The utility of survey and administrative data to generate information for research and outcomes-based oral health services development

A Thesis Submitted for the Degree of Doctor of Philosophy

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Figures

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Original articles

This thesis is based on the following five articles, which will be referred to in the text by their roman numerals:

(I) Guiney, H.,Woods, N.,Whelton, H., O' Mullane, D. (2011) Non-biological factors associated with tooth retention in Irish adults. *Community Dental Health*, 28 (1):53-59.

(II) Guiney H., Woods N., Whelton H., Morgan N. (2011) Predictors of utilisation of dental care services in a nationally representative sample of adults. *Community Dental Health*, 28 (4):269-273.

(III) Guiney H., Felicia, P., Whelton H., Woods N. (2012) Comparing epidemiologically estimated treatment need with treatment provided in two dental schemes in Ireland. *BMC Oral Health*, 12(31).

(IV) Guiney H., Felicia, P., Whelton H., Woods N. (2013) Trends in dental treatment provision in Ireland over a 12-year period. *Journal of Dental Research*, 92 (7S): 63-69.

(V) Guiney H., Felicia, P., Whelton H., Woods N. (2012) Utilisation of dental services in a social insurance scheme in Ireland: analysis of administrative data.

Declaration

This thesis is my own work and has not been submitted for another degree, either at University College Cork or elsewhere.

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Helena Guiney

Dedicated to my family

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"Whether you think you can, or you think you can't - you're right"

Henry Ford

"With ordinary talent and extraordinary perseverance, all things are attainable"

Thomas Foxwell Buxton

Glossary

AIC	Akaike's Information Criterion
BIC	Bayesian Information Criterion
CSO	Central Statistics Office
CSV	Comma Separated Values
DSP	Department of Social Protection
DTBS	Dental Treatment Benefit Scheme
DTSS	Dental Treatment Services Scheme
EU	European Union
FMM	Finite Mixture Model
FMNB	Finite Mixture Negative Binomial
GB	Gigabyte (a unit of information used to quantify computer memory or storage capacity)
HSE	Health Services Executive
NBRM	Negative Binomial Regression Model
NSAOH	National Survey of Adult Oral Health
NT	Natural Teeth
PAYE	Pay As You Earn
PPS	Personal Public Service
PRM	Poisson Regression Model
PRSI	Pay-Related Social Insurance
RAM	Random-access memory (a form of computer data storage).
SES	Socio-Economic Status
SLÁN	Survey of Lifestyle, Attitudes and Nutrition in Ireland
SUNT	Sound Untreated Natural Teeth
TPM	Two-Part Model
WHO	World Health Organization
ZINB	Zero-Inflated Negative Binomial
ZTNB	Zero-Truncated Negative Binomial

Abstract

Background:

Oral disease is estimated as the fourth most expensive disease to treat in most industrialised countries, and in 2012, the EU27 spending on dental care and treatment was approximately €79 billion. Given the large cost of these services, efforts to increase efficiency are worthwhile. While epidemiological surveys have played a role in informing service design, they're expensive, sporadic, and the relationship of the data to real-life practice is uncertain. Technical advances in personal computers now affords the opportunity for more detailed interrogation of oral healthcare service databases traditionally used for administrative purposes, thus providing a complimentary source of oral health data. Analysis of the big datasets held by dental systems administrators can generate health outcomes data and detailed information on uptake of services, which could be used for analysis of trends, impact of changes in service design, and more evidence-based future planning of services.

Aims/Objectives:

The aim of this research was to develop a method of generating valid information for health policy makers by applying statistical analyses and current technologies to oral health administrative and survey databases. This thesis illustrates a method to develop a comprehensive picture of status and trends for oral health among Irish adults in a way that was previously unattainable.

Objectives one and two: The first and second objectives of this research related to identification of the wider socio-demographic influences on oral health and utilisation of dental services in the Irish adult population. Survey data were used to describe the context within which the remainder of the research, which focused on dental claims databases, was carried out.

Objective three: The third objective was to investigate the potential of a dental service claims database to provide information on the utilisation of services, and to investigate factors associated with utilisation.

Objective four: The fourth objective was to determine the extent to which the administrative data could yield information on the impact of reported improvements in oral health on the volume and types of treatment provided to Irish adults.

Objective five: The final objective was to further exploit the claims database to explore the validity of epidemiologically defined dental treatment need in estimating future uptake of services (dental treatment provided) among Irish adults.

Methods:

Data employed in this research were from the administrative databases of the two main state-run dental schemes in Ireland, namely the Dental Treatment Benefit Scheme (DTBS) for employed adults and the Dental Treatment Services Scheme (DTSS) for less well-off adults. Background, contextual and comparative data were drawn from the 1989/90 and 2000/02 National Surveys of Adult Oral Health (NSAOH) and the 2007 Survey of Lifestyle Attitudes and Nutrition in Ireland (SLÁN). The DTBS data had not been interrogated in this way prior to this research and required extensive processing before building the database and creating the datasets for analysis.

Utilisation was the common variable of interest for all five objectives, and was represented in a variety of ways: annual visits and number of visits during a five-year period, and any self-reported visit in the past year (dichotomous). Logistic regression analysis and count data models were used to examine factors associated with utilisation in these forms. Utilisation was also represented as visiting for a check-up, self-reported regular visiting (at least once a year or every two years), proportion of those eligible for the DTBS who used the scheme, and types of treatments provided.

In comparing epidemiologically estimated treatment need with treatment provided to employed adults (DTBS data) and less well-off adults (DTSS data), the chi-square test was used to compare proportions, and the student's t-test was used to compare means. In investigating time trends in the DTBS, information on the number of patients and treatments each year over a 12-year period were extracted from the DTBS data. Average annual rates of change were estimated using logarithmic trend regression. To determine if there was a shift in provision of preventive/diagnostic treatments by

dentists, the ratio of preventive/diagnostic versus invasive treatment (PDI), per dentist, was calculated annually.

In the 2000/02 national survey database, retention of natural teeth was measured as number of natural teeth (NT), number of sound untreated natural teeth (SUNT), 21 or more NT, 28 or more NT, 18 or more SUNT, and odds of being dentate. Factors associated with retention of natural teeth were analysed using count data models and logistic regression as appropriate. In the SLÁN database, utilisation was measured as use of dental services in the past year (a question included in the survey questionnaire), and analysed separately for males and females using logistic regression analysis. Andersen's behavioural model informed selection of explanatory variables from the socio-demographic and behavioural questions used in the SLÁN survey.

Results:

Objectives one and two: The main findings were that there were differences in tooth retention by Socio-Economic Status (SES), with employed adults having greater retention of natural teeth, and disadvantaged adults or those with only primary education having fewer teeth. Visiting the dentist regularly was negatively associated with retention of NT and SUNT among 16-24 year-olds, however visiting regularly and/or for a check-up was positively associated with tooth retention among 35-44- and 65+ year-olds. SES also affected dental care utilisation, with adults with more income and education more likely to report use of dental services in the past year.

Objective three: Utilisation data were successfully obtained from the DTBS database. An analysis of the five year utilisation behaviour of a 2003 cohort of dental attendees revealed that age and being female were positively associated with visiting annually and number of treatments during the five-year period. Number of teeth was positively associated with visiting annually, but negatively associated with number of treatments.

Objective four: A longitudinal analysis of the DTBS, from 1997 to 2008, revealed that the number of adults using the scheme increased, and mean number of treatments per patient decreased, over time. Dentists provided 15.5 million treatments to 1,271,937 adults over the 12-year period of study. As a percentage of overall treatments,

restorations, dentures, and extractions decreased, and prophylaxis increased. Type of restoration provided also changed, with a decrease in amalgams, composites on anterior teeth, pin-retained fillings and restorations of incisal angle or tip, and an increase in white fillings on back teeth/glass ionomers and crowns.

Objective five: Significant differences were found between epidemiologically estimated dental treatment need in a representative sample of adults and treatment provided to those using the dental services. Among less well-off adults, the proportion of 16-24 and 35-44 year-olds that had extractions provided was significantly greater than estimated as needed in the national survey. Among employed 35-44 year-olds, the proportion that had restorations provided was greater than estimated as needed. Mean number of extractions provided was less, and mean number of restorations provided was greater, than estimated as needed.

