The observed relationship between tooth loss and osteoporosis was more pronounced in post-menopausal women and less among men and pre-menopausal women (Taguchi et al., 1995, Inagaki et al., 2001). While most researchers evaluated this relationship among post-menopausal women (Krall et al., 1994, Nicopoulou-Karayianni et al., 2009, Astrom et al., 1990).

Similar to these reported studies, this study also found a statistically significant relationship of edentulism and number of teeth with osteoporosis. The results also showed that osteoporosis was a risk indicator for being edentate ($p < 0.001$, RRR=2.13, CI=1.57-2.89) and having 1-19 teeth ($p = 0.001$, RRR=1.41, CI=1.14-1.74) relative to have 20 or more teeth, before controlling for other cofactors. Whereas, this relationship was only present between 1-19 teeth and osteoporosis after controlling for age, gender, smoking, BMI, education level and area of residence (Table 6-12). This relationship was found between both males and females not only among females. Similar to the studies of Kribbs and colleagues and Bando and colleagues, osteoporosis in this study was found to be a risk indicator for being edentate, but in contrast to other studies, there was no relationship between osteoprosis and edentulism, after controlling for reported cofactors (Kribbs, 1990, Bando et al., 1998).

The bidirectional relationship between osteoporosis and number of teeth was also evaluated in this study. Not only was osteoporosis found to be a risk indicator for edentulism (without controlling for other cofactors) and 1-19 teeth, but the number of teeth was also a risk indicator for osteoporosis after controlling for other cofactors (Table 6-13). Increase in number of teeth was indicative of the less risk of osteoporosis, after controlling for age, gender, BMI, smoking, education and area of residence (Table 6-13). Although an increase in the number of teeth was found to be a weak risk indicator for osteoporosis (OR= 0.97, CI=0.96-0.98), it requires further evaluations to look at the clinical significance of these relationships.

In summary, this study and most of the previous literature are quite clear about the relationship of tooth loss and osteoporosis. However, well-controlled longitudinal studies are needed for the investigation of this relationship because, in older age, osteoporosis and tooth loss can be present but the reasons for tooth loss may be other than osteoporosis.

6.4.4 Oral health and cognition

Cognitive function declines with age and this decline is more pronounced in older age because of more physiological and pathological changes in one or more domains of cognition (Plassman et al., 2007). Different studies have used a range of methods to assess oral health and cognition, the different cofactors, sample characteristics, follow up time and analysis tools. For example, studies used different cognitive impairments such as dementia or Alzheimer's disease and different measurements such as low MMSE and low MoCA scores to evaluate the relationship between poor cognition and oral health. These have reported a bidirectional relationship between oral health and cognition (Wu et al., 2008, Grabe et al., 2009, Arrive et al., 2012, Yamamoto et al., 2012, Reyes-Ortiz et al., 2013, Naorungroj et al., 2015, Cerutti-Kopplin et al., 2016). In this research, the MoCA score was used as a continuous variable to assess the relationship between oral health and cognition. Studies have reported the unsurprising evidence that older adults with cognition decline had poor periodontal health and tooth loss (Petersen and Ueda, 2008, Wu et al., 2008). A study by Stewart and colleagues reported that poor oral health had an association with cognitive decline throughout life, not only in old age (Stewart et al., 2008).

An effect of poor oral health on cognitive decline has also been evaluated and it has been stated that poor oral health is also one of the risk factors for the cognitive decline (Stein et al., 2007, Kaye et al., 2010, Batty et al., 2013, Furuta et al., 2013, Cerutti-Kopplin et al., 2016). Specifically for periodontal health, there is conflicting evidence in relation to periodontal disease as a risk factor for cognitive decline, especially in older adults (Stein et al., 2007, Kaye et al., 2010, Batty et al., 2013, Furuta et al., 2013, Cerutti-Kopplin et al., 2016). Unlike studies which support the relationship between cognitive decline and poor periodontal health, this study did not find any relationship, between an increase in MoCA score and periodontal health, before or after controlling for other cofactors (Table 6-14).

Studies have also reported that not only was poor cognitive function a risk indicator for tooth loss, but that tooth loss was also a risk indicator for poor cognitive function, along with multiple cofactors in this context. Three possible mechanisms relate tooth loss and cognitive decline, (i) mastication-induced sensory stimuli that increase blood flow to brain (see details in Onozuka and colleagues and Chuhuaicura and colleagues) although this theory is still controversial (ii) poor nutritional status (iii) periodontal disease inflammatory biomarkers (Onozuka et al., 2002, Yaffe et al., 2004, Tucker et al., 2005, Stein et al., 2007, Narita et al., 2009, Paganini-Hill et al., 2012, Batty et al., 2013, Chuhuaicura et al., 2019). One study also reported that tooth loss before the age of 35 years was a risk factor for dementia (Gatz et al., 2006).

In this research, there was a statistically significant relationship between cognitive decline (decreased in MOCA score) and edentulism and having 1-19 teeth relative to have 20 or more teeth (Table 6-15). But unlike the study of Yamamoto and colleagues, the relationship between cognitive decline and tooth loss and no denture wearing was not evaluated (Yamamoto et al., 2012). Low MoCA score was a risk indicator for being edentate and have 1-19 teeth, both before and after controlling for other cofactors of age, gender, BMI, smoking, education level and area of residence. Similar to the systematic review by Cerutti-Kopplin and colleagues, a relationship between less than 20 teeth (1-19 teeth) and cognition decline was found in this study both before ($p<0.001$, RRR=0.88, CI=0.86-0.91) and after controlling for other cofactors of age, gender, BMI, smoking, education level and area of residence ($p<0.001$, RRR=0.94, CI=0.91-0.97) (Cerutti-Kopplin et al., 2016). Their hypothesis was that having less than 20 teeth was a risk indicator for cognition decline, whereas in this study it was the reverse hypothesis, that cognition decline was a risk indicator for possession of 1-19 teeth.

Nonetheless, there was a similar relationship between poor cognition and possession of fewer than 20 teeth, in this study and Cerutti-Kopplin's study. Their random effect analysis reported that the individuals with <20 teeth were at a 20% higher risk for developing cognitive decline (HR= 1.26, 95% CI=1.14-1.40) and dementia (HR = 1.22, 95% CI=1.04-1.43) than those with ≥20 teeth (Cerutti-Kopplin et al., 2016). Whereas this study found that the increase in MoCA score decreased the risk of being edentate (RRR=0.84, CI=0.81-0.88) and having 1-19 teeth (RRR =0.88, CI=0.86-0.91), relative to have 20 or more teeth.

In the context of the relationship between tooth loss and cognition, this study found a relationship after controlling for other cofactors and oral health was measured objectively. However, some studies such as that of Yamamoto and colleagues evaluated tooth loss by self-reported data which could have questionable validity (Yamamoto et al., 2012). One limitation to this study is, the lack of longitudinal evaluation of the relationship between tooth loss and cognition like many other studies did (Stein et al., 2007, Yamamoto et al., 2012, Arrive et al., 2012).

The other problem in the relationship of oral health and cognition, similar to the other systemic diseases reviewed is that both diseases are multifactorial, and it is not known what kind of pathophysiological relationship exists between oral health and cognition. It is suggested that it is necessary to develop an oral-cognitive health model with a limited number of covariates playing a role in the background. This should minimise the other behavioural, physical and systemic factors causing cognitive decline and include oral health and cognition clinical assessments. Well-controlled longitudinal cohort studies are required to evaluate the direct effect of oral health decline on cognitive decline and vice versa.

6.4.5 Strengths and limitations of this study

This study had the advantage of large sample size and the use of objective oral health data which was more accurate in the assessment of oral health status than subjective data. Access to the TILDA subjective and objective systemic health data, availability of longitudinal systemic health data and inclusion of other socioeconomic and behavioural cofactors were among other advantages in this study. Sample age was also valuable in exploring any relationship between oral health and above reported systemic health conditions, as these relationships may be more obvious in older than in younger age groups because of the chronic nature of systemic diseases and oral health conditions. The sample age also had a disadvantage because, in older age, many unknown diseases and circumstances might have confounded the results which could show a false relationship between tooth loss and systemic health conditions. This is because the causes of tooth loss and periodontal disease are difficult to determine in old age and could be other than systemic health conditions (Haworth et al., 2018). Any relationships between oral health and systemic health conditions are clearer in well-controlled and longitudinal studies than simple cross-sectional studies. Future work is required to make valid conclusions about relationships of tooth loss and periodontal health with systemic health conditions (diabetes, ACD, osteoporosis and cognition) among the same TILDA cohort by longitudinal evaluation of these relationships.

This study also was limited by the inclusion of only community-dwelling adults. Those adults in the TILDA sample with severe systemic health issues and cognitive disorders who were living in institutional care were not included in this study. So, this study is not representative of older adults with severe systemic and mental health issues. For this reason, the actual relationship of oral health and the four reported systemic health condition might be different among nationally representative sample of adults aged 50 years and over in Ireland. For example, unlike reported studies in literature, this study did not find any relationship between periodontal health and diabetes, among other reasons, one could be that adults with other major mental and physical health issues were not included in the OHA. It may also be the case that the diabetic adults in the OHA sample were able to maintain their glycaemic level and periodontal health better and so no relationship between the two was found. In future waves of the TILDA study, the inclusion of adults living in institutional care would be particularly valuable to evaluate the relationship between oral health and systemic health conditions. Other reason could be very few diabetic adults with shallow or deep pockets (n=273) in this study (see Table 6-4).

One reason for not getting relationship between periodontal health and systemic diseases is the method used in this research for evaluation of periodontitis. This research used CPITN for diagnosis of periodontitis. Although CPITN is a WHO recommended internationally recognised index which record both periodontal health and treatment need among population, but it has short comings. For example, CPITN does not record mobility, furcation and clinical attachment loss (CAL). An older adult may not have periodontal pocket but can have CAL because of previous periodontal disease. In such cases CPITN underestimates the periodontal disease prevalence. Furthermore, this research did partial mouth periodontal assessment on CPI index teeth for periodontal disease prevalence. Periodontal assessment on index teeth underestimates the prevalence of periodontal disease and overestimates the extent and severity of periodontal disease (Leroy et al., 2010, Chu and Ouyang, 2015).

Another limitation of this study is that adults who were classified as having any of the four above reported systemic disease might have had more than one systemic health condition. For example, adults who were classified as having ACD might also have had osteoporosis or poor cognition, and tooth loss or poor periodontal could be because of the latter two conditions other than ACD. To overcome this limitation, a final regression analysis was carried out to see the relationship of periodontal health and number of teeth after controlling for all four systemic health conditions. No statistically significant relationship was found between periodontal health and any of the systemic health condition along with other cofactors of age, gender, education level, area of residence, BMI and smoking. Although the indicators of oral health used in this research, the number of teeth and periodontal health, are the traditional oral health indicators, nonetheless their use is still questionable. As reported by Haworth and colleagues, “The reasons for tooth loss are uncertain and may not be due to systemic health conditions. Tooth loss as an indicator of oral health should be used with caution because multiple factors play a role in the tooth loss, including other oral health conditions and access to oral health care” (Haworth et al., 2018).

Evaluation of the relationship between periodontal health and systemic health conditions did not show any relationship (except ACD and shallow and deep pockets). Among other reasons, one could be that the method of periodontal health assessment using CPITN on index teeth was not sufficiently sensitive for the evaluation of periodontal health of older adults. The measurement of attachment loss and the analysis of gingival crevicular fluid might be more valid for finding the relationship between diabetes and ACD. Another reason might be as reported in relation to tooth loss, poor periodontal health might be influenced by other factors such as brushing habits, dietary factors, genetic factors and the immune response of the individual. These factors were not considered in this study. The other possible reason may be that in older age most of the teeth with advanced periodontal disease might have already been extracted and so no relationship between periodontal health and systemic disease could be found. Another reason could be fewer adults with any of the systemic health conditions had worse periodontal disease (deep pockets) (Table 6-4).

In this study, the extraction of teeth with periodontal disease might be the reason that a clearer relationship between tooth loss and systemic diseases was found. From the evaluated statistically significant relationship of tooth loss and systemic health disease in this research it can be stated, "Although no statistically significant relationship between periodontal health and reported systemic health conditions was found, there could be an indirect relationship between periodontal health and the reported systemic health conditions by tooth loss being a present or past marker of periodontal disease."

It is important to note that the evaluated relationships between oral health and systemic health conditions showed only association and risk indication. This study did not evaluate any causal relationship between tooth loss and systemic health conditions because the relationships reported above, might have other factors in the background supporting these relationships. Although this cross-sectional study did not report any causative relationship and being just a part of this research, it has its own value. It has provided a base and good indication of relationships between tooth loss and periodontal health with four above reported systemic conditions for further evaluations by future studies in this aspect.

Future study is required to assess the changes in the oral health status of the same cohort, which can be done in future waves of TILDA. It is also suggested that future studies should also compare the changes in oral health status of adults with and without the reported four systemic diseases. It will also help to make final conclusions about the relationship of oral health with systemic health conditions among older adults.

Although the main aim of this study was to assess the oral health status of older adults in Ireland, but TILDA also provides opportunities to assess systemic health and socioeconomic data of same cohort and longitudinal evaluations of oral health status and its relationship with systemic and socioeconomic status of cohort. Future research should be done in this context.

7 Discussion and conclusions

7.1 Introduction

The growth in the older population is posing a care challenge for health service planners both nationally and internationally. Oral health is vital for healthy living and it is an integral part of the general health and wellbeing of an individual. Oral disability, caused by progressive tooth loss, is the cumulative effect of oral disease throughout life and is more pronounced with age due to the direct or indirect effects of ageing against the background of other general health conditions. As reported in the literature review (Chapter 2), an intimate bidirectional relationship exists between the oral health and general health of an individual. It is impossible to be healthy without a healthy mouth (U.S. Department of Health and Human Services, 2000).

Along with complete tooth loss, the ageing population is at higher risk of oral impairment due to changing dentition status, untreated caries, poor oral hygiene and periodontal disease, conditions like oral cancer, xerostomia, craniofacial pain, discomfort, and problems with dentures. These oral health conditions require accurate assessment and the identification of high-risk groups (Petersen et al., 2010, World Health Organization, 2013, Oral Health Policy Academic Reference Group, 2016). These oral health assessments not only describe the disease level among adults in Ireland but also provide potential indicators for the design of the oral health care system for this age group as well as benchmarks for measuring the outcome of interventions.

An oral health survey is a recording of oral health status in a representative sample of a population, carried out by trained and calibrated examiners using standardised examination criteria at a specific time. Whereas surveillance is defined as, "The ongoing, continuous or periodic collection, analysis and interpretation of population health data and the timely dissemination of such data to users," (World Health Organization, 2013). The data may be collected through a surveillance network of general dental practitioners.

In contrast to the WHO recommendations of oral health surveys in the same community every five to six-years, in Ireland, it has been more than 17 years since last national oral health survey of adults was conducted (World Health Organization, 2013). The TILDA oral health study has provided a timely opportunity to report on the oral disease patterns among community-dwelling adults aged 50 years and over. It has highlighted that although there have been positive trends in oral disease levels among adults, there is still a need for improvements in the provision of oral health care among older adults. For example, the results of this research indicated that the prevalence of edentulism has reduced over time in Ireland, and the mean number of retained teeth has increased over the same period in Ireland. This improvement in retention of teeth is likely to require more complex treatments compared to the complete dentures which would have predominated in the past. In 1982, the WHO set the retention of more than 20 natural teeth as a goal for oral health in adults aged 65 years and older (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004). In this study, 43.3% of adults had fewer than 10 tooth contacts, which suggests a less than desirable functioning dentition that may require more complex management among older adults and this treatment need may be further complicated by aspects of physical, mental or systemic health that are common in this age group.

Historically, in Ireland, the first health act was introduced in 1953 which also included access to some dental care. The Health Act 1970 defined eligibility for state-funded health care, including dental care, and although it has been amended in different ways, it remains the basis for eligibility for state-funded dental care at the time of writing. Under the 1970 Health Act, adults who meet the income criteria for receipt of a medical card are eligible for free dental care. However, since 1970 only very limited treatment has been made available to this group. In November 1994, the Dental Health Action Plan (DHAP) was one of the first major and formal initiatives of the Health Strategy policy document, “Shaping a Healthier Future” and it still underpins the current dental health services (Department of Health, 1994a, Department of Health, 1994b). Along with other high-risk groups, it identified the persons aged 65 years and over as a priority group for routine dental treatment. Most recently, in 2013, oral health policy under the cover of, “Healthy Ireland,” the National Framework for Health and Well-being in Ireland, outlined four goals for the attainment of health for the Irish public which are; increase the proportion of people who are healthy at all stages of life, reduce health inequalities, protect the public from threats to health and wellbeing and create an environment where every individual and sector of society can play their part in achieving a healthy Ireland. These goals aimed to increase the proportion of people who are healthy at all stages of life and to reduce health inequalities (Department of Health, 2013).

On the 3rd of April 2019, a new National Oral Health Policy (NOHP), “Smile agus Sláinte,” was launched in Ireland. It has three strategic strands; health and oral health promotion and protection, oral healthcare service provision and evaluation of oral health in the population (clinical surveillance programme). This policy adopted three key philosophies, a ‘Primary care approach’, (in which a local dentist chosen by the individual will provide the most of their oral healthcare), a ‘Life-course approach’, (it will help the prevention of disease and provide oral healthcare from birth into old age) and a 'Common risk factor approach' (this approach is based on the concept that the poor oral health and poor general health have similar risk factors such as a sugar-rich diet, alcohol and tobacco use). This policy is aimed to minimise the barriers for people with disabilities and vulnerable people to obtain access to oral healthcare services compared to that of the rest of the population (Department of Health Ireland, 2019).

In Ireland there is a hybrid system of providing dental services by four approaches; among these the three state-supported schemes are the Public Dental Service (PDS in the Health Service Executive) which mostly provides care for children and adolescents, the Dental Treatment Services Scheme (DTSS) through the Health Service Executive which provides limited dental care for eligible adults (medical card holders) through general dental practitioners and the Dental Treatment Benefit Scheme (DTBS - Department of Social Protection) which provides partially state-funded care through general dental practitioners. In the latter scheme, patients make top-up payments to the dentist who is paid a fee by the state. In the DTSS dentists are prohibited from charging the patient an additional fee. The fourth method of access to dental care is by paying in full for private dental care. In 2014, 23% of the population was eligible for Public Dental Service (PDS) out of those, 23% were treated (total cost €60m), 31% of the population was eligible for the Dental Treatment Services Scheme (DTSS) out of those, 30.3% were treated (total cost €69.7m) and 33% of the population was eligible for the Dental Treatment Benefit Scheme (DTBS) out of those, 18% were treated (total cost €9m) (Oral Health Policy Academic Reference Group, 2016). These figures suggest that a considerable proportion of the population which was eligible for public dental services schemes could not or did not access these services. The results of this study also reported poorer oral health status among medical cards holders as compared to non-medical card holders. The adults with a medical card had fewer retained teeth and a higher proportion of them was edentate as compared to adults without a medical card. So improvements are required at national level, in the provision of public healthcare towards the retention of natural teeth, for this group.

Because of this disease burden in oral health services provision, it is also important to identify high-risk groups in different population ranges and the value of different methods for providing oral healthcare for these adults. This approach could have a high-value impact on their oral health-related social, physiological and physical well-being towards healthy ageing (Petersen et al., 2010, World Health Organization, 2013, Oral Health Policy Academic Reference Group, 2016).

The discussion about the results of this study, trends over time and the national and international comparisons, strengths and limitations of each section of research and comparisons with other studies have already been presented with each chapter. This discussion chapter focuses on the higher-level issues in relation to sample selection, methods used, the validity of self-reported oral health compared with objectively measured oral health and issues related to the relationship between oral health and systemic health conditions.

7.2 Sample selection

As reported in Chapter 4, the oral health assessment (OHA) sample was an opportunistic (convenience) sample derived from the TILDA Wave 3 health assessment sample who attended the TILDA health centre in TCD, while the full TILDA sample is a nationally representative population sample. The full TILDA sample was a randomised sample selected by stratification and clustering as reported in Chapter 3 (Whelan and Savva, 2013). A random sample by multistage stratified clustered sampling design was also used to select the sample of oral health surveys in other countries such as Australia and New Zealand (Slade et al., 2007, Ministry of Health New Zealand, 2010).

The OHA sample (n=2504) had more adults aged 65 years and over (n=1286) as compared to the last national oral health survey of adults in Ireland in 2000-02 when a total 714 adults aged 65 years and older were examined. This national survey also used the RANSAM method of sampling based on the electoral lists. It is notable that while the 2000-02 sample was designed to be representative of the country, it was not representative of all regions. The reported response rate for this national survey was described as “a conservative estimate of between 27% and 39%” (Whelton et al., 2007). Its findings are valuable while keeping the limitations of the differences in characteristics of OHA sample and TILDA sample in mind (Whelton et al., 2007). Similarly, in NZOHS of 2009, total 8938 participants were selected from New Zealand Health Survey. Out of these 6173 were contacted, 4906 participated in the interview, 4241 agreed to participate in the dental examination and 3196 had a dental examination. The overall response rate in NZOHS of 2009 was 49% for the face-to-face interview and 41% for the dental examination (Mason et al., 2010). Similarly, in the Australian oral health survey of 2004-06, total 14,123 adults aged 15 years and over were interviewed with participation rate of 49.0% and 5,505 completed the oral health examination with a participation rate of 43.7%. Whereas, among adults aged 55 years and over, only 2008 were the targeted population for oral health examination. Weights were applied to reduce the sample participation bias (Slade et al., 2007).

In the context of the reported differences between the two samples (OHA and TILDA Wave3- see section 4.2), the OHA sample might have represented a more favourable picture of the oral health status of community-dwelling adults. For example, the OHA sample had statistically significant more adults from Dublin than the TILDA Wave 3 cohort and the results reported that adults living in rural areas had fewer teeth and more shallow and deep periodontal pockets than those living in urban areas. So, an opportunistic inclusion of more adults from Dublin in OHA sample might have produced higher numbers of retained teeth and fewer shallow and deep periodontal pockets among the sample than in a nationally representative sample of community dwellers in the same age group. Similarly, the results of this study reported that the mean number of teeth was higher among younger adults in the sample and among adults with higher levels of education. An opportunist inclusion of a higher proportion of younger adults and adults with third/higher-level education in the OHA sample might have given the more favourable picture of retained teeth than the actual level of retained teeth among community-dwelling adults in Ireland. Most of the previous national-level studies in Ireland and other countries have reported that community-dwelling younger adults and adults with better education levels had more retained teeth than older adults and this trend has been similar overtime (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011, Steele et al., 2012).

Another potential bias in the evaluated oral health status is the exclusion of very old or frail adults and adults with severe physical, mental or systemic health problems from the OHA sample. These adults had health assessments at home and were not included in the OHA. It is to be expected that adults with severe physical, mental or systemic health problems might have poorer oral health than adults who were healthy. For example, in 2014, the Intellectual Disability Supplement to The Irish Longitudinal Study on Ageing (IDS-TILDA) also reported that in Ireland, the edentulism prevalence in the nationally representative sample of adults with intellectual disabilities was 34.1% as compared to other adults in population (14.1%), while the edentulism in the OHA sample in this research was 9.9% (Mac Giolla Phadraig et al., 2015). So, the exclusion of the adults with physical, mental or severe systemic health issues, might have given a better picture of the oral health status of community-dwelling adults in Ireland.