Conclusions:

This research confirms the utility of survey and administrative data to generate knowledge for policy and planning. These administrative data represent a previously untapped resource for measuring trends in treatment provision and real utilisation of dental services. Public administrative databases have not been designed for research purposes, but they have the potential to provide a wealth of knowledge on treatments provided and utilisation patterns. This research explored and exploited that potential, and the approach used could now be extended to other similar databases for creation of knowledge. Substantial time was spent preparing the DTBS data for this study, however this could be reduced, and the data would be more amenable to statistical analysis, if computer software were used to record the data, in the dentists' practice and/or in the Department of Social Protection. The use of software with mandatory fields for data entry, or electronic health records, would decrease time spent cleaning administrative data. Universal identifiers to facilitate linking administrative records across databases would greatly enrich the variable set for the Irish population. Although the data refer to specific schemes in Ireland or to Irish adults generally, similar schemes are in place worldwide for which the findings and recommendations of this research can be applied.

1. Introduction

1.1. Background

Much research that has been carried out on factors associated with utilisation of health services generally in Ireland (Layte and Nolan, 2003; Layte et al., 2009; Nolan, 2011; Nolan and Smith, 2012), however dental services have not received similar attention. Oral disease has been estimated as the fourth most expensive disease to treat in most industrialised countries (World Health Organization, 2003), and in 2012, the EU27 spending on all aspects of dental care and treatment was close to €79 billion (Patel, 2012). Dental services are sought both for relief of pain (Ekanayake and Mendis, 2002) and for their potential for maintaining and improving oral health (Nguyen, 2008). As in many developed countries, dental health in Ireland has improved in recent decades, with reductions in caries experience among children (Whelton et al., 2006), and increased tooth retention among adults (Whelton et al., 2007). Consequently, one would expect that utilisation of services and the treatments provided have changed. The direction of this change is unknown; more teeth may translate to more treatments as more teeth are susceptible to caries, or there may be fewer treatments as oral health has improved.

Evaluating data on dental health and behaviour is considered "essential for the planning and evaluation of dental health services" (Petersen, 1984). For informed oral health policy, policy-makers need to know the factors associated with varying levels of oral health, the extent to which dental services are being provided to deal with the oral health problems, and the degree to which needs are being met (Brown, 2009). No studies have investigated (1) trends in treatment provision in Ireland, (2) the differences between need and utilisation by socio-economic status (SES), and (3) the bi-directional relationship between tooth retention and utilisation of services in Ireland, and the relationship between these two variables and SES. SES incorporates economic, social, and work status, based on income, education, and occupation. According to Adler and Newman (2002), SES underlies three major determinants of health, namely health care, environmental exposure, and health behaviour. Social gradients have been found in oral health (Sabbah et al., 2007), and higher SES groups have been found to have clearer knowledge, more positive attitudes and better dental health behaviour than those in lower SES groups (Keogh and Linden, 1991).

Utilisation of health services can be assessed from the patient's or the physician's perspective. The traditional method of providing information to obtain measures of utilisation of services is from the patient's perspective, via cross-sectional survey data (Celeste et al., 2011; Pizarro et al., 2009; Stahlnacke et al., 2005; Whelton et al., 2007). However, one of its shortcomings is that the reference period is quite long (usually a year or a few years) so there is potential for recall errors (Holtz et al., 1998; Roberts et al., 1996). Patients may count multiple visits as a single visit or can overestimate consumption (Bellon et al., 2000; Nitschke et al., 2001; Sjöström et al., 1998). Gilbert and colleagues (2002) carried out a prospective study of the validity of self-reported use of dental services, and found 84-91% agreement between self-reports and dental charts among 714 participants at half yearly interviews over 48 months. Although this is encouraging, the recall period (six months) was short, and therefore it was easier for participants to remember a dental visit, than the measure usually used in surveys of utilisation, where participants are asked to recall utilisation in the past year or few years. Borges Da Silva and colleagues (2011) consider the physician's perspective to be the most objective as it "hinges on volume of medical services offered by physicians to patients and recorded in databases".

Information from the physician's perspective is frequently recorded in administrative/claims/payments databases, also referred to as data warehouses. These administrative databases are considered critical for cutting-edge empirical research (Card et al., 2011), and a useful resource for the evaluation of health service delivery and quality, and policy development (Tricco et al., 2008). They offer much larger sample sizes, no non-response issues, and have fewer problems with attrition and fewer measurement errors than traditional survey data (Card et al., 2011; Rodgers and Herzog, 1987). del Aguila and Felber (2004) suggested that data warehouses can play a key role in evaluating the implementation of evidence-based treatment guidelines. To meet the research needs of future evaluations of policies and schemes, Holtz and colleagues (1998) predicted "a growing emphasis on building administrative databases for linking information across time and across schemes and agencies". Dental administrative databases have been used to examine the longevity of treatments (Bogacki et al., 2002; Burke and Lucarotti, 2009; Lucarotti and Burke, 2009), patient-based determinants of care (Grembowski et al., 1997), and to identify potential management policies (Leake et al., 2005). According to Leake and Werneck

(2005), full advantage has not been taken of dentists' claims data, especially in the area of identifying and recommending changes in dental health care policies.

Many of these databases, especially those for state insurance schemes, such as the Irish Dental Treatment Benefit Scheme (DTBS), were designed primarily to record claims for payments to dentists, and the feasibility of meaningful analysis has not been explored. Holtz and colleagues (1998) recommended research on the "comparability of administrative and survey data if administrative data are to become a trusted and appropriately used source of data in high-quality research so that limitations can be reduced or removed".

Using both administrative and survey data, this thesis investigates the factors influencing dental services utilisation and tooth retention. It estimates several models of the use of dental services, which treat the decision-making process of utilisation as a one-stage or two-stage process. It examines the factors associated with tooth retention, including those that also influence utilisation of services, and dental care utilisation. The empirical analyses are based on samples drawn from the 2000/02 Irish National Survey of Adult Oral Health (NSAOH), the 2007 Survey of Lifestyles Attitudes and Nutrition in Ireland (SLÁN), and the DTBS and Dental Treatment Services Scheme (DTSS) claims databases. This thesis presents results from the first analysis of the DTBS data. Reference is also made to data from previous national surveys carried out in 1989/90 (O'Mullane and Whelton, 1992) and 1979 (O'Mullane and McCarthy, 1981). This thesis provides insight into the association between dental health and utilisation of dental services for a nationally representative sample of the Irish population. In addition to an understanding of the differences between estimated need and use of dental services for two socio-economic groups (employed and low-income adults), and factors associated with utilisation of dental services, this thesis also contributes to an understanding of how utilisation of dental services, and changes in patterns of treatment provided, correspond with improvements in dental health. Survey and administrative data are compared in Articles III, IV and V, and recommendations are made for the design of future administrative databases.

Figure 1.1 presents the four main subject areas of this study, namely dental health, need for treatment, utilisation of dental services and treatment provided, all of which are inextricably linked. Dental health in articles I, II and V refers to tooth retention.

Davis (1982) suggested that in considering the implications of increasing dental utilisation, it is useful to distinguish between professionally-defined needs, wants (self-perceived need), and demands (wants converted into requests for treatment). Use of dental services begins with a self-perceived need for treatment, converted into demand for a check-up. During this check-up, the dentist may recommend further treatment having examined dental health (professionally-defined need). Actual utilisation of services and the types of treatments provided are influenced by need (self-perceived and professionally-defined) and dental health.

Figure 1.1 Four main subject areas of this study

1.2. The dental health care system in Ireland

In 2001, the Department of Health and Children published a health strategy document 'Quality and Fairness: A Health System for You' outlining the goals of the Irish health system: better health for everyone, fair access, responsive and appropriate care delivery, and high performance (Department of Health and Children, 2001). To help achieve these goals, the objectives included a reduction of health inequalities, equitable access, people-centeredness, and that evidence and strategy objectives underpin all planning/decision-making (Department of Health and Children, 2001, p.59). Widström and Eaton (2004) suggested that the system for the administration and financing of oral healthcare in Ireland follows the hybid model, and it has adopted some features of the Beveridgian system (as found in the United Kingdom). The

earliest legislation aimed at controlling the practice of dentistry in Ireland was the Dentist Act of 1878. That Act made it an offence for any person to use the title 'dentist', or any similar title, unless s/he was registered under the Act. It was not, however, an offence for a person to practice dentistry if s/he were not registered. The Dentists Act of 1928 superseded the earlier legislation and has since controlled the practice of dentistry in Ireland (Kostlan, 1979: 65).

The public oral health service originated with the Public Health (Medical Treatment of Children) Act of 1919. That act imposed on local authorities the obligation of providing for the medical inspection of children attending primary schools and for having their physical health attended to without direct charge (Kostlan, 1979: 65). Section 14 of the 1953 Health Act stated that certain adults (and their dependents) would be entitled to free dental treatment and appliances (Gelbier, 2002; Government of Ireland, 1953). These adults were defined as "persons who are unable to provide by their own industry or other lawful means the medical, surgical, ophthalmic, dental or aural treatment, or medicines, or medical, surgical or dental appliances necessary for themselves or their dependants" (Government of Ireland, 1953).

Publication of the strategy document 'Shaping a Healthier Future' (Department of Health and Children, 1994) marked a major landmark in the development of the health care delivery system in Ireland. In November of that year, the Department of Health's DTSS was introduced as part of the national *Dental Health Action Plan 1994*. The scheme provides free dental care to people who are aged 16 years or over who have a Medical Card, and the dentist claims the full cost of service from the National Shared Services Primary Care Reimbursement Scheme (formerly the General Medical Services (Payments) Board). The scheme is currently (since 2005) maintained by the Health Services Executive. Anyone over the age of 16 years who is ordinarily resident in the Republic of Ireland is entitled to apply for a Medical Card, which entitles the holder to a range of free health services. People qualify for a Medical Card by being means-tested. People also quality if the HSE decides that the financial burden of medical expenses or other exceptional circumstances would cause undue hardship, even though their income is over the financial guidelines. Those with European Union entitlement are automatically entitled to a Medical Card (Health

Services Executive, 2013). Since April 2010, priority has been given to emergency dental care with a focus on relief of pain and sepsis.

The other main scheme for dental care provision for adults in Ireland is the DTBS under the Treatment Benefit Scheme, maintained by the Department of Social Protection. The grounding legislation for the DTBS was the 1952 Social Welfare Act, which established the Social Insurance Fund. Section 25 created the Treatment Benefit Scheme which comprised of the DTBS. The scheme may be accessed by employees (aged 16 years and over), retired people, and their dependent spouse/partner, if they have sufficient contributions in Pay Related Social Insurance (PRSI) Classes A, E, H and P. A PRSI contribution consists of an employer's and, where payable, an employee's share of PRSI; it is a percentage of an employee's reckonable earnings each week (Department of Social Protection, 2013). The contribution week begins on the 1st of January each year; an employee working for the full tax year is awarded 52 contributions (Department of Social Protection, 2013). The contribution one pays depends on income and occupation (PRSI class), hence the term 'Pay Related Social Insurance' contribution. Currently (in 2013), someone in Class A earning less than €352/week does not pay any social insurance, and the employer pays a contribution of 4.25% on the employee's income. Someone earning over €352/week pays 4% on their income (deducted directly from their income) and the employer pays 4.25% on the employee's income up to €356 and 10.75% thereafter (Citizens Information, 2013b).

According to Citizens Information (2013b), Class A is applicable to "people in industrial, commercial and service-type employment who are employed under a contract of service with a reckonable pay of €38 or more per week from employment. It also includes civil and public servants recruited from 6th April 1995". Class E is applicable to "ministers of religion employed by the Church of Ireland Representative Body". Class H is for "NCOs and enlisted personnel of the Defense Forces", and Class P is for "sharefishermen/women that are classified as self-employed" (Citizens Information, 2013b). In 2008, there were 2,405,896 people in these classes (2,397,198 + 166 + 8,518 + 14) (Department of Social Protection, 2009), however not all these would have sufficient contributions to be eligible for treatment benefit.

Government expenditure on the DTBS in 2008 was €69,419,000 (Department of Social Protection, 2009).

The amount of contributions required depends on age. For example, those under 21 years qualify for treatment if they have paid at least 39 contributions at any time, whereas those aged 25 to 65 years must have at least 260 paid contributions and a certain number of contributions must have been made recently (Citizens Information, 2013a). Those on the average industrial wage (€32,000) contribute approximately €20 per week as PRSI contributions (Irish Dental Association, 2009).

Under the DTBS, until 1st January 2010, insured persons who had made sufficient PRSI contributions were entitled to a range of free or discounted dental treatments. Dental treatment is provided by private dentists on the DTBS panel. The Department of Social Protection contributed a certain amount towards the cost of each treatment item, which was paid directly to the dentist. Dentists billed the patient for the balance of the fee, where applicable. The McCarthy Report (McCarthy et al., 2009) recommended the discontinuation of the Treatment Benefit Scheme (Dental, Aural, Optical and Hearing benefits) (p.190), with an estimated saving of €92.0m, and the Irish Government announced cuts to the DTBS from January 1st 2010 in Budget 2009. Eligible adults, and their spouses, are now entitled to one free oral examination per year.

A greater range of treatments had been provided in the DTBS (a cost-sharing scheme for employed adults) than the DTSS (free dental care mostly for low-income adults). Since 2010, limited resources have imposed restrictions on the public sector supply of dental services, and cover provided by both schemes has reduced. In addition, with increasing unemployment, the numbers eligible for the DTBS (employed adults) have decreased, and numbers eligible for the DTSS (mostly unemployed adults) have increased. The DTBS is further outlined in Articles III, IV and V, and the DTSS is further outlined in Article III. Table 1.1 presents summary information on state-funded dental schemes in Ireland.

Table 1.1 State-funded dental schemes: scheme operated by, who is covered, and numbers covered in 2008

Scheme	Operated by	Who is covered	Numbers	% of population[1]
Dental Treatment Benefit Scheme	Department of Social Protection	Eligible PRSI contributors (and retired adults with sufficient contributions) and their dependent spouses.	1.7 million	37.9
Dental Treatment Services Scheme	Health Service Executive	Medical card holders and their dependents.	0.9 million	20.1
Child health schemes	Health Service Executive	Children under 16 referred from (a) child oral health examinations, and (b) school oral health examinations.	0.8 million[2]	17.1
Other schemes	Health Service Executive	Holders of a Health (Amendment) Act Card.	1,700	0.04
Tax Relief	Revenue Commissioners	All PAYE workers and their dependents.	NA	

Sources: Department of Social Protection, Department of Health and Children. [1]Calculated based on a population estimate (4,485,070) (Central Statistics Office, 2013). [2]Number of children age 4-16 years (767,438), based on a population estimate (Central Statistics Office, 2013). NA = Not Available.

While upwards of 80% of the population were, at the time of this study, entitled to some degree of free/subsidised dental services, many did not qualify for treatment under any of the State schemes. According to The Competition Authority (2007), there may also be many consumers who are unaware of their entitlements or fail to claim them.

1.3. Specific aims and themes of the study

The aim of this research was to develop a method of generating valid information for health policy makers by applying statistical analyses and current technologies to oral health administrative and survey databases. This thesis illustrates a method to develop a comprehensive picture of status and trends for oral health among Irish adults in a way that was previously unattainable.

Using five specific studies, this research strives to answer the following questions:

Contextual Research

- What non-biological factors are associated with retention of natural teeth and sound untreated natural teeth among adults in Ireland? What influence does use of services have on retention of teeth? (Article I)

- What are the factors associated with reported utilisation of dental services in Ireland? Is there a relationship between SES (as measured by education, employment and income) and utilisation of dental services? (Article II)

Development of datasets from administrative databases, and application of data for research

- What is the potential of a dental administrative/claims database to provide information on the utilisation of services? What is the best way to model utilisation of dental services (measured as number of treatments) for a single cohort followed over five years? What was this cohort's pattern of dental care utilisation? (Article V)

- To what extent can useful data on temporal treatment patterns be extracted from a dental service claims database? What are the changing patterns of treatments provided in the DTBS in Ireland? Are increases in tooth retention and decreases in caries, reported in surveys of oral health, reflected in the volume and types of treatment provided to adults? (Article IV)