In the context of limitations related to the OHA sample, it is suggested that the OHA sample selection in next TILDA wave should be designed to be more nationally representative. A larger sample with the inclusion of the adults who are unable to come to the health centre for health assessments is advisable. The inclusion of more adults, adults at home and high-risk adults in the OHA sample, will reduce the bias in the OHA sample selection and increase the number of adults in the sample, which will also make it possible to apply the weights calculated by TILDA for nationally representative conclusions (Whelan and Savva, 2013). Nonetheless, while the OHA sample was not a nationally representative sample for evaluation of oral disease levels and treatment needs, it does provide very valuable insight into the likely national trends.

7.3 Methods used for the oral health assessment

This section will cover the discussion about the value of the methods used in this study and will make recommendations for future studies. As reported in Chapter 3, the WHO recommended methods, comparable with previous Irish surveys, were used in this study. The purpose of the WHO handbook entitled "Oral Health Surveys Basic Methods" is to allow for comparisons between surveys within and between countries. By using agreed diagnostic criteria, along with trained and calibrated examiners, it becomes possible to make sound comparisons between surveys whether within the same country or between countries. Such comparisons are then valid and allow for the outcomes of different health care systems to be evaluated (World Health Organization, 2013).

In this study oral health was reported in terms of denture wearing, number of teeth, number of tooth contacts, mean DMFT, tooth wear and CPITN for periodontal health. Aspects of oral health such as oral mucosal lesions, xerostomia, craniofacial pain and discomfort were not included. As reported in the methods section, the time allocated for the oral health examination was a maximum of 10 minutes. Because it was not possible to record everything that might be desirable in this time, the examination focused on recording the most common oral health indicators which were the most valuable for oral health services planning for this age group. Each index was chosen on the basis that it would provide essential oral health data on a critical aspect of the oral health status of this age group and resembled previous Irish and other international studies of national level (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Sullivan et al., 2011, Steele et al., 2012). The data set used for oral health assessment in this study is also comparable with the FDI/ICHOM minimum data set requirement of adults' oral health assessment and WHO recommendations (World Health Organization, 2013, FDI and ICHOM, 2018).

7.3.1 Edentate status and denture wearing

As reported in the literature review chapter, many countries such as Australia, New Zealand and the UK have reported the oral health status of the dentate sample only, as they excluded the edentate adults from clinical examinations (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011). This approach may be considered reasonable given the falling levels of edentulism world-wide, but it removes an opportunity to assess the need for repair or replacement complete dentures and possibly the need for implant-supported complete dentures as many edentate people have difficulty wearing lower complete dentures. In this study, 9.1% of adults were wearing complete upper and lower dentures. Thus, the denture treatment needs of these adults could not be evaluated if they were excluded from the dental examinations. It would also provide an incomplete picture of the treatment needs of the population group.

Another important point to consider is, "Does oral health only involve the presence or absence of teeth and oral impairment in the form of dental disease (caries and periodontal disease)?". Oral health evaluation and restorative treatment needs in the form of repair, replacement or new dentures are also important especially in adults who are edentate and in older age. So only calculating denture treatment need (repair or replacement of dentures) among the dentate sample gives a false indication of oral health status and treatment needs among any population group who may need implants instead of complete dentures (Dudley, 2015). For example, in the Irish national oral health survey of 2000-02, among those aged 65 years and over, 40.8% were dissatisfied with the appearance, comfort or fit of their complete upper and lower dentures and 33.8% were dissatisfied with the appearance, comfort or fit of their complete lower denture and had a need for replacement and repair of dentures or might have benefited from implant supported dentures (Whelton et al., 2007). Inclusion of edentate adults in clinical examinations of oral health studies is important for the assessment of dentures or implants treatment needs among older adults.

7.3.2 Number of teeth

A tooth was recorded as present in the mouth if even a cusp tip/one edge of tooth was visible in the mouth or a retained root was present. Number of teeth is a traditional and easily obtained indicator of oral health status. Reporting the mean number of teeth is a crude measurement of oral health status because it provides no information about the condition of these teeth. The increased provision of dental services to such a population may decrease the mean number of teeth per person in that population but improve oral health. So, recording the number of teeth alone may not be a good indicator of oral health status, as it does not report dental disease, oral impairment and specificity of treatment need among the population (World Health Organization, 2013, FDI and ICHOM, 2018).

Along with the prevalence of edentulism, number of teeth may be an indicator of access to dental treatment among the population group. For example, low numbers of retained teeth may be indicative of previous caries or periodontal disease and may also indicate that a person had only access to simple treatments like extractions but not restorative treatments. Although access to care is influenced by multiple factors, one of them may be limited oral health services provided in the region (Lamster, 2004, Dolan et al., 2005). Tooth loss does not just represent the cumulative effect of oral disease, it also gives an indication of treatment need for replacement of missing teeth in the sample and access to the provision of oral health services.

Another issue in reporting the mean number of teeth is related to data distribution. Mean number of teeth is not a good measure of central tendency as the data on the number of teeth present is usually not normally distributed, as in this study. However, mean number of teeth it is still used for historical comparisons with previous Irish and international studies (Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, O'Sullivan et al., 2011, Steele et al., 2012). To enhance the value of the mean number of teeth other measures such as sound untreated natural teeth (SUNT) and 20 or more teeth and 10 or more tooth contacts were also calculated in this study.

There is also an issue of recording the mean number of teeth among the whole sample or among dentate sample only. As reported above, several countries like Australia, New Zealand and the UK have reported mean number of teeth in the dentate sample only, as they excluded the edentate adults from clinical examinations (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011). Apart from the bias of sample selection (dentate only), in populations with higher levels of edentulism, this approach may not be a full representation of the oral health status of a population or group as it will report a higher mean number of teeth and less treatment need than in the whole population. For example, in 2009, in New Zealand among adults aged 55-64 years, 14.5% of adults were edentate and in the same age group, the mean number of teeth among dentate adults was 24.0. It is probably a biased reflection of the mean number of teeth and dental treatment needs in this age group of the population because the sample already excluded the 14.5% edentate adults of same age group, which led to the higher mean number of teeth among this sample of the population (Haisman et al., 2010).

It is recommended that in the cases where edentate adults were calculated by self-reporting and were excluded from oral health examinations, such as in the UK, Australian and New Zealand oral health surveys, an estimation of mean number of teeth among full sample (edentate and dentate) could be done by inclusion of these edentate adults with 32 missing teeth in the data (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011). Then the calculation of the mean number of teeth among the dentate and self-reported edentate total would be more representative of the population.

One strength of this study is that keeping in mind the need for evaluation of the level of oral disease and treatment need among edentate adults, in this research edentate adults were also clinically examined. The number of teeth both in the full sample (edentate and dentate) was calculated, but for international comparisons (Australia, New Zealand and the UK), the mean number of teeth among dentate adults only was also calculated.

7.3.3 Sound untreated natural teeth (SUNT)

Similar to the previous two Irish oral health surveys, this research also calculated sound, untreated natural teeth (SUNT) and the proportion of adults with 18 or more SUNT among the sample. SUNT represents the teeth that were not restored for any reason (caries or trauma) throughout life and so it provides an indication of the dental caries and trauma, experience throughout the life of an individual. Although the proportion of a sample with 18 or more SUNT is an arbitrary measurement nonetheless in a population-based study it can also provide insight into the caries experience among groups of adults or in geographical areas. For example, apart from other reasons, a higher proportion of adults with 18 or more SUNT in a specific geographical area could be because of lower caries risk in that area. Recording of SUNT has also allowed for the comparisons between previous Irish surveys and this study. This research shows that among adults aged 65 years and over, the proportion of adults with 18 or more SUNT was more than doubled from 1989-90 to 2014-15 (2.1% to 4.9%). From 1989-90 to 2014-15 this increase in the number of SUNT along with an increase in the mean number of teeth suggests better preventive care over that time, such as increased access to fluoride (water fluoridation or toothpaste) or improvements in oral health literacy level among adults in Ireland. Caution is required in making final conclusions about this aspect because of the OHA sample bias as reported in Section 7.2. Nonetheless, mean number of SUNT in conjunction with the mean number of teeth, provides valuable information about the condition of the teeth and treatment needs.

However, recording of SUNT has its own limitations, as it just reports the condition of the tooth not periodontal health of the tooth. In older adults recording of SUNT may have less value than in younger adults, because of greater prevalence of periodontal disease and recession with age (Whelton et al., 2007, Eke et al., 2016). As reported in previous Irish oral health surveys (2000-02), with age there was an increase in clinical attachment loss (CAL) among adults (in those aged 35-44 years, 32.1% had 4mm or more CAL and in those aged 65 years and over, 75.8% had 4mm or more CAL) (Whelton et al., 2007). In older adults, the recorded SUNT might have had poor periodontal health with a short-term prognosis. So, it is recommended that recording of SUNT should be accompanied by the periodontal health status of an individual to report real-life disease and trauma-free experience of these SUNT.

7.3.4 Tooth contacts

Keeping in mind the WHO recommendation on retention of 20 or more teeth in older age, the number of tooth contacts per person was also recorded in this study. The number of tooth contacts (occluding units) is a good indicator of the functional ability of the remaining teeth. As reported in the literature review (section 2.4), a minimum of 20 teeth in occlusion is required to fulfil the demand of masticatory burden without the use of a prosthesis and thereby maintain body mass index (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004). The recording of tooth contacts not only gives an idea of the masticatory capacity of the adults; it also indicates the restorative treatment needs for appropriate functionality of teeth among adults (Todd and Lader, 1991, Steele et al., 1998, Sheiham et al., 2002, Dhingra et al., 2017). The number of tooth contacts alone can only provide an indication of the basis for a minimum functioning dentition, it cannot provide information on the distribution of those contacts or the condition of the remaining teeth (Batista et al., 2014). For example, a person might have minimum functioning dentition, but the teeth involved in occluding units might have periodontal disease, caries or tooth wear, which will reduce the value and functionality of the minimum functioning dentition. So along with reporting of minimum functioning dentition, it is important to report the health status of teeth or it should be reported in the context of conditions such as periodontal disease, tooth wear and restorable dental caries.

7.3.5 Dental caries

Caries prevalence was recorded using the WHO recommended DMFT index because it gives the history of dental caries experience and reporting each component of DMFT also has its own value from a policy point of view (World Health Organization, 2013). For example, the “D” component of DMFT reports unmet treatment need which may be because of poor access to treatment, constraints on oral health services or treatment failure. The missing and filled components indicate access to treatment of different types. The recording of the missing and filled components of DMFT also have their own limitations. For example, the missing component along with access to treatment need (extraction) also indicates failed or unmet treatment.

The “F” component of DMFT should include only a filling or a crown provided because of caries, so in this research, adults were asked about the reasons for crowned teeth. If they were sure their teeth were crowned because of trauma or for aesthetic reasons, it was not included in the “F” component of DMFT. On the other hand, a bridge abutment, which according to the WHO criteria, is not included in “F” component of DMFT, might have experienced caries prior to the placement of the crown on the abutment. So, among other limitations of DMFT, one could be the underestimation of the "F" component in adults with bridges in the mouth.