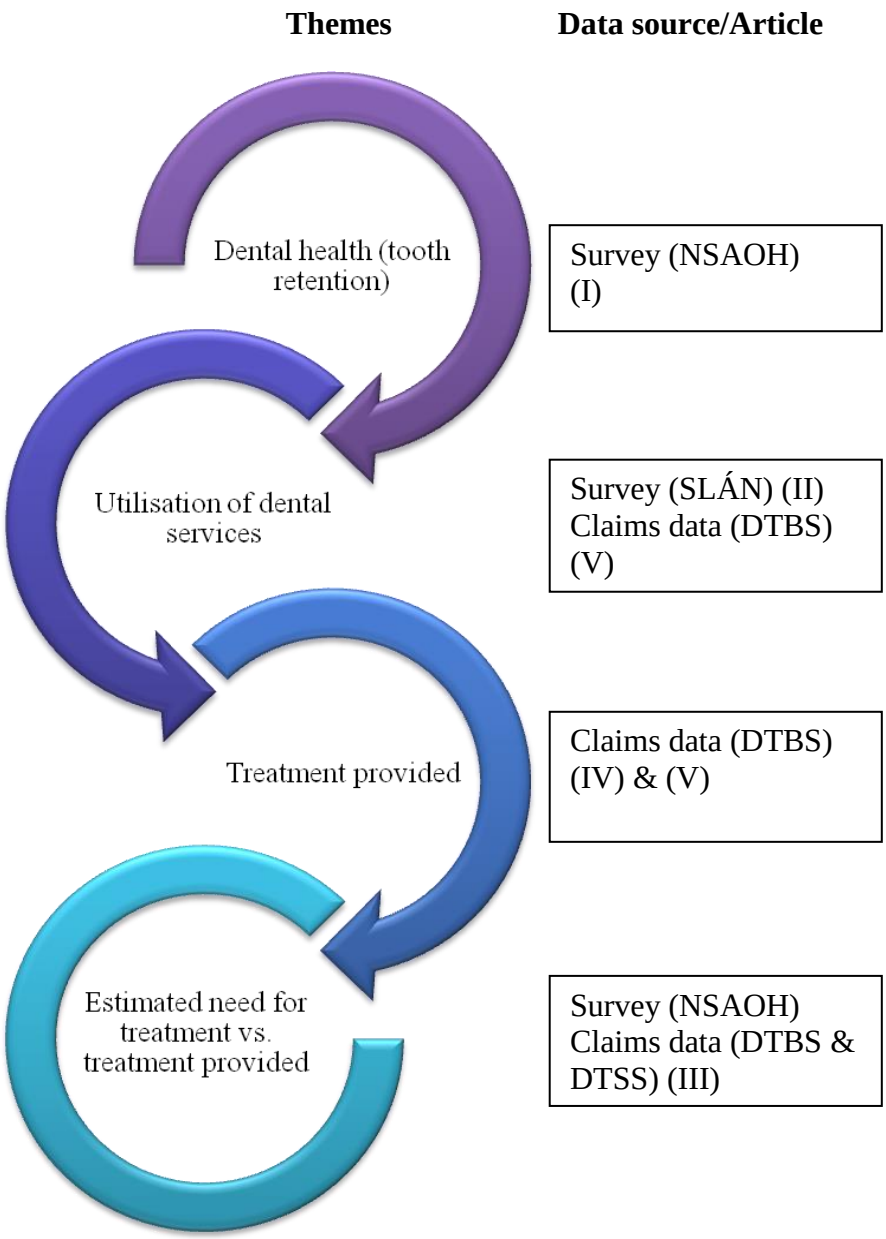
- Is there a significant difference between epidemiologically estimated oral health treatment need, and treatment provided, as measured from the DTBS and DTSS administrative databases? (Article III)

The first two articles explore the wider influences on oral health and utilisation of services among adults in Ireland, and provide the background knowledge within which the administrative databases can be explored. As a prelude to exploring the services databases, the epidemiological data (NSAOH 2000/02) was used to identify factors which might be relevant to tooth retention and the 2007 SLÁN survey identified factors which were associated with self-reported utilisation of dental services. These were subsequently used to help inform and interpret analyses of information from the administrative databases. Exploring these survey data helped to

determine the feasibility of using the variables available in the DTBS database to analyse factors associated with utilisation. It also helped to identify important or missing variables from the DTBS database, and informed the interpretation of Article V.

Figure 1.2 presents the themes covered in the study, and the data source used for the analyses. The data sources are explained in detail in Chapter 3.

Figure 1.2 Themes studied, and the data source used for the analyses



NSAOH = National Survey of Adult Oral Health 2000/02, SLÁN = Survey of Lifestyle Attitudes and Nutrition in Ireland 2007. DTBS = Claims data for the Dental Treatment Benefit Scheme, DTSS = Claims data for the Dental Treatment Services Scheme.

1.3.1. Theme 1: Non-biological factors associated with tooth retention

Recent decades have seen major improvements in dental health in developed countries, such as reductions in caries and increased tooth retention. In England, Wales and Northern Ireland, edentulousness decreased from 28% in 1978 to 6% in 2009 (Fuller et al., 2011). In the Republic of Ireland, surveys conducted in 1979 (O'Mullane and McCarthy, 1981), 1989/90 (O'Mullane and Whelton, 1992) and 2000/02 (Whelton et al., 2007) found that the percentage of edentulous 35-44 year-olds were 12%, 4% and 0.9% respectively, and corresponding figures for 65+-year-olds were 72%, 48% and 40.9% respectively. Nonetheless, Irish 50+ year-olds (n = 1,134) had the second-highest rate of edentulousness (48.0%) in the 2006/07 Survey of Health, Ageing, and Retirement in Europe (Listl et al., 2012), so factors associated with tooth retention in Ireland must be investigated.

In Article I, the relationship between tooth retention and self-reported use of services and other non-biological factors were analysed, using data from the 2000/02 NSAOH. Considering that dental status significantly affects diet and nutrition (Akpata et al., 2011; Nowjack-Raymer and Sheiham, 2003; 2007; Wakai et al., 2010; Yoshihara et al., 2005), keeping as many natural teeth as possible would have an important influence on general health. Indeed, studies have shown that oral health affect quality of life and general health (Einarson et al., 2009; Kandelman et al., 2008), and tooth loss is regarded as the "ultimate barometer of failure or success in dentistry and dental health programmes" (al Shammery et al., 1998).

Thomson and colleagues (2000) suggested that the loss of any tooth due to preventable diseases such as caries is a failure for the dental care system. According to Copeland and colleagues (2004), tooth loss is recognised as the final outcome of a complex process that encompasses disease-related factors, health behaviours, patient preferences, and professional interventions. Edentulism, or complete tooth loss, is considered the definitive indicator of disease burden for oral health (Cunha-Cruz et al., 2007). Knowledge of tooth loss is considered important as "the Shortened Dental Arch concept strongly influences treatment planning" (Muller et al., 2007), and measuring tooth loss/retention in a population is regarded as "extremely important" when predicting utilisation or planning oral health services (Ettinger, 1992).

Patterns of tooth retention in Ireland have changed for several reasons such as the decline in caries, largely attributed to the introduction of water fluoridation in 1964 (Whelton et al., 2006; Whelton et al., 2007), and developments in local anaesthetics and restorative materials, which make restorations a more attractive alternative to extractions (Eklund, 1999). In the past, extractions and dentures were the typical response to dental caries and periodontitis (Eklund, 1999), however in recent decades, there has been a move towards preventive and aesthetic dentistry (Kiyak and Reichmuth, 2005). Tooth loss is no longer considered an inevitable part of the aging process, and, according to Eklund (1999), people now expect to have a "functional, comfortable and aesthetic dentition throughout life".

Three well-recognised measures of dental health were used in Article I: number of natural teeth present, 21 or more natural teeth, and number of sound untreated natural teeth (SUNT). In 1992, the World Health Organization (WHO) suggested that the aim of at least 20 functioning teeth, not requiring prosthesis, is a milestone on the road to retention of all natural teeth in future generations (World Health Organization, 1992). Retention of more than 20 natural teeth is associated with a reasonable level of oral health (Whelton et al., 2007). According to Steele and colleagues (2000), at around 21 or more teeth, people "tend to experience dietary freedom and are able to rely on natural teeth without dentures for comfortable function".

Number of teeth is considered a "crude indicator of oral health status" as it provides information mostly on previous experience of dental disease (Suominen-Taipale et al., 2001). According to Yule and Parkin (1985), the major inadequacy of 'number of remaining teeth' is that no account is taken of the condition of those teeth which remain. Therefore, in addition to examining factors associated with retention of natural teeth, factors associated with number of sound untreated natural teeth were also examined (Article I). High numbers of sound untreated natural teeth have often been associated with those who avoid visiting a dentist regularly but can also indicate a well cared-for mouth (Kelly et al., 2000). When examining the relationship between utilisation and number of teeth, the use of a measure indicating dental health is considered more appropriate than the frequently used decayed, missed, filled teeth (DMFT) or decayed, missing, filled surfaces (DMFS) measures (Geyer and Micheelis, 2012). This is because visiting the dentist regularly is associated with preventive

habits directed towards maintaining oral health (Geyer and Micheelis, 2012). 18+SUNT was used as an arbitrary measure of dental health in the UK survey of adult oral health (Kelly et al., 2000) and in the most recent report on adult oral health in Ireland (Whelton et al., 2007), and is used in Article I for completeness.

1.3.2. Theme 2: Utilisation of dental services

Understanding factors associated with seeking care and utilisation of dental services is, according to Locker (1989), necessary for the promotion of "effective and efficient care". According to Grossman's demand theory, the demand for medical care is derived from the demand for good health (Grossman, 1972). Demand for dental services is defined as the number of requests for care (Grytten, 1992), and utilisation has been defined as the amount of services or treatments received (Grytten, 1992; So and Schwarz, 1996) or the "actual attendance by members of the public at health care facilities to receive care" (Spencer, 1980). In terms of access, utilisation reflects the extent to which potential access is converted into realised access (Aday and Andersen, 1981), or realised access is the actual use of services (Andersen, 1995; Andersen and Davidson, 2007). In agreement with traditional demand theory, according to Sintonen and Maljanen (1995), "demand for oral health depends on the price of oral health per unit, constraining income, the price of all other commodities, and the value people place on oral health as a source of consumption benefit". Compared to hospital and GP services, demand for dental services is considered to have a low priority. According to Hu (1981), in the past, dental care for anything other than dental disease was regarded primarily as a "luxury" or "cosmetic" service, and may still be considered as such by many people. In the most recent survey of the oral health of Irish adults, Whelton and colleagues (2007) found that visits are mostly undertaken for symptomatic reasons and the most common reason for infrequent dental attendance was a perception that there was no need to attend.

In describing the utilisation of dental services, three major concepts are described in the literature: inequality (Listl, 2011), need (Maharani and Rahardjo, 2012; Smith and Sheiham, 1980; Tennstedt et al., 1994; Wanman and Wigren, 1995) and utilisation (Muirhead et al., 2009; Pavi et al., 2010; Sintonen and Maljanen, 1995). Studies of utilisation of dental services are considered important tools for planning and developing oral health policies (Ekanayake and Mendis, 2002; Manski et al., 2001;

Pavi et al., 2010), and it has been suggested that better information is required on health status linked to use of services (Sabbah and Leake, 2000). Osterberg (1995) suggested that early identification of groups with low utilisation would contribute more to an overall improvement of dental health than a continued increase in utilisation among those who already have the highest attendance rate.

The proportion of adults visiting regularly for a check-up has increased in the Republic of Ireland in the last few decades. Surveys conducted in 1979 (Clarkson and O'Mullane, 1983), 1989/90 (O'Mullane and Whelton, 1992) and 2000/02 (Whelton et al., 2007) found that the percentage of adults who responded that they visited the dentist regularly for a check-up was 20%, 35.5% and 47.4% respectively. Corresponding percentages for those who visited only when in pain/trouble were 58%, 37.5% and 27.2%. In the 2000/04 World Health Survey, 88.6% of those surveyed in Ireland (n = 220) who said they had problems with their mouth or teeth in the last 12 months received treatment. Ireland ranked well in comparison to the other countries; only three other countries out of the 52 surveyed (Czech Republic, Luxembourg and Slovakia) had better oral health care coverage (Hosseinpoor et al., 2012). Hosseinpoor and colleagues also calculated a relative index of inequality (RII) and found a social gradient in coverage in favour of the wealthy (RII = 1.12). However, the value is so near one that it indicates no inequality with this sample (Hosseinpoor et al., 2012). A study using data from the 2006/07 Survey of Health, Ageing, and Retirement in Europe (Listl et al., 2012), found that, among those aged 50 years and over, 40.9% of Irish respondents (n= 1,134) reported seeing a dentist within the past year, ranking them 10th out of the 14 countries analysed.

Dental health impacts on the demand for, and utilisation of, dental services (Álvarez and Delgado, 2002; Nguyen, 2008; Suominen-Taipale et al., 2000), and utilisation has been found to influence dental health (Nguyen, 2008; Treasure et al., 2001; Ylostalo et al., 2004). Davies and colleagues (1987) found that those with poorer health status were less likely to visit the dentist, and when they did, they spent more money. Schicke (1981) suggested that "'deferred' demand and lower emphasis on prevention can contribute to a disproportionally high and costly share of rehabilitative prosthetic services". Regular dental visits enable dentists to provide preventive services, early diagnosis and treatment of oral conditions (Susi and Mascarenhas, 2002). Schwarz

and Hansen (1976) found that those who attended regularly tended to have preventive and conservative treatments, whereas those who attended less often received dentures or extractions at their last dental visit. A commonly used measure of the utilisation of dental services is whether an individual visited a dentist during the past year (Celeste et al., 2011; Manski and Magder, 1998; Millar and Locker, 1999; Muirhead et al., 2009; Pizarro et al., 2009; Sabbah and Leake, 2000). Another measure is frequency of use in a five-year period (Astrom et al., 2011b; Christensen et al., 2007; Eddie, 1984; Eddie and Davies, 1985; Heloe, 1978; Heloe et al., 1988; Nuttall, 1984; Petersen et al., 2004; Schwarz, 1996a).

1.3.2.1. National utilisation of dental services

In Article II, the aim was to identify the factors associated with self-reported utilisation of dental care services by adults in Ireland, using data from SLÁN 2007. The influence of ability to pay, measured by income level, on use of services was analysed. Income has been found to be an important factor influencing reported use of dental services. In a study of Canadians, Sabbah and Leake (2000) found that use of dental services is more likely to occur for young, healthy, wealthy and highly educated people. Gerdtham (1997) suggested that "individuals who are economically poorer may not be as well informed about health matters compared with those who are economically better-off". Financial limitations were found to be the most prevalent reason for refraining from seeking dental treatment in Sweden (Wamala et al., 2006), despite those with lower SES generally having a greater need for treatments (Hjern et al., 2001).

The Andersen model of health care utilisation was applied as the theoretical foundation to study socio-economic determinants of self-reported utilisation of dental services in Ireland (Article II). Using this model, factors that explain utilisation of dental services by adults may be classified into three categories. These are predisposing factors (such as age, gender and education); enabling factors, which affect one's ability to access the healthcare system (such as health insurance and income); and need factors, which motivate the individual to seek care (such as perceived or evaluated need, number of teeth, dentures, perceived oral health, and perceived oral health problems) (Andersen, 1995; Kiyak, 1986). According to Andersen and Davidson (2007), inequitable access to health care occurs when social

characteristics and enabling resources, such as ethnicity, insurance coverage, or income, determine who receives care. They define equity of access as "the value judgement that the system is deemed fair or equitable if need-based criteria are the main determinants of whether or not (or how much) care is sought" (p.12).

1.3.2.2. Scheme-specific utilisation of dental services

A large focus of this research is the DTBS, which is essentially a public insurance scheme. Evidence-based planning of dental services could be enhanced by the use of service data to identify factors which influence utilisation and outcomes of utilisation. As explained in Section 1.2, to qualify for benefit, patients must meet certain PRSI conditions, and until January 2010, eligible adults and their spouses were entitled to free or subsidised treatment. According to Grytten (2005), when a patient must pay a contribution towards their dental fees, there is a reduction in quantity consumed. Less consumption also means lower costs for the scheme (Grytten, 2005).

The primary purpose of Article V is to identify the potential of the DTBS database to provide information on the utilisation of services. It describes the approach taken, the challenges, and the resulting utilisation dataset. The secondary purpose is to examine strategies for modelling utilisation of dental services (measured as number of treatments), and empirically characterise and explain observed patterns of dental care utilisation. The utilisation rate of the DTBS in 2003 is estimated, and the distribution of treatments provided over the subsequent five years (2004–2008) is investigated. The patterns of attendance, and the factors associated with utilisation of dental services for this cohort are investigated, using different empirical models. This is with a view to contributing to a better understanding of utilisation of dental services and to inform service design and planning.

1.3.3. Theme 3: Trends in dental treatment provision

Two aspects of utilisation that must be considered are the quantity and the content of care received (Stahlnacke et al., 2005). Although total number of visits has been used as a measure of utilisation, and is used in Article V, Yule and Parkin (1985) suggested that it is an inadequate measure of demand for dental service utilisation. They indicated that the fundamental problems in using visits to measure the quantity of

services demanded are failure to distinguish between patient and dentist-initiated visits, and failure to consider the volume or mix of treatments provided.