The indices used in this research were chosen because of their validity, effectiveness, and importance from a service planning point of view. In this research, DMFT was recorded but not DMFS, though the latter would have provided a more detailed evaluation of the extent of tooth destruction due to caries, but it would have been more time-consuming. In the two previous national adult surveys in Ireland, the caries status of each surface of the teeth was recorded but was only reported in latest one (Whelton et al., 2007) and the other national surveys reviewed, only reported DMFT (O'Mullane and Whelton, 1992, Health Canada, 2010). There may be some value in reporting the extent of tooth destruction in younger adults, in older age groups where people are more likely to have crowns or bridges provided, DMFS recording is probably less useful.

The WHO recommended method records caries at cavitation level, which is quite an advanced stage. In this research, caries was recorded both at cavitation and visual level using the BASCD criteria (Pitts et al., 1997, World Health Organization, 2013). The mean DMFT at visual caries level was just 0.1 more than mean DMFT at cavitation level, indicating that reporting visual caries prevalence did not have much impact on mean DMFT in this sample.

Although the DMFT index is useful in the evaluation of caries experience and prevalence in a population, there are some issues that limit its usefulness in older adults. Previously, early tooth loss was higher in adults than now, and the exact reason for tooth loss was often uncertain in older adults. For this reason, the WHO recommendation is that in adults aged 30 years and over, teeth missing for any reason should be included in, "M" component of DMFT (World Health Organization, 2013). Nowadays, because of improvements in tooth retention and in oral health awareness among older adults, it may be possible to determine the reasons for tooth loss, and so avoid including the teeth missing other than due to caries, in the "M" component of DMFT. For this reason, in this study, the missing component of DMFT was recorded differently. Where there was certainty about the reasons for loss other than caries, (periodontal disease, premolars missing due to orthodontic extractions or congenital absence, third molars extracted due to impaction and teeth lost due to trauma), these teeth they were recorded as missing for other reasons and were not counted in the "M" component of DMFT. Similarly, in the edentate group, third molar teeth were not recorded as missing due to caries. However, for international and national comparisons mean DMFT was calculated with all missing teeth included in the "M" component of DMFT, as recommended for adults aged 30 years and over by the WHO (World

Health Organization, 2013). The WHO method of DMFT calculation caused an obvious increase in mean DMFT among adults of this study, because of inclusion of all missing teeth in the "M" component of DMFT.

As with the mean number of teeth, there is an issue as to whether to calculate the mean DMFT among the full sample (edentate and dentate) or dentate sample. Although the WHO recommends the calculation of DMFT among the full sample, many of the national oral health surveys, (probably because of financial constraints) did not include edentate adults in clinical examination and so mean DMFT was not reported for these adults (Slade et al., 2007, Haisman et al., 2010). As with the mean number of teeth, in this research mean DMFT was calculated both in the full sample (edentate and dentate, n=2504) as well as among the dentate sample (n=2255). When the mean DMFT was calculated among the dentate sample only, there was a decrease in mean DMFT because the adults with the highest DMFT score 32 (completely edentate) were excluded from the calculation. Although in populations with a lower prevalence of edentulism, this issue could be less significant, it is suggested that in future research DMFT should be reported both for the whole sample and the dentate sample. Given the increased tooth retention in older adults, it is difficult to justify the difference in the calculation of the mean DMFT in adults over 30 years compared to those aged under 30 years. It is suggested that in the next wave of TILDA among the sample of adults aged 50 years and over, DMFT should include only teeth missing due to caries in the "M" component of DMFT as reported for adults under 30 years by WHO (World Health Organization, 2013).

In the context of an increase over time, in the mean number of teeth, and the issues with the recording of the, "M" component of DMFT, as reported above, it may be an appropriate time to consider changes in the WHO method of calculating the mean DMFT for this older age group. From an oral health services planning point of view, the reporting of untreated caries is more valuable as an indication of unmet treatment need, as was done in the Adult Dental Health survey in UK (2009) which only reported untreated caries, but it gives no idea of the trend in dental caries experience (O'Sullivan et al., 2011).

7.3.6 Periodontal health

With increased retention of teeth among older adults, recording periodontal health status becomes much more important, as treatment need for periodontal disease in this age group is expected to be higher than previously. The WHO recommended periodontal index, CPITN was used in this research, though due to time constraints only the index teeth were scored (as reported in Chapter 3) rather than all teeth in a sextant as recommended by the WHO for adults (World Health Organization, 2013).

Also due to time constraints, recession was not measured though it was recorded (Yes/ No) if present, in the examination of tooth status. Recession is an important aspect of periodontal status as teeth may have a low CPITN score but have considerable levels of recession and therefore at risk of being lost due to previous periodontal disease. In the 2000-02 Irish national survey, loss of attachment including recession was recorded and reported in the 65 years and older age group; 66.9% had loss of attachment equal to or greater than 6 mm while 11.6% had loss of attachment of 9mm or more. In terms of the extent, there was loss of attachment of 6-8mm in 0.3 sextants, 9-11mm in 0.1 sextants and 12mm or greater in 0.1 sextants (Whelton et al., 2007). Though it must be remembered that in 2000-02 the edentulism in this age group was 48%, so many of the teeth with severe periodontal disease may have been extracted. Similarly, other countries also reported a high prevalence of attachment loss among adults 50 years and over (Slade et al., 2007, Haisman et al., 2010, O'Sullivan et al., 2011). These figures provide important information for the level of attachment loss and its importance for recording during oral health assessment of older adults.

The WHO amended the criteria for CPITN use among adults, from recording only on index teeth to recording the scores on all teeth (World Health Organization, 2013). Similarly, Eke and colleagues reported that the partial mouth recording of periodontal health considerably underestimates the prevalence of periodontal disease prevalence among adults (Eke et al., 2010). So, with increasing numbers of retained teeth among older adults, it may be preferable to record periodontal status for all teeth in a sextant and to include a measurement of recession in the recording of clinical loss of attachment (CAL). The impact of these changes on the time needed for the examination would need to be assessed, especially in the context of the value of the data obtained.

Another aspect of the reporting of CPITN is whether it should be related to the mean numbers of teeth present. As mentioned above there is likely to be more periodontal disease in older populations with more retained teeth. It may be difficult to demonstrate improvements in periodontal health in this age group without taking account of the increased number of natural teeth. For example, in Ireland among adults 65 years and over, in 2000-02 the proportion of adults with a maximum CPITN score of shallow pockets was 37.6%, for deep pockets it was 12% along with a mean number of teeth of 8.5 but in this study, in 2014-15, for the same age group the proportion of adults with shallow pockets was 46.4%, with deep pockets was 4.7% and the mean number of teeth was 14.6 (Whelton et al., 2007). These figures indicate that even with increased tooth retention periodontal disease was not severe and the periodontal treatment needs were still not complex. The question arising from these two sets of figures is whether it is possible to state that periodontal health has improved in this age group between these two surveys. If taken out of the context of the mean number of teeth, the suggestion might be that there was not an improvement in periodontal health, but the proportion with deep pockets had decreased and the treatment need remained similar which is the main purpose of recording periodontal status with the CPITN index.

In older adults recording of periodontal recession is also important as these adults might not have periodontal pockets but might have previous loss of attachment in form recession. CPITN alone does not measure all aspects of periodontal disease and ideally should be accompanied with recording of recession to be included in the calculation of periodontal attachment loss and so provide a more comprehensive picture of periodontal health (World Health Organization, 2013, Eke et al., 2016). To overcome the complexity of clinical periodontal examinations and shortcoming of partial mouth, Eke and colleagues from analysis of NHANES 2009-10 data reported that self-reported questions could be used for prediction of periodontitis among population (Eke et al., 2010, Eke et al., 2013). They used 8 self-reported questions for prediction of periodontitis (Eke et al., 2013). Out of these 5 questions including; Tooth and gum health, loose teeth not due to injury, having gum disease, bone loss around teeth, and teeth that "don't look right" had highest correlation with prediction of periodontitis in US population (Eke et al., 2013). The finding of Eke and colleagues are different from most of the studies which found poor sensitivity of self-reported data for periodontal disease as reported in literature review section (Tervonen and Knuuttila, 1988, Gilbert and Nuttall, 1999, Nagarajan and Pushpanjali, 2008). This could be because of the difference in question's design used in evaluation of periodontal disease. The questions which were more related with periodontal disease had good sensitivity for periodontal disease assessment. Other reason could be that the Eke and colleagues study found good sensitivity of self-reported questions for periodontitis while other studies did it for periodontal disease. Periodontal disease could be mild as bleeding or calculus while periodontitis is the advance stage of disease which is more obvious. So well-structured questions were recommended to use for surveillance of periodontitis in population instead of traditional periodontal examinations.

7.3.7 Tooth wear

In this research, the Bardsley tooth wear index was used to record wear into dentine among the adults (Bardsley, 2008). Tooth wear was recorded by visual assessment in six sextants and was reported (in the same way as CPITN) by maximum score per person and the mean number of sextants affected by the different wear scores. Approximately 39% of adults had severe wear but with less than one sextant affected by this score. There are several indices of tooth wear including erosion, some of which are very time consuming and were developed for the clinical management of wear and are probably not suitable for epidemiological surveys (Smith, 1984, Donachie and Walls, 1996, Bardsley, 2008, Bartlett et al., 2008, Ganss et al., 2011). The review of the literature on tooth wear revealed many methodological issues in the recording of tooth wear and suggested that there is a need for agreed, standardised indices of tooth wear for use in epidemiological studies (Ganss et al., 2011). The index used in this research was found to be useful, easy, and less time consuming among this group of adults. This index also reported more advanced dentine wear which helped to rule out tooth wear that was only a physiological ageing process. It is suggested to use the same index for longitudinal evaluation of tooth wear prevalence in the next wave.

7.4 Level of oral health information required in older adults

Apart from the limitations and value of different indices used, another issue to discuss is how much information it is necessary to collect among older frail adults with multiple health issues. It is more onerous for an older adult to have a long clinical oral health examination than a younger person. For this reason, it is important to choose indices that are more acceptable to participants yet which provide sufficient, high-quality clinical data (Atchison and Dolan, 1990, Ferreira and Kowal, 2006, Leroy et al., 2010, FDI and ICHOM, 2018). In this study, the strict time limit for the oral health assessment ensured that there was a rigorous assessment of the value of the data being collected.

Even if the time available for the oral health assessment is reasonably long, it must be remembered that older adults because of limited cognitive, physical and systemic health conditions may be less cooperative during an oral health examination (Dolan and Atchison, 1993, Holm-Pedersen et al., 2005). Older adults because of poor oral health along with other reasons, can find the examination more intrusive than younger adults (Dolan and Atchison, 1993). For example, they may be more sensitive to pain and pressure during the oral health examination. Apart from these behavioural and general health conditions, being frail and possibly with dry mouth, older adults might get tired from opening their mouths and need short intervals to relax during an oral health examination (Dolan and Atchison, 1993, Holm-Pedersen et al., 2005). In this study, the OHA came generally at the end of the approximately 3-hour health assessment, which itself was tiring for many respondents. Furthermore, the older adults being edentate or with poor oral health may not be confident enough to undergo an oral health examination because of the impairment in appearance, function and comfort (Foltyn, 2015).

For all above reasons as well as those issues discussed in section 7.3 above, there is a need to evaluate the extent of oral health information that is essential to collect for the provision of oral health services towards healthy ageing. It is desirable to develop an effective model for oral health assessment of older adults in epidemiology studies. The model should utilise targeted oral health indicators that measure key aspects of oral health and treatment need in these adults which can be used in the limited time frame available for an oral health assessment. Some key questions should be asked about each index to be used in the data collection. These are

1. Can national and international comparisons be made with this index?
2. Is the data collected appropriate for monitoring oral health status in this age group?
3. Will the data be useful for formulation or oral health policy and predicting treatment need?
4. How onerous for the participant is the collection of data with this index?
5. Is it possible to collect less data and still achieve the aims of the research?