While many studies have reported the composition of treatments provided, many are at a point in time, or consider the total treatments over time, for example: (Eddie and Davies, 1985; Grembowski et al., 1990; Hayden, 1997; Manski and Moeller, 2002; Vysniauskaite and Vehkalahti, 2006). However, there is also a need for information on changes in the types of treatment provided. A measure of the success of provision of dental services to children is improved oral health among adults. Also, since dental health has reportedly improved (Whelton et al., 2006; Whelton et al., 2007) and patterns of dental care logically follow the patterns of dental disease (Eklund, 1999), it is of interest to examine treatment patterns over time. According to Spencer and colleagues (1994b), "trends in the distribution and volume of dental services provide an empirical base upon which hypotheses on future service provision can be tested". They are important to obtain a complete view of the conditions that may influence the overall volume of treatment provided. It has been suggested (Randall et al., 2002) that patients' desire to keep their teeth will lead to increased endodontic treatment need, the provision of dental treatment is becoming increasingly influenced by patients' perceptions, and that treatment needs are becoming more diverse and complex, with a decline in the amount of simple treatments provided. Demand for treatment in the past was primarily based on extractions and dentures, however, it was gradually substituted by restorative dentistry, and now the focus is moving towards prevention. Although this is known anecdotally, it has not been quantified in the DTBS.

Researchers and policy-makers aspire to rapid adoption of best practice by dentists through dissemination of evidence. One way of determining change in practice is through examining trends in the number and types of restorations provided. Recent decades have seen advances in restorative materials (Cramer et al., 2011) and developments in evidence of effectiveness (Burke and Lucarotti, 2007; Janus et al., 2006; Opdam et al., 2010). Caries, the main reason for provision of restorations (Deligeorgi et al., 2001; Tyas, 2005) is decreasing (Whelton et al., 2006; Whelton et al., 2007). Other reasons for the provision of restorations include aesthetics, wear and fractured teeth (Clarkson et al., 2000). The choice of restorative material is based on

factors such as the clinical situation, the dentist, patient's choice (Clarkson et al., 2000), caries location and gender of the dentist (Lubisich et al., 2011). In addition, concern about aesthetics (Christensen, 2007) and ongoing developments in restorative material (Cramer et al., 2011) may influence the type of restoration provided. Amalgam restorations are considered versatile (Bharti et al., 2011), and have been found to be preferred by dentists "in more challenging restorations with respect to caries activity, lesion depth, and tooth type" (Vidnes-Kopperud et al., 2009), however there may be a tendency for dentists to provide tooth-coloured restorations. In some countries, for example, Sweden, Norway, Denmark, Finland, The Netherlands, and Japan, use of amalgam restorations have been reduced or banned (Burke, 2004; Feeney, 2008; Roeters et al., 2004; Shibatani et al., 2009; Vidnes-Kopperud et al., 2009).

The improvements in the processing power of desktop computers have increased the feasibility of mapping annual trends in the volume and mix of dental treatments provided in practice. This article harnesses these technological developments to analyse a large insurance database in Ireland. This research set out to describe trends in dental services utilisation, i.e., to determine the frequency and distribution of treatments for those who used the DTBS by year; and identify the factors that may have influenced the trends in total number of treatments over 12 years. It provides an otherwise unavailable detailed understanding of the magnitude and nature of the specific treatments that patients received in the scheme. It illustrates the value of investigating the links between the pattern of dental treatment provision and improvements in oral health. Although it can be difficult to attribute the determinants of change in behaviour, it is important for policy-makers when planning future services to detect changing trends in treatment provision.

1.3.4. Theme 4: Comparison of epidemiologically-estimated need with treatment provided

Assessing treatment need is considered a necessary first step in oral health care (Aleksejuniene and Brukiene, 2009), and is at the core of health planning (Sheiham and Tsakos, 2007). Its purpose is to "gather the information required to bring about change beneficial to the health of the population" (Stevens and Gillam, 1998). Need for treatment has been conceptualised as two components: subjective need and

objective need. Subjective need is expressed by the individual as the perceived need for treatment and varies according to the "psychological, social and historical context in which the individual lives" (Mosha and Scheutz, 1993). Bradshaw (1972) refers to this as 'felt need' which is equated with want expressed as the individual's own assessment or his or her health state. Furthermore, expressed demand is when 'felt' need is converted into demand by seeking care. Objective need is usually assessed by a professional (normative or evaluated need).

The aim of Article III was to determine the validity of survey data to inform planning. Normative (epidemiologically assessed) need for selected treatments, as measured on a randomly-selected representative sample, is compared with the treatment actually provided in the population from which the sample was drawn. The objective of this article was to compare epidemiologically estimated oral health treatment need, with treatment provided, as measured from administrative databases, for selected treatments. The comparison is undertaken for two dental schemes serving employed adults (DTBS) and less well-off adults (DTSS). Although epidemiologically-estimated need provides useful data on the treatments required, survey data can be augmented by comparing with real (administrative) data for planning.

1.4. Layout of thesis

Chapter 2 provides details and results of the systematic literature searches relating to the four main themes of this research, as outlined in Section 1.3. Chapter 3 describes the data sources and methods used to address the objectives of this research. Chapter 4 summarises the results of the analyses. In Chapter 5, the benefits and drawbacks of the data sources are discussed, as are results in the context of previous research. Chapter 6 provides a summary of the findings, and recommendations are proposed for future research. Appendices, and the articles upon which this thesis is grounded, follow.

2. Systematic literature searches

To inform the articles in this thesis, and to contextualise the studies in terms of previous research conducted in the area of non-biological factors associated with tooth retention, factors associated with utilisation of dental services, comparing epidemiologically estimated need with treatment provided, and patterns of dental treatment provided, literature reviews were undertaken. Literature was first searched unsystematically using PUBMED and Google, and the reference lists of all relevant articles were further checked to identify additional suitable studies. Google was included to help identify grey literature. Much of this literature is referenced throughout the thesis and in the articles. To ensure that all relevant 'non-grey' literature had been found, systematic literature searches were conducted in PUBMED in July and August 2012. The search was updated in February 2013. In this chapter, details of the systematic literature searches, and a summary of the findings, are outlined for each of the four main themes of this thesis.

The number of articles found in the searches and final number of articles included in the reviews are summarised in Table 2.1. Excluded from the final number of articles were those not relevant on further reading. Variations existed in study size, population, time period, and the outcome measured.

Table 2.1 Number of articles found during systematic searches and final number of articles

Theme	Search	Relevant based on title	Final number of articles
Non-biological factors associated with tooth retention	5,727 (+125)	169 (+3)	99 (+3)
Factors associated with utilisation of dental services	1,737 (+89)	202 (+16)	133 (+9)
Trends in dental treatment over time	1,813 (+16)	30 (+3)	29 (+3)
A comparison of epidemiologically-estimated need with treatment provided	539 (+12)	16 (+1)	5 (+0)

Note: numbers in parentheses refer to those for the updated search in February 2013.

2.1. Non-biological factors associated with tooth retention

The electronic database PUBMED was searched in August 2012, with no time limits, using search terms ("tooth loss" OR "dental health" OR "dental conditions" OR "number of teeth" OR "tooth retention" OR "retention of teeth" OR "sound untreated natural teeth" OR "natural teeth") AND (implications OR factors OR determinant* OR evaluat* OR relation* OR socio*) limited to adults, adolescents, humans and the English language. The initial search retrieved 5,727 non-duplicate articles. One hundred and sixty nine of these articles seemed relevant based on their titles, and 99 articles were included in the final review. The search was repeated in February 2013, with a custom date range beginning June 2012. This retrieved 125 non-duplicate articles, of which three seemed relevant based on their titles, and all three articles were included in the final review. A summary of the data source and population, dental status indicators used, type of analysis, and the findings are presented in Appendix 1. Apart from Article I (Guiney et al., 2011a), no investigations of factors associated with tooth retention in Ireland were found.

Although one of the objectives of this thesis was to analyse factors associated with tooth retention, the dental status indicator most frequently used in studies was 'tooth loss'. Measures of tooth loss vary from tooth loss for any reason (Al-Bayaty et al., 2008; Bole et al., 2010; Eklund and Burt, 1994; Hanioka et al., 2007a; Jung et al., 2011; Lopez and Baelum, 2006; Mundt et al., 2011; Ojima et al., 2007; Sanders et al., 2007; Susin et al., 2005; Susin et al., 2006; Taiwo and Omokhodion, 2006; Yanagisawa et al., 2010), or due to caries or gum disease (Bernabe and Marcenes, 2011; Okoro et al., 2012; Thomson et al., 2000). Factors associated with tooth loss during the past 12 months (Haugejorden et al., 2003; Miller and Locker, 1994), 24 months (Gilbert et al., 1999), three years (Drake et al., 1995), four years (De Marchi et al., 2012), or 10 years (Holm, 1994) have been studied. Factors associated with number of teeth lost (Adegboye et al., 2012; De Marchi et al., 2012; Jansson and Lavstedt, 2002) have been analysed, and other longitudinal studies of incidence of tooth loss have been conducted (Adegboye et al., 2010; Astrom et al., 2011a; Copeland et al., 2004; Dietrich et al., 2007; Eklund and Burt, 1994). Studies also examined factors associated with loss of at least one tooth (Atieh, 2008; Barbato and Peres, 2009; Casanova-Rosado et al., 2005; Slade et al., 1997).

Another frequently used dental status indicator was total tooth loss, i.e., edentulousness, analysed as percentage of edentate adults (Ahlqwist et al., 1999; Beal and Dowell, 1977; Heloe et al., 1988; Jack and Bloom, 1988; Palmqvist et al., 1991; Richards and Ameen, 2002) or factors associated with being edentulous (Ahlqwist et al., 1989; Ahlqwist et al., 1991; Dogan and Gokalp, 2012; Dolan et al., 2001; Hugo et al., 2007; Li et al., 2011; Musacchio et al., 2007; Paulander et al., 2004; Petersen et al., 2004; Suominen-Taipale et al., 1999; Turunen et al., 1993; Unell et al., 1998; Wu et al., 2012), trends in edentulism (Cunha-Cruz et al., 2007) or probability of becoming edentulous (Burt et al., 1990). Mean number of missing teeth was analysed in several studies (al Shammery et al., 1998; Chung et al., 2011; Zitzmann et al., 2008), as was number of missing teeth (Chatrchaiwiwatana, 2007; Mundt et al., 2007; Pallegedara and Ekanayake, 2005; Telivuo et al., 1995). A South Korean study analysed factors associated with missing teeth with unmet needs (Kim et al., 2007), a Japanese study analysed factors associated with more than eight missing teeth (Yanagisawa et al., 2010), and a U.S. study examined the relationship between six or more missing teeth and socioeconomic characteristics (Nikias et al., 1977). Factors associated with number of extracted teeth or teeth removed because of gum disease or tooth decay (Finlayson et al., 2009; Hesser and Jiang, 2008; Suominen-Taipale et al., 2001) or having at least one tooth extracted (Okoro et al., 2012) were also investigated.

Tooth retention was measured as being dentate (Marcus et al., 1996; Osterberg et al., 2006; Steele et al., 2000), number of teeth present/retained (Adegboye et al., 2010; Ahlqwist et al., 1991; Ahlqwist et al., 1999; Bernabe et al., 2010; Bernabe et al., 2012; Cunha-Cruz et al., 2007; Daly et al., 2003; Fan et al., 2006; Forslund et al., 2002; Fukuda et al., 1997; Joshi et al., 1996; Musacchio et al., 2007; Pearce et al., 2004; Unell et al., 1998), and mean number of retained teeth (Hescot et al., 1997; Palmqvist et al., 1991; Sakki et al., 1994; Yanagisawa et al., 2010). Other measures included retention of 20 or more teeth (Ahlqwist et al., 1989; Aida et al., 2011; Heloe et al., 1988; Hescot et al., 1997; Hugo et al., 2007; Koltermann et al., 2011; Osterberg et al., 2006; Petersen et al., 2004; Richards and Ameen, 2002; Thorstensson and Johansson, 2010), 1-20 teeth (Richards and Ameen, 2002), 1-19 teeth (Heloe et al., 1988; Hugo et al., 2007), fewer than 19 teeth (Hanioka et al., 2007b), fewer than 20 teeth (Heegaard et al., 2011; Sanders et al., 2007; Yiengprugsawan et al., 2011),

number of restored teeth (Ahlqwist et al., 1999), or number of sound teeth (Donaldson et al., 2008). Geyer and Micheelis (2012) analysed factors associated with number of caries-free and unrestored healthy teeth in Germany.

Factors associated with tooth loss include smoking (Arora et al., 2010; Atieh, 2008; Copeland et al., 2004; Fan et al., 2006; Osterberg et al., 1991), a BMI of less than 20 (Lawton et al., 2008), nocturnal eating (Lundgren et al., 2010), frequent snacking or having a poor diet (Atieh, 2008; Daly et al., 2003), having a lower subjective social status (Tsakos et al., 2011), and living in a high disadvantaged area (Sanders and Spencer, 2004). Tooth loss was found to increase with age (Al-Shammari et al., 2007; Astrom et al., 2011a; Wu et al., 2012) and was found to be greater among males in many of the studies (Bernabe and Marcenes, 2011; Copeland et al., 2004), although there were some exceptions (Ringland et al., 2004). Factors associated with retention of teeth include frequent tooth brushing (Aida et al., 2011; Hamasha et al., 2000; Mumghamba and Fabian, 2005), consumption of green tea (Koyama et al., 2010), and regular or frequent visits to the dentist (Bernabe and Marcenes, 2011; Fan et al., 2006). Frequent dental visits were found to be associated with fewer missing teeth (Sheiham et al., 1985). More than two years between check-ups was found to increase the odds of being edentulous or having fewer teeth (Pihlgren et al., 2011). SES was also associated with tooth retention/loss and being edentulous (Bernabe et al., 2012; Dixon et al., 1999; Donaldson et al., 2008; Finlayson et al., 2009; Pearce et al., 2004), with socio-economic inequalities in tooth loss “appearing to manifest early in life” (Thomson et al., 2000).

2.1.1. General observations on methods used in the studies

The type of analysis most frequently used was logistic regression analysis, as is usual when the dependent variable is a dichotomous variable. Count data models have been used to a lesser extent. This may be because the data was initially recorded as a dichotomous variable or because logistic regression is familiar to most people and so the results are easier to interpret than for count data models. Although analysing factors associated with tooth retention, as a dichotomous variable, is very useful, analysing factors associated with number of teeth, as a count variable, enables an explanation of the effect of the explanatory variables for every one extra tooth retained. Dichotomising leads to several problems, such as loss of information (so the

statistical power to detect a relationship is reduced), uncertainty in defining the cut-point (Royston et al., 2006), and can yield misleading results (MacCallum et al., 2002). According to Cohen (1983), dividing subjects into two groups leads to the loss of between 1/5 and 2/3 of the variance accounted for by the original variables.

Only one study used number of sound untreated natural teeth as the dependent variable (Donaldson et al., 2008), although Geyer and Micheelis (2012) used number of caries-free and unrestored healthy teeth as a measure of oral health. A tooth is considered sound if it is not decayed, filled, or otherwise restored or traumatised on its coronal surface, and so is a more accurate representation of the health of the dentition than tooth loss or number of remaining teeth.

Water fluoridation, measured as "percentage lifetime exposure to water fluoridation" has been associated with lower caries levels in children and adolescents (Armfield, 2010; Singh et al., 2003), however no studies have analysed the influence of percentage lifetime exposure to water fluoridation on tooth retention among adults. Although the effect of having access to a fluoridated water supply on tooth retention was assessed in one study (Barbato and Peres, 2009), currently living in an area with fluoridated water provides no information on exposure over a lifetime.

2.2. Factors associated with utilisation of dental services

The electronic database PUBMED was searched in August 2012, with no time limits, using search terms (predictors OR factors OR determinants OR enablers) AND (consumption OR use OR utilisation OR utilization) AND (dental services OR dental care services OR dental care) limited to adults, adolescents, humans and the English language. The search retrieved 1,737 non-duplicate articles. Two hundred and two of these articles seemed relevant based on their titles, and 133 articles are included in this review. The search was repeated in February 2013, with a custom date range beginning in June 2012. This search retrieved 89 non-duplicate articles, of which 16 seemed relevant based on their titles, and nine articles were included in the final review. A summary of the data source and population, measure of utilisation, type of analysis/theoretical framework, and the findings are presented in Appendix 2. Apart from Article II (Guiney et al., 2011b), no studies on factors associated with utilisation of dental services in Ireland were found.

Since utilisation of dental services in this thesis analyses data from the general population, articles reporting data collected from special-interest groups (and therefore focusing on specific explanatory variables), such as pregnant women, fishermen, cancer survivors, those with HIV, or disabilities, refugees, migratory agricultural workers, substance abusers, and those in institutions were excluded from the literature review. In total, 142 studies met the inclusion criteria, in that the authors performed an analysis to determine factors associated with utilisation of dental services.