For example, it may be justifiable from a cost point of view not to clinically examine the edentate people in an epidemiological survey. However, if it is expected to determine treatment need for complete dentures then it will not be possible with this approach.

While the recording of the presence of 20 or more functioning teeth (tooth contacts) gives no indication of the condition of these teeth, it is nonetheless very useful to have this statistic for oral health policy and monitoring of oral health status and functional ability. But in older adults, the reporting of a functioning dentition should probably be taken in the context of caries status, periodontal health and tooth wear in that sample. The value of a functioning dentition can be informed by the health of remaining teeth. For example, if an adult has a functioning dentition but most of the remaining teeth (occluding units) have deep pockets or severe recession or caries or they are badly worn then the value of these functioning units would be low. It is recommended that in such cases functional ability and impact of functioning dentition on oral health should be analysed in conjunction with the levels of periodontal disease, tooth decay and level of tooth wear.

It is suggested to overcome the issues of caries recording by DMFT and difficulties related to international comparisons, the reporting of dental caries should be done by both mean DMFT and untreated caries both at visual caries level and cavitation level. Furthermore, the examiner should try to evaluate and record the reasons for missing teeth other than dental caries as reported in

Section 7.3.4. DMFT should be calculated both by the WHO method of, “M” component inclusion and TILDA method of, “M” component inclusion as reported in Chapter 4 discussion. It is also recommended that the WHO method of recording DMFT, might need some modifications when used for older adults because of improvement in the retention of teeth in recent years.

With regards to CPITN, it would probably be useful to investigate in this age group whether there is a benefit in examining all remaining teeth in a sextant. The index teeth chosen in CPITN are those likely to experience the most severe periodontal disease as they are the earliest permanent teeth to erupt and are usually the most severely affected in aggressive periodontal disease. However, the distribution of pockets in older adults with more retained teeth in recent years may be different and so this may justify examining all teeth. As periodontal disease recording only on index teeth can give the underestimation of periodontal disease level in an epidemiology study (Leroy et al., 2010). The justification for measuring recession and adding it to loss of attachment measurements in pockets is that a person may have a healthy (zero) CPITN score but have recession because of loss of attachment indicating that at the time of assessment the periodontium was healthy but there previously was periodontal disease which may now be inactive. As some recession is part of the ageing process (physiological) it would be of value to record recession in the evaluation of periodontal health among older adults and to agree what constitutes pathological loss of attachment in older adults in order to reduce the chances of overestimation of periodontal disease level. The issue is then determining the policy implications and treatment needs arising from this recession. Leroy and colleagues suggested that periodontal attachment studies should be age-related which may deal with the physiological loss of attachment (Leroy et al., 2010).

The main issues with the measurement of wear are the lack of an agreed, standardised index to measure wear in this age group that differentiates between physiological and pathological wear, especially when it is complicated by missing teeth (Ganss et al., 2011). As with CPITN, determining the implications of the data on tooth wear in the context of retained teeth is also important both for treatment need and oral health policy. For example, vertical wear on anterior teeth with missing posterior teeth can cause loss of vertical dimension which may indicate the need for replacement for posterior teeth. Similarly, the differentiation between physiological and pathological wear is also important for the estimation of treatment need. For example, the attrition on most of the retained teeth might be indicative of bruxism. Whereas the treatment needed for erosion and abrasion is different.

The above-reported limitations and strengths of each oral health index have highlighted the importance of oral health assessment model for older adults. Studies have reported good validity of oral health assessment models for adults in residential care settings such as The Oral Health Assessment Tool (OHAT). The OHAT was a component of the Best Practice Oral Health Model for Australian Residential Care study. It was a modification of the Kayser-Jones Brief Oral Health Status Examination (BOHSE) and is also recommended by National Institute for Clinical Excellence in the UK because of its good reliability (Kayser-Jones et al., 1995, Chalmers et al., 2005, National Institutes for the Health and Care Excellence, 2016).

Similarly, there is a need to develop an effective and internationally accepted oral health assessment model for older adults through the WHO. It should also demarcate age-related physiological changes in oral health from pathological changes (Leroy et al., 2010). This model should provide high quality and essential information for formulation or oral health policy and predicting treatment need that could also be used for national and international comparisons.

7.5 Oral health and systemic health conditions

Ageing is one of the factors leading to poor oral health and increased tooth loss. The cumulative and progressive nature of oral disease makes it likely to be worse with age (Vargas et al., 2001, Petersen, 2005, Whelton et al., 2007, Slade et al., 2007, Haisman et al., 2010, Health Canada, 2010, Petersen et al., 2010, O'Sullivan et al., 2011, Steele et al., 2012, Oral Health Policy Academic Reference Group, 2016). In the background of many factors, ageing plays a vital role directly or indirectly in the progression of both main oral diseases and other physical, mental and systemic health conditions (Shlossman et al., 1990, Steele et al., 1998, Walls et al., 2000, Chapple, 2009). The WHO has highlighted the importance of oral health for the prevention of chronic systemic diseases (Petersen and Yamamoto, 2005). Thus the relationship between oral diseases and other health conditions, is more prominent in old age although these relationships were present at an early age, but progression with age makes this relationship more obvious (Shlossman et al., 1990, Petersen and Ueda, 2008).

General health aspects of oral diseases and oral aspects of general health conditions are of major concern in oral health care, specifically in older age groups, as reported in the literature review section (Petersen and Ueda, 2008, Oral Health Policy Academic Reference Group, 2016). For a successful health policy (including oral health policy), the complete picture of an adult's health is only visible by looking at the general health aspects of oral diseases and oral aspects of general health conditions, including physical and mental systemic health conditions (Gooch et al., 2006, Oral Health Policy Academic Reference Group, 2016, Association of State and Territorial Dental Directors, 2018). In this research, the relationship between oral health conditions and systemic health conditions was evaluated. The evaluation of these relationships is important because it not only provides insight into the factors playing in the background of oral health disease or systemic disease, it also highlights the high-risk groups for prevention of both oral disease and systemic diseases (Petersen and Ueda, 2008, Department of Health Ireland, 2019). These evaluations may be used in oral health policy to minimise the prevalence and impact of oral or systemic health diseases and target treatment need planning (Oral Health Policy Academic Reference Group, 2016, Department of Health Ireland, 2019).

This research evaluated the relationship between two oral health conditions (periodontal disease and number of teeth) with each of four systemic health conditions separately; diabetes, atherosclerotic cardiovascular disease, osteoporosis and cognition, after controlling for other cofactors (age, gender, BMI, smoking, education level and area of residence). The relationship of periodontal disease and each of systemic health condition was evaluated between the dentate sample only (n=2255). However, the relationship between the number of retained teeth and each of the systemic health condition was evaluated in the full sample (edentate and dentate, n=2504). These evaluations were done to find

- Was there any statistically significant relationship between periodontal health and tooth loss and each of the four systemic health conditions either in the absence or presence of other cofactors as reported above?
- Were any of the systemic health diseases a risk indicator for periodontal health and tooth loss?
- To identify high-risk groups for oral disease related to systemic health conditions for oral health policy.

As reported in Chapter 6, different models were used to evaluate these relationships. Data on the number of teeth was not normally distributed so the sample was divided into three categories, edentate, 1-19 teeth and 20 or more teeth. It is widely accepted that having a functional dentition of more than twenty teeth is important to maintain a healthy diet, a satisfactory nutritional status and an acceptable body mass index (World Health Organisation, 1992, Witter et al., 1994, Marcenes et al., 2003, Armellini and Von Fraunhofer, 2004). From many decades tooth loss and reduced chewing capacity have been reported as a cause of the dietary restrictions and compromised nutritional status over time which could place older people at a health risk (Chauncey et al., 1984).

This research did not find any relationship between diabetes and periodontal disease unlike other literature which reported diabetes as a risk factor for gingivitis and poor periodontal health (Nelson et al., 1990, Papapanou, 1996, Taylor et al., 1998, Tsai et al., 2002, Mealey and Oates, 2006, Lalla and Papapanou, 2011, David and Famili 2017). Unlike the studies which reported that periodontal disease was also a risk factor for diabetes, this research also did not find that periodontal disease was a risk indicator for diabetes (Taylor et al., 1998, Tsai et al., 2002, David and Famili 2017). The possible reasons could be the OHA sample consisted of a higher proportion of healthier (physically and mentally), younger and adults with a higher education level, who were able to control their diabetes. As reported by various studies, glycaemic control plays an important role in the relationship of diabetes and periodontal disease (Safkan-Seppala and Ainamo, 1992, Seppala and Ainamo, 1994, Taylor et al., 1998, Tsai et al., 2002, Al-Emadi et al., 2006, Kaur et al., 2009, Chapple and Genco, 2013, David and Famili 2017).

Similarly, unlike many studies reported in the literature review section, no relationship between periodontal disease and osteoporosis and cognition was found. However, this research did find that atherosclerotic cardiovascular disease was a risk indicator for shallow and deep pockets relative to a healthy periodontium. But after controlling for the other cofactors of age, gender, BMI, smoking, education, area of residence, this relationship was lost.

A detailed discussion of the lack of any statistically significant relationship between each of the four systemic health conditions and periodontal disease has been reported in the Chapter 6 discussion section. The possible reasons for no significant relationship between periodontal disease and these four systemic health conditions were: the exclusion of very old, frail adults and adults with severe physical and mental health issues who did not come to the TILDA health centre assessment, and might have worse periodontal health because of poorly controlled diabetes, poor cognition or physical disabilities compared to the OHA sample. The methods used for periodontal health assessment in the OHA sample could be another reason for not finding this relationship, because in this research the recording of periodontal pocketing depths was only done on index teeth (as reported in Chapter 3) and partial recording during periodontal examinations has been reported to underestimate the periodontal disease prevalence (Leroy et al., 2010, Eke et al., 2010). Furthermore, in this research, the pocketing depth recording was not accompanied by clinical attachment loss recording. The adults examined might have had recession because of previous periodontal experience but not active periodontal disease at the time of the OHA. One reason could also be that adults with severe periodontal disease might have experienced early tooth loss and have become edentate and so were not included in the periodontal assessment. Another reason could be that the OHA sample had more adults with a higher level of education and living in Dublin/Co Dublin than full the TILDA sample. Chapter 4 reported that adults with a higher level of education and living in Dublin/Co Dublin were at less risk of having shallow and deep pockets than adults with lower education level and living in rural areas. It showed that the OHA sample used in the regression models for these evaluations was already at less risk of having periodontal disease. One reason for not finding a relationship between periodontal health and diabetes and atherosclerotic CVD could be that the adults on anticoagulants, with valvular heart disease and with stents were excluded from periodontal examinations (n=58) as reported in Chapter 3. These adults might have had poor periodontal health because of any of these conditions or these conditions could be because of complications of diabetes. As reported in Chapter 5, among the dentate adults in the OHA sample, just 3.9% never visited the dentist and 64.9% of the dentate adults visited the dentist more than every 2 years, while 75.4% of the OHA sample visited a general dentist as a private patient and 20.5% with the medical card. These figures suggest a positive attitude of the OHA sample towards self-care. This could be one of the reasons no relationship between periodontal disease and any of the chosen systemic health diseases was found.

It is important to re-state the cross-sectional nature of this research; as reported by Eke and colleagues cross-sectional studies are unable to demonstrate the causal relationship between periodontal disease risk factors and periodontal disease (Eke et al., 2016). Because of the multifactorial nature of systemic health conditions and periodontal disease it is recommended to have further longitudinal studies with controlled cofactors, for these evaluations.

Unlike periodontal disease, a statistically significant relationship with number of teeth and diabetes, atherosclerotic cardiovascular disease, osteoporosis and cognition was found. It was further evaluated that adults with diabetes and with decreased cognition had the highest risk of being edentate relative to having a functional dentition (20 or more teeth), before and after controlling for other cofactors (age, gender, BMI, smoking, education level and area of residence). This could be another reason that no relationship was found between periodontal health and any systemic health condition. However, osteoporosis and atherosclerotic cardiovascular disease were found to be risk indicators for being edentate but not after controlling for other cofactors (age, gender, BMI, smoking, education level and area of residence).

Furthermore, it was evaluated that for the possession of 1-19 teeth, relative to have a functional dentition, diabetes was the strongest risk indicator, followed by osteoporosis, atherosclerotic cardiovascular disease and poor cognition, both in the absence and presence of other cofactors (age, gender, BMI, smoking, education level and area of residence). This study also found that not only diabetes and osteoporosis were risk indicators for having fewer teeth, fewer teeth were also a weak risk indicator for diabetes and osteoporosis. Finding relationship between number of teeth and these four systemic health conditions could be the other reason why no relationship of periodontal disease with these systemic health conditions was found because previous periodontal disease could be among one of the multiple causes of tooth loss in adults aged 50 years and over, with any of these systemic health conditions.

In a nutshell, these findings indicate that among the OHA sample, the adults with diabetes, osteoporosis, atherosclerotic cardiovascular disease and poor cognition were a high-risk group for treatment needs related to missing teeth, but this research did not find high-risk groups for periodontal treatment need by systemic health conditions after controlling for cofactors of age, gender, BMI, smoking, education level and area of residence.

One important factor to evaluate in these relationships is the time period in which the oral health disease developed, its severity and the systemic health disease. Such relationships can reveal the changes in oral disease level in the presence of systemic disease and can be found in longitudinal studies with specific sample selections. One limitation of this research is, it considered diagnosis of a systemic disease and not how well managed these diseases were, because another important factor to consider in the relationship of oral health condition and systemic health disease is whether the oral disease or systemic disease is being well treated and under control or not. If the respondent is aware of the disease and getting treatment for systemic disease, no statistically significant relationship of the systemic disease with oral health disease may be found. In a well-controlled systemic disease group, apart from fewer pathophysiological effects, one reason could be that the adults who were well-aware and getting appropriate treatment of the systemic disease may also be maintaining their oral health well. So, for diagnosed and well-controlled systemic disease or oral disease these relationships may not be very visible. It also suggests that along with other behavioural cofactors, the personal attitude of adults towards their oral health and systemic health care might be an important cofactor in such relationships.

The TILDA study provides an excellent opportunity to undertake a longitudinal analysis with multiple cofactors, for evaluation of in detailed relationship between oral health conditions and systemic health conditions.

7.6 Conclusions

The results in this thesis suggest the need for changes in the prevention and treatment of oral diseases by services delivered to older adults. This study suggests that there has been a considerable reduction in edentulism prevalence among adults aged 50 years and over in Ireland since the 2000-02 survey, which indicates changes in oral disease treatment needs among this group. Missing teeth were more common among older age groups, and among adults with poor economic status, lower education level and living in rural areas. So, there appears be higher demands for restorative treatment needs among these groups.

This study has also highlighted the importance of periodic assessment of oral disease prevalence and patterns among older adults. For example, this study was done almost 15 years after the last national oral health survey in Ireland. It reported the changes in oral health treatment needs among older community dwellers in Ireland. If there had been a periodic national level oral health assessment of adults, the provision of oral health treatment should have already changed and affected the oral health status among community dwellers aged 50 years and over. Ideally, the purpose of periodic oral health assessments is to report the changes in the oral health of adults which then underpins the service planning, but it may not always happen.

The recent National Oral Health Policy reported the projected prevalence of complete tooth loss among adults aged 65 years and over, will be 8.7% by 2026, 4.7% by 2036 and 2.5% by 2046 (Department of Health Ireland, 2019). This reduction in tooth loss with ageing, in a growing older population will pose considerable challenges for the oral health services. So healthy ageing requires a lifetime of oral health prevention strategies, which would lead to a healthy dentition in older age. It is predicted that there will be a significant increase in dependent older adults both in residential and institutional care in coming years because of the increase in longevity in older adults (Oral Health Policy Academic Reference Group, 2016). Maintaining good oral health with more retained teeth among dependent older adults with different general health conditions is also more challenging for service planners. There is a need to provide oral health services which are accessible, appropriate and acceptable to them.

In a nutshell, this research provides a broad range of information about the oral health status and treatment needs of community-dwelling adults by their socioeconomic and systemic health status. It also provides guidance for innovations in the oral health assessment and oral health care needs among growing older adults in Ireland for healthy ageing.

8 Recommendations for improving the oral health of older adults

8.1 Measuring oral health among older adults

Oral health assessment is the process of measuring the level and extent of oral disease and provides data that can be used to inform oral health policy and oral healthcare. As recommended by the WHO, these assessments should be carried out periodically (5-6 years) to report on oral health disease patterns and trends (World Health Organization, 2013). These oral disease patterns should be used by the public health authorities to inform health policies and programmes. Nutbeam recommended that “Evaluation should form the key aspects of policy development and planning, providing feedback on intervention effect and justify the use of limited resources” (Nutbeam, 1999). For effective and successful oral health care, it is important to evaluate the oral disease level and identify those groups at high risk of oral disease either because of general health conditions, socioeconomic status or behavioural factors. The assessment of high-risk groups with oral disease will be important in order to use the limited resources in the most effective way.

These oral health assessments should be specific (focused), easily measurable, appropriate to the needs of a population group, realistic (achievable in real-life settings) and time-related (specific time periods). This is because unless we are aware of oral disease prevalence, its impact on healthy living, and the services required for ageing adults, we cannot improve oral health care in order to facilitate healthy ageing in Ireland. The recommendations for the different indices for use in oral health assessments of older age groups are listed as follows:

1. The oral health assessment of populations of older adults should involve clinical assessment of both edentate and dentate samples. This is necessary to evaluate accurately the prosthetic treatment need (repair and replacement of dentures or implant requirement) among the whole population examined. Because so-called, “Oral health status” is not just about the presence and absence of teeth. It is also recommended that the reasons of complete tooth loss should be elucidated from individuals who are edentate.

2. To report on the oral health status of adults, one index cannot be used in isolation. The indices used for dental caries, minimum functioning dentition, periodontal health and tooth wear should be reported in the context of each other to provide an overall context

within which the oral health status at individual and population level of the older adults could be understood.

3. To reduce the sample selection bias, the mean number of teeth should be calculated on the whole sample, both edentate and dentate. This will give an accurate picture of the mean number of teeth among the population group. Even if, because of constraints, the edentate sample was excluded from clinical examination, the edentate sample should be included as missing 32 teeth in data analysis to get an accurate evaluation of the mean number of teeth among the population.

4. Caries prevalence using the DMFT/S index should be calculated on the full sample (edentate and dentate) and the dentate sample. While DMFS provides much more information about the extent of destruction of teeth due to caries, it may not be possible to carry out this more detailed assessment in some situations. Furthermore, the WHO method of counting all missing teeth in the "M" component of DMFT among adults aged 30 years and over should be considered for modification (World Health Organization, 2013). With increased retention of teeth among older adults, it becomes increasingly possible to ascertain the reasons for tooth loss and so it is also recommended that the reason for missing teeth should be asked from respondents. Another issue is in the WHO criteria for the "F" component of DMFT is that a bridge abutment is not included in it, even though abutment tooth might have experienced caries prior to the placement of the crown on it, though it is likely to be difficult for a respondent to know this information.

5. In relation to periodontal assessment, a paper commissioned by the European Association of Dental Public Health by Leroy and colleagues which was published in 2010, reported the difficulties related to the recording of periodontal status in epidemiological studies (Leroy et al., 2010). One of the points made about CPITN is that the scoring is hierarchical, which means that a tooth scored with a shallow or deep pocket (score 3 or 4) may not have bleeding or calculus present. It must be remembered that CPITN was devised as an index of treatment need so in that context this approach may be justified. This issue was addressed in the 2000-02 Irish national survey by recording all scores per sextant not only the maximum score (Whelton et al., 2007). Leroy and colleagues also reviewed the difficulties intrinsic to periodontal probing and the type and accuracy of the probes used. The extent to which a probe penetrates into the base of a pocket will vary due to the effects of inflammation and the calibration of the examiner. The physical characteristics and physical markings on probes have also been shown to vary considerably. Training and

calibration of examiners is of particular importance in periodontal assessment but the repeated periodontal examination of the same subject in a calibration exercise also raises difficulties. Another issue specific to an older population is physiological attachment loss and at what point whether age-related, or measurement-related this may be defined as pathological loss. The authors in the Leroy and colleagues article made some recommendations, the first of which was the need for "a uniformly agreed measure and a measuring tool" but they acknowledged that given the wide variation in probes and operator preferences this may be difficult to achieve. They also recommended that (i) partial mouth recordings should be accompanied by a correction factor calculated on a full mouth assessment of a portion of the sample, (ii) rigorous training and calibration are required for all examiners and (iii) the combined use of clinical attachment loss (CAL), pocket depth and bleeding on probing should be considered as the three key variables to be assessed in epidemiological studies of periodontal disease (Leroy et al., 2010).

6. In relation to the recording of tooth wear in epidemiological studies the main issue as reported by Ganss and colleagues, is that there is no internationally recommended and agreed index for recording tooth wear. Most of the indices used for clinical management of wear are not suitable for epidemiology. Most of these indices cannot differentiate between different types of tooth wear (Smith, 1984, Donachie and Walls, 1996, Bardsley, 2008, Bartlett et al., 2008, Ganss et al., 2011). There are also no recommended guidelines to differentiated age-related physiological and pathological wear, which might be more useful in the epidemiological evaluation of tooth wear among older adults (Ganss et al., 2011). For these reasons there is a need to develop internationally agreed and recommended age-related index of tooth wear for epidemiology studies.

7. Oral health assessment of older adults should also include the oral mucosal lesions, salivary flow, taste, temporomandibular disorders because these conditions are more common in older adults. National Health Service data reported that, "Seven in eight cases of oral cancers affect the people aged over 50 years" (National Health Service, 2017). The oral health assessment can help for early diagnosis and management of these conditions.

8. Although the above recommendations should be followed for assessing the oral health of older adults with no or minimal physical, mental and systemic health issues, but there is a need to develop a minimum data set assessment tool for oral health assessment of frail adults with moderate to severe, physical, mental and systemic health issues or adults in the residential and institutional care. This is because the WHO and FDI-ICHOM minimum

data sets might be more intrusive and have constraints related to the time needed for oral health assessment according to the population of adults examined (World Health Organization, 2013, FDI and ICHOM, 2018).

8.2 Oral health awareness programmes

Some of the obstacles affecting healthy, independent and successful ageing are oral impairment by oral disease and oral disability due to the cumulative effects of oral disease. Not only is the relationship between oral and general health important for ageing, in older age, oral health may be of less priority and so overlooked because of other health issues. There is a need to promote the value of oral health and its impact on healthy ageing, with awareness programmes among adults, carers and all health care providers. There is also a need for increased awareness of oral health maintenance and the value of good oral health like general health, and how both are interrelated and can affect successful ageing.

A national oral health awareness programme should be implemented. These programmes should work to improve the knowledge of individuals towards their own oral health and oral health care. It should explain the value of good oral health for healthy ageing. As suggested above adults in older age may not be aware of the importance of oral health and so they may prioritise their other health issues over their oral health. They should know the relationship between oral health and their general health, as “Prevention is better than cure”. These oral health awareness programmes are not only important for older adults, but it is also suggested that these programmes should have a life course approach, from early childhood to old age. The future oral health of older adults is dependent on the oral health of young adults because having good oral health at old age is a lifelong process (Heilmann et al., 2015, Oral Health Policy Academic Reference Group, 2016). In Ireland, the recently launched oral health policy also recommended the life course approach for oral health care (Department of Health Ireland, 2019). These oral health awareness programmes should not only work for adults and older adults, but they should also target the carers in institutions and in the homes of older adults who should also help to maintain the oral health of these adults.

These oral health awareness programmes should also improve both oral health literacy (specifically periodontal health) and personal oral health care/denture care skills among adults and their carers. These awareness programmes should also ensure that adults are well informed about the dental services available to them through the medical card (DTSS scheme) or other schemes. As reported in chapter 5 only 50% of adults who had the medical card used it for a dental check-up which may be due to a lack of awareness of the scheme or difficulty in accessing the care needed through this scheme. So, there is a need to improve the oral health literacy level both in area of oral health care, access to oral care and free oral health (state funded) services available among older adults.

Oral diseases are largely behavioural in aetiology and it is more difficult to change such lifelong behaviours in older adults as compared to younger adults (McGrath et al., 2009). For example, it is easy to understand why we should be careful about our diet and oral hygiene for oral health maintenance but believing in it and changing behaviour from our comfort zone to spend time on oral health care and changing personal preferences in eating can be difficult to achieve. Oral health programmes for older adults might need stronger physiological and behavioural change strategies (Nakre and Harikiran, 2013).

8.3 Improvements in access to oral health care

There is a need to improve access to care among older adults. These improvements should be made by enhancing acceptability, availability, accessibility and affordability of oral health care. In older people, these four elements make considerable demands on service providers and oral health policy.

Acceptability is required on both sides; the service providers (health authorities and dental professionals) and beneficiaries (older adults). Service providers should accept the increasing demand for oral health care for a growing older population. They need to launch strategies to fulfil normative oral health needs of a growing older population. On the other hand, achieving and maintaining good oral health in later years should be seen as possible through self-care and access to appropriate services.

Availability of oral health services can be improved by an increase in type and volume of oral health services offered by service providers according to the type and volume of oral health treatment needs among adults. Furthermore, to improve the availability, the geographical variations in dental personnel need to be addressed because there may be very few dental practices in rural areas engaging with the state-funded dental schemes. This geographical variation will further hamper the access to care for older adults in these areas who actually need more dental care than adults in urban areas as reported by findings of this research and other countries studies (Slade et al., 2007, Haisman et al., 2010). This issue can also be addressed by the implementation of the primary care approach, which is also helpful to improve the access to basic oral health care in rural areas where there are very few dental clinics as reported below in section 8.4.

Affordability of oral health services can be improved by free oral health examinations, age-related reduction or contributions from the government for oral health treatment of older adults. For example, in Ireland, for adults aged 65 years and over, the recently launched Oral Health Policy (Smile agus Sláinte) proposes for adult medical card holders a three layered oral health care system; preventative package, primary care package and an advanced care package. The preventive package for adults not in the high-risk group and aged 65-69 years will be available every 2 years. Details of these packages are reported elsewhere (Department of Health Ireland, 2019). It could make dental treatment more accessible to older people and will facilitate successful ageing in Ireland. The findings of this research also reported that a higher proportion of adults without the medical card visit the dentist as a private patient as compared to adults with medical cards (a proxy of poor economic status). This finding suggests that affordability is one of the important factors in access to oral health care which should be addressed.

Accessibility can be improved by encouraging older adults to attend their local dentists for a regular check-up which could reduce the travel cost and transport fatigue for older adults. Specialist dental services should provide care for adults with complex physical, mental or medical illnesses. The new oral health policy in Ireland also proposes a life course approach to oral health care for eligible groups, which is also helpful to improve the accessibility for oral health care (Department of Health Ireland, 2019). It is important to report that in the recent NOHP, among adults with a medical card, access to oral health care will be improved by providing primary oral healthcare services at the local dentist of adult’s choice. However, more advanced and special care dental treatments are provided by the community oral healthcare services (the reoriented Public Dental Service) and by the advanced oral healthcare centres (Department of Health Ireland, 2019).

Access to oral health care should be improved for adults in residential care and for immobile community-dwelling older adults, either by mobile dental units or by facilitation in terms of transport to the dentist. There should be regular visits to the mobile dental teams to provide for a regular check-up for these adults and a dental professional should be part of the care team of each institution.

8.4 A primary care approach-a shift from the dental care team to shared care

In the last few decades, a primary care approach has been introduced in health policy in Ireland. A primary care approach recommends that along with dental care team, oral health care should also include medical professionals (doctors, nurses, pharmacists) (Raison et al., 2017, Harnagea et al., 2017). Integration of oral health care in primary care approach is helpful for health promotion, oral disease prevention and health equity (Prasad et al., 2019). It reduces the oral disease burden and helps for the health care of adults with low health literacy level and adults of vulnerable and disadvantage group (Harnagea et al., 2018, Prasad et al., 2019).

According to the principles of a Primary Health Care Approach, primary oral health care is expected to provide scientifically sound but technologically appropriate and affordable, community-based care (World Health Organisation, 1978). An example of this is the Basic Package of Oral Care (BPOC) programme which has three components: urgent care, affordable fluoride toothpaste and atraumatic restorative treatment (ART) (Frencken et al., 2002). This approach improves the accessibility of both preventive and curative oral health care for adults in the background of limited resources and challenging environmental (Raison et al., 2017).

An adult is more frequently in contact with a medical professional than a dentist because medical visits are more common, especially later in life, than the dental visits. It was estimated that every year, 108 million American visit physician who do not visit dentist (Vujicic et al., 2014). A visit with medical professional could be a good opportunity to keep adults well informed about their oral health. Similarly, dental visits could be a good opportunity to keep adults well informed about their general health. It has been estimated that in USA, every year 27 million people have a dental visit but no medical visit (Vujicic et al., 2014). To achieve this, requires integration of the primary care team and inter-professional learning. For example, given knowledge of the oral manifestations of systemic diseases and the common risk factor approach, a physician should include a few questions on oral health in history taking. During the examination of a medical condition, a physician should ask or look for related oral health problems and should refer the patient to the dentist. Similarly, a dentist can ask questions related to the systemic diseases and can refer a patient to a medical practitioner (Oral Health Policy Academic Reference Group, 2016, Department of Health Ireland, 2019). For example, an adult on long term medications for diabetes or hypertension, when visiting the physician, he/she should be asked about dry mouth, or problems with gums and should be made aware of the need to have regular dental visits. Pharmacists also can play an important role in shared care, to identify the high-risk groups among older adults. As in the TILDA study, polypharmacy (5 or more medicine) was reported in one in five adults aged 50 years and over (Richardson et al., 2012, Murphy et al., 2018). One of the contributing factors for oral health diseases could be polypharmacy as many of the medications prescribed for common conditions in older age cause hypo-salivation.

Other medical staff such as nurses and medical assistants have also been reported to play an important role in the integration of oral health care in primary care. In Arizona, Neighborhood Outreach Action for Health (NOAH), an oral health programme reported success in primary care teamwork by sharing oral healthcare responsibilities with nurses, medical assistants and other members of the team (Heuer, 2007).

The primary care approach is also helpful for reducing the socioeconomic and demographic inequities in primary oral health care access. For example, in a rural area or there may be a higher population to dentist ratio as compared to urban areas, which will limit the primary oral health care access in rural areas. For example, in Ireland the dentist to patient ratio has been reported as lower in Donegal (37: 100,000) than in South Dublin (63: 100,000) (Department of Health Ireland, 2019). Similarly, in non-industrialised countries such as in Africa, the dentist to population ratio has been reported approximately 1:150,000 compared to about 1:2,000 in most industrialised countries (Raison et al., 2017). In such cases, the primary care approach plays an important role by overcoming these inequities, because current dental problems and not having a regular dentist were reported to be the predictors for oral health consultations with non-dental primary care providers (Lowe et al., 2007). Multiple domains have been reported to be included in primary care approach such as risk assessment, oral health evaluation, preventive intervention, communication, and education as well as inter-professional collaborative practice (Prasad et al., 2019). Different countries such as Brazil, USA and UK have used different frameworks for integration of oral health in to primary care approach (Harnagea et al., 2018).

Raison and colleagues reported that multi-level factors related to availability, affordability and acceptability, influence the utilisation of primary health care services for oral health care which need to be addressed in order to improve the effectiveness of primary oral health care services (Raison et al., 2017). Details of these multilevel factors associated with primary oral health care services in the form of a logic model are reported elsewhere (Raison et al., 2017). Similarly, in Ireland, the National Oral Health Policy also integrated the primary oral health care approach against the background of the general health and oral health promotion and protection programmes (Department of Health Ireland, 2019).

8.5 Inter-professional education and improving competencies of health care providers

Studies have reported that lack of oral health related training is among one of the reasons for not getting necessary oral health advice from medical professionals (Sanchez et al., 1997, Lewis et al., 2000, Romano-Clarke et al., 2007). There is an emerging need for inter-professional education and training rather than just a specific health profession, focused education and training (Pronych et al., 2010, Close et al., 2010). Oral healthcare-related training is required for the dental professional and other health care professionals to improve the awareness of the importance of good oral health.

Bloom and Krathwohl reported, “Knowledge, skills and attitude are the most important and reported units of competencies of primary healthcare providers” (Bloom et al., 1956). There is also a need to improve knowledge of non-dental and dental care providers towards primary care approach in oral health care. A study reported that in the USA, the paediatricians with a high level of competencies adopted oral health care in their daily routine five times more than those with low competencies (Dela Cruz et al., 2004). So inter-professional education is also a key component for the promotion of primary care approach towards oral health care.

There is also a need to make changes in the curriculum of both medical and dental professionals to include inter-professional learning towards strong integration between oral care providers and health care providers for successful ageing. Both medical and dental care providers need to realise their roles in oral health care and medical health care of the adults (Hummel et al., 2015). Furthermore, these inter-professional education and training standards should be set for accreditation at the national level (Institute of Medcine of the National Academies, 2011).

It is also recommended to improve in dental education and training system for dental professionals. A dental professional should be trained to treat the patient with complex oral health care needs. A dental professional should be capable to treat more vulnerable and underserved adults with ease and comfort (Institute of Medcine of the National Academies, 2011).

8.6 An integrated electronic record model of oral health and general health

There is a need to develop an integrated electronic record model for oral health and general health (physical, mental and systemic health). These electronic records should be accessible to both dental care professionals and health care professionals. One recommendation for this electronic record model is an electronic digital coding system which can integrate both the oral health record with the general health record of the same adult. This will help to report different general health conditions to an oral health care provider and vice versa. It will make information exchangeable between care providers on behalf of older adults who may not be able to give proper medical or dental history because of debilitating general health conditions. This integration of aspects of oral health into the medical health record will also indicate the importance of oral health care for the patient and encourage referrals for dental care by medical professionals and vice versa. This integration could improve both oral and medical health care of older adults and will facilitate healthy ageing.

There is also a need to have an integrated referral system associated with these electronic health records which can work between medical care and dental care providers. Because the studies have reported that poor referral systems and deficient interface were important factors towards poor integrated oral health care (Maunder and Landes, 2005, Lowe et al., 2007, Tenenbaum et al., 2008, Atchison et al., 2018).

Furthermore, adults must be able to access the prescription and instructions as a part of this integrated electronic record system. It will make easier for older frail adults to review instructions related to their integrated, oral health and medical health care while sitting at home.

8.7 Identification of high-risk groups

It is recommended to identify high-risk groups by behavioural habits, socioeconomic status, systemic health conditions, and geographical locations, to facilitate better oral health care for older adults, which will also facilitate the effective use of resources. This study not only helped to report the prevalence of oral diseases and treatment needs in community-dwelling adults aged 50 years and over in Ireland, but it also reported the variations in disease level among different population groups. This study found that other than older age and being female, among the OHA sample the adults with the medical card, having only primary school education and living in other than Dublin/Co Dublin were a high-risk group for being edentate and should be prioritised for complete denture treatment. Similarly, the adults with the medical card and with primary education were also identified to have less than 20 teeth relative to have 20 or more teeth and should be prioritised for restorative treatment of missing teeth. For periodontal treatment need the adults living in another town/city and rural areas should be prioritised because they were identified as high-risk groups for shallow and deep pockets. Similar to this study, a national level identification of high-risk groups is required to improve the effective use of the available resources for oral health care.

Because of heterogeneity between older adults by their oral, physical, mental or systemic health, economic status, education level, area of residence, attitudes, these identified high-risk groups should be prioritised for access to oral health care. Similarly, in Ireland for adults 65 years and over, the new oral health policy has also proposed access to primary care and complex care every year, so that the data from these check-ups could be analysed to evaluate high-risk groups for oral health care (Department of Health Ireland, 2019).

8.8 Improvements in subjective oral health evaluation

The subjective method of oral health evaluation needs to be improved by enhanced validity of the questions asked because it could be a simple tool in oral health monitoring among older adults. Well-structured questions which are most relevant to obtain the required oral health information should be used in subjective data collection. These questions should be first piloted among different population groups to check their validity and then used for subjective evaluation. To reduce the bias of physical, mental, systemic health limitations of older adults, dental nurses should provide help to these adults with disabilities during the subjective evaluation of oral health. There is also a need to develop a subjective oral health assessment tool to evaluate the oral health status of this vulnerable population. This subjective tool should have good validity against objective assessment and treatment need.

8.9 Improvements in national oral health care provision

In the context of the findings of this research and the above-reported recommendations, improvements in oral health care provision and actions are required to make quality oral health care services available to older adults. From 2016 to 2046, the projected increase in the proportion of adults aged 60 years and over, is reported to be from 18.3% to 31.3% , along with a projected decrease in complete tooth loss from 19.5% in 2013 to 2.5% in 2046 (Central Statistics Office, 2017, Department of Health Ireland, 2019). This growing population of dentate older adults poses challenges and requires changes from the service providers of oral health care. The improvements in retention of natural teeth among adults will demand changes in the oral health services available to older adults. For example, from the last Irish oral health survey to the findings of this research, treatment needs among older adults changed from mainly complete dentures to other restorative treatments such as periodontal treatment need and partial prostheses for replacement of missing teeth. These changes in treatment need demand, changes in the provision of free dental treatments under the DTSS scheme, as most of the adults with low-income level have been evaluated to have poor oral health as compared to adults on higher incomes. The improvements are needed to expand the coverage of DTSS scheme to improve the oral health of vulnerable and underserved adults in the population.

Along with an increase in retained teeth, an increase in the proportion of older frail adults in residential and institutional care will be more challenging as they are likely to require more complex oral health treatments. Regular assessment of oral disease patterns among adults and an evidence-based oral health care update is also required at the national level. Oral health inequalities between different population groups should be minimised. Oral health care strategies should support a healthy living environment for older adults both at home and in institutions so as to ensure the successful ageing process in Ireland and worldwide. Nonetheless, successful ageing is dependent on the integration of regular cycles of assessment of treatment needs and changes in oral health care strategies and practices.

8.10 Oral health research promotion

There is a need to promote oral health research to fulfil the deficiency in the collection, analysis and evidence-base data on oral health. The government, foundations and agencies should support oral health-related research to improve the methods and technologies towards the provision of oral health care of vulnerable and underserved populations. In Ireland, to improve the oral health research and evaluations, “An oral health evaluation programme by the pathfinder surveys” is one of the three strands of national oral health policy (Department of Health Ireland, 2019).

Furthermore, research should be promoted to evaluate the access, quality, payments and regulatory systems for oral health care at the national level. This type of research is crucial for planning, implementation and achieving improvements in oral health care for the ageing population.

9 Future work

- Future work is required for the longitudinal evaluation of oral health of the adults in the next TILDA waves. This will allow the evaluation of the changes over time in oral disease patterns in this cohort of older adults. It will report the effects of changes in the oral health of adults with the implementation of the new oral health policy

- It is intended to evaluate the oral health status and treatment need of adults in residential and institutional care in the next waves

- It is aimed to evaluate the relationship between oral health and nutritional intake of older adults in the next waves of TILDA

- Different models of oral health assessment for older adults with priority given to high-risk groups need to be developed and tested

- An integrated model of oral health and medical health needs to be developed and tested

- Improvements in the method of subjective oral health data collection need to be explored

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Appendix 1

PH507 Question 1; Which best describes the teeth you have?

CODE THE ONE THAT APPLIES
1. [I/He/She] [have/has] all [my/his/her] own natural teeth – none missing
2. [I/He/She] [have/has] [my/his/her] own teeth, no dentures – but some missing
3. [I/He/She] [have/has] dentures as well as some of [my/his/her] own teeth
4. [I/He/She] [have/has] full dentures
5. [I/He/She] [have/has] no teeth or dentures
98. DK= 6
99. RF = 7
(SLAN)

PH508 Question 2; Would you say your dental health (mouth, teeth and/or dentures) is?

CODE THE ONE THAT APPLIES
1. Excellent
2. Very good
3. Good
4. Fair
5. Poor
98. DK=6
99. RF =7
[ELSA wave 3]

PH509 Question 3; In the past 6 months, have any problems with mouth, teeth or dentures caused you to have any of the following?

CODE ALL THAT APPLY (OUT OF THE FIRST 5 OPTIONS)
1. Difficulty eating food 0=N0, 1=yes
   [ph509_01]
2. Difficulty speaking clearly
   [ph509_02]
3. Problems with smiling, laughing and showing teeth without embarrassment
   [ph509_03]
4. Problems with emotional stability, for example, becoming more easily upset than usual

   [ph509_04]
5. Problems enjoying the company of other people such as family, friends, or neighbours
   [ph509_05]
96. None of these
   [ph509_96]
98. DK
   [ph509_98]
99. RF
   [ph509_99]
[ELSA wave 3]

PH510 Question4; Over the last few years, how often you have visited the dentist?

CODE THE ONE THAT APPLIES
1. More frequently than every 2 years
2. Less frequently than every 2 years
3. Never
98. DK=4
99. RF =5

PH511 Question5: If you needed a routine visit for dental care, which one of the following would you attend?

CODE THE ONE THAT APPLIES
1. A general dental practice as a private patient [with or without PRSI reimbursement]
2. A general dental practice through the Medical Card Scheme
3. A HSE dentist at the local clinic
4. A Dental Hospital (either UCC or Trinity College Dublin)
5. A dental technician
98. DK= 6
99. RF= 7

Appendix 2

TILDA SUBJECT NUMBER (Affix label)

INITIALS | **AGE** | **GENDER**

Examination date

EXAMINER NUMBER

1. PERIODONTAL CONDITION

1.7/1.6	1.1	2.7/2.6
4.6/4.7	3.1	3.7/3.6

2. CORONAL TOOTH WEAR

Score worst tooth per sextant

1.8 -1.4	1.3-2.3	2.4 -2.8
4.8-4.4	4.3-3.3	3.4 -3.8

3. DENTURE STATUS

WEARING OF DENTURE	CODE
UPPER	
LOWER	

4. NEED FOR PROSTHETIC REPLACEMENT OF MISSING UNITS

0 = NO and 1 = Yes

	PATIENT'S OPINION	DENTIST'S OPINION
UPPER		
LOWER		

5. CONTACTS

Score Lower teeth only (0 or 1 or X)

Posterior teeth in contact in MIP

Anterior teeth in contact in MIP <u>or</u> appear to contact in normal functional movement

48 D	48 M	47 D	47 M	46 D	46 M	45	44	43	42	41	31	32	33	34	35	36 M	36 D	37 M	37 D	38 M	38 D

V6

PARTICIPANT NUMBER

	UR							UPPER JAW								UL
TOOTH	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.1	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8
PRESENCE																
SPACES																
CROWN																
ROOT																
Tx CROWN																
Tx ROOT																

	LR							LOWER JAW								LL
TOOTH	4.8	4.7	4.6	4.5	4.4	4.3	4.2	4.1	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
PRESENCE																
SPACES																
CROWN																
ROOT																
Tx CROWN																
Tx ROOT																

Appendix 3

Coding Sheet

CPITN

0 - No disease

1 - Bleeding

2 - Supra or sub gingival calculus

3 - Pocket 4-5mm

4 - Pocket > 5mm

9 – Not possible to make a recording

X - Excluded

CORONAL WEAR

0 - No wear

1 - Dentine exposed <1/3 of worst surface

2 - Dentine exposure greater than 1/3 of worst surface

X - Sextant excluded

WEARING DENTURES

0 - Not possessing a denture

1 - Possessing and wearing RPD

2 - Possessing and not wearing RPD

3 - Possessing and wearing CD

4 - Possessing and not wearing CD

TOOTH STATUS

A - Permanent tooth

P - Primary tooth

U - Unerupted

M - Missing due to caries

G -Missing due to periodontal disease

E - Missing due to other reasons

(orthodontic treatment, trauma, congenital)

K - Missing for unknown reasons

<u>SPACE STATUS</u>

0 - No space

1 - Space

2 - Replaced by conventional bridge

3 - Replaced by resin bonded bridge

4 - Replaced by denture

5 - Replaced by implant

<u>CROWN STATUS</u>

S= Sound

V=Visual caries

D= Decayed, cavity

F= Filled - amalgam

G = Filled - non amalgam

K - Filling (amalgam) & caries

I - Filled (non amalgam) & caries

C - Crowned due to caries

Q - Crowned & caries

T - Trauma

Y - Veneer (not due to caries)

X - Excluded

<u>ROOT STATUS</u>

0 - No exposed root surface

R - Recession, no current or past caries

2 - Caries, no restoration

3 - Amalgam restoration

4 - Non amalgam restoration

5 - Restoration with caries

X - Unable to score

W - Worn to depth of ≥2 mm, with no caries or restoration

CROWN TREATMENT NEEDED

0 - none

1 - One surface restoration

2 - Two surface restoration

3 - Three surface restoration

4 - Fissure sealant or PRR

5 - Crown

6 - Pulp treatment due to coronal caries, followed by restoration

7 - Extraction due to caries, no replacement

8 - Extraction due to caries, replacement

9 - Extraction due to periodontal disease, no replacement

10 - Extraction due to periodontal disease, replacement

W - Extraction for other reasons

V - Veneer

X - Other treatment for coronal caries

TREATMENT NEEDED FOR ROOT CONDITION

0 - No treatment required

1 - One surface restoration

2 - Two surface restoration

3 - Pulp treatment

4 - Extraction due to root caries

5 - Other treatment

Appendix 4

TILDA ORAL HEALTH ASSESSMENT FEEDBACK

Name ___________________________________ Date ____________________

GUM HEALTH	Acceptable	☐	Less than acceptable	☐
DENTURE CONDITION	Acceptable	☐	Less than acceptable	☐
MISSING TEETH	Acceptable	☐	Less than acceptable	☐
TOOTH PROBLEMS	Acceptable		Less than acceptable	☐

Recommended next visit to your dentist ☐ Routine ☐ Soon ☐ Urgent ☐

Signed ______________