The most commonly used measure of utilisation in the studies was reported use of dental services in the "last 12 months"/"past year" (Arcury et al., 2012; Australian Research Centre for Population Oral Health, 2010; Brown, 2009; Brown et al., 2009a; Celeste et al., 2011; Choi, 2011; Finlayson et al., 2010; Gift and Newman, 1993; Grytten, 1991; Grytten et al., 2012; Jack and Bloom, 1988; Koletsi-Kounari et al., 2011; Kronstrom et al., 2002; Manski and Magder, 1998; Marin et al., 2010; Marino et al., 2005; Millar and Locker, 1999; Mumcu et al., 2004; Pavi et al., 2010; Sabbah and Leake, 2000; Sanchez-Garcia et al., 2007; Seirawan, 2008; Sohn and Ismail, 2005; Spencer and Harford, 2007; Stadelmann et al., 2012; Suominen-Taipale et al., 2000; Suominen-Taipale et al., 2001; Tomar et al., 1998; Vikum et al., 2012). Use during the calendar year was also measured (Nguyen et al., 2005; Osterberg et al., 1995), as was reported use of dental services in the "previous year" (Baldani and Antunes, 2011; Kaylor et al., 2010; 2011; Locker et al., 2011; MacEntee et al., 1993; Mucci and Brooks, 2001; Ohi et al., 2009; Okunseri et al., 2004; Pizarro et al., 2009; Slack-Smith et al., 2007; Wu et al., 2005) and "prior year" (Watson and Brown, 1995). Expenditure in the preceding 12 months was also used as a measure of utilisation (Tuominen et al., 1985; Tuominen and Paunio, 1987). Number of visits in a year (Bhatti et al., 2007; Bloom et al., 1992; Evashwick et al., 1982; Jack and Bloom, 1988; Nguyen and Hakkinen, 2006; Skaar and Hardie, 2006; Tennstedt et al., 1994), and number of visits in a year given at least one visit (Grytten, 1992; Pavi et al., 2010) were also used as measures of dental service utilisation.

Other time periods in measuring utilisation were use of dental services in the last month (Maharani and Rahardjo, 2012; Zavras et al., 2004), previous three months (Álvarez and Delgado, 2002; Garrido-Cumbrera et al., 2010), previous six months

(Brothwell et al., 2008; Suominen-Taipale and Widstrom, 1998), or in the last two years (Ahlberg et al., 1996; Anderson and Kim, 2010; Ekanayake and Mendis, 2002; Kosteniuk and D' Arcy, 2006; Manski et al., 2010; Schwarz and Lo, 1994; Stewart et al., 2002). Use of dental services in 15 months and three years were also used, for example, number of visits in 15 months (Sintonen and Maljanen, 1995), use of dental services in the preceding 15 months (Evashwick et al., 1984), number of dental visits during the last three years (Lissau et al., 1989), and use of a program within the past three years (Kiyak, 1987). Five-year periods were also used, for example, having visited a dentist one or more times during the last five years (Christensen et al., 2007), or less than five years ago (Stewart et al., 2002), annual dental care over the preceding five years (Li et al., 2011), and regular (at least once a year) dental behaviour during the past five years (Schwarz, 1996a).

Other measures of utilisation were time since last dental visit (Evashwick et al., 1982; Lester et al., 1998; Tennstedt et al., 1994; Wu et al., 2007), probability of any use (Conrad et al., 1987; Ekanayake et al., 2001a), whether or not people visited regularly (undefined) (Hjern et al., 2001; Kaprio et al., 2012; Koletsi-Kounari et al., 2011; Schwarz and Lo, 1994), visit less than once a year (Bagewitz et al., 2002), visit the dentist in the past year for non-emergency treatment (McGrath et al., 1999), and choice of public and private practice (Nyyssonen et al., 1983).

Regular use was also defined by use within a one-month recall interval (Maharani, 2009), 6-monthly use of dental services during a 24-month period (Gilbert et al., 1998), visiting the dentist at least once in a year (Manski et al., 2001; Petersen, 1983a; Sogaard et al., 1987), twice a year or more (Kronstrom et al., 2002), or at least once in two years or every second year (Manski et al., 2012; Sintonen and Maljanen, 1995; Widstrom et al., 1984). Regular users were also defined as those who visited a dentist within the last two years and the reason for their last dental attendance was for scaling/polishing or for a check-up (Pavi et al., 1995), or people who visited every year to have their teeth examined versus going to the dentist if there is a problem (Ugur and Gaengler, 2002). Rajala and colleagues (1978) defined regular use as visiting annually or once in two years. Factors associated with regular visits for a check-up were also analysed (Sugihara et al., 2010; Wu et al., 2007), or preventive

check-up once every one to two years or once every three to five years (vs. emergency visit) (Sakalauskiene et al., 2009).

Other more specific measures of utilisation were preventive dental visit or emergency dental visit in the past 12 months (Neff et al., 2010), usually visit for check-up (Australian Research Centre for Population Oral Health, 2010), dental extraction in the past year (Australian Research Centre for Population Oral Health, 2010; Roberts-Thomson et al., 2008), dental visit for relief of pain within the past two years (Roberts-Thomson et al., 2008), and use of services by adults who had experienced oral health problems during the previous 12 months (Varenne et al., 2006). Type of service received, or reason for a dental visit was also analysed (Geyer and Micheelis, 2012; Jaafar and Razak, 1988; Skaar and Hardie, 2006; Stadelmann et al., 2012; Tuominen et al., 1988). Armfield (2012) examined factors associated with avoiding going to the dentist, and Jatrana and Crampton (2012) focused on deferring visits to a dentist in the preceding 12 months because of cost. Geyer and Micheelis (2012) examined factors associated with visiting a dentist because of complaint (vs. prevention/early detection).

Infrequent dental attendance was measured by last visit to the dentist greater than or equal to one year ago (Muirhead et al., 2009), no visit to the dentist last year (Osterberg et al., 1998), in the last 1.5 years (Scheutz and Heidmann, 2001), in the last two years/24 months (Hjern et al., 2001; Lawton et al., 2008), in a 2.5-year period (Roberts-Thomson et al., 2011), or at least five years since last dental visit (Australian Research Centre for Population Oral Health, 2008; Osterberg et al., 1998; Skaret et al., 2003). When examining factors associated with non-use of dental services, other dependent variables included not having a dental visit in the previous year (Locker et al., 1991), not having had a dental visit or cleaning in the past year (Okoro et al., 2012), no dental examination in the last year, or never had a dental examination (Yu et al., 2001). Factors preventing regular dental care (annual check-up) were also analysed (Syrjala et al., 1992), as were barriers to dental attendance (Lester et al., 1998; Mattin and Smith, 1991).

In an effort to distinguish between types of users, Kuthy and colleagues (1996) created categories of dental user types (no dental service use, but used medical or pharmacy services, two complete dentures, compliant, infrequent and unclassified).

Stahlnacke and colleagues (2005) categorised users as high users (visited a dentist less than one year ago and used dental care services two or more times per year), low users (latest dental visit more than one year ago and regular visits every second year or more seldom), and all others were characterised as 'normal'. Nihtila and colleagues (2010) defined heavy users as having had six or more visits, and low users as having had three or fewer visits in a year.

Andersen's behavioural model of health care utilisation was the most frequently used theoretical framework (Kiyak, 1986; Pizarro et al., 2009; Sabbah and Leake, 2000). Factors found to influence utilisation of dental services include gender, age, and perceived need (Álvarez and Delgado, 2002; Brodeur et al., 1988; Christensen et al., 2007; Grytten and Holst, 2002; Maharani and Rahardjo, 2012; Suominen-Taipale et al., 2000). Marital status was found to influence utilisation in a number of studies (Anderson and Kim, 2010; Brown et al., 2009a; Seirawan, 2008; Sibbritt et al., 2010; Skaar and Hardie, 2006). The supply of dentists, or dentist per population ratio, was found to influence utilisation of dental services (Groenewegen and Postma, 1984; Nguyen et al., 2005), as was residing in an urban area (Sibbritt et al., 2010). Dentition status (measured as number of teeth) and a variety of social and behavioural factors, such as education, income, health behaviour and employment status have also been found to be important influences of utilisation of dental services (Álvarez and Delgado, 2002; Alvesalo and Uusi-Heikkila, 1984; Nguyen et al., 2005; Sabbah and Leake, 2000; Suominen-Taipale et al., 2000; Suominen-Taipale and Widstrom, 1998; Tomar et al., 1998). Rise and Holst (1982) found that dental status was the most important determinant of use of services, and that age affected utilisation mainly indirectly through dental status. Reisine (1987) found that the effects of age on use of services are due to the correlation between age and number of decayed, missing and filled teeth.

Socio-economic gaps have been found in visiting the dentist (Celeste et al., 2011; Maharani and Rahardjo, 2012; Mumcu et al., 2004; Nguyen et al., 2005; Petersen, 1983b; 1984; Unell et al., 1996; Vikum et al., 2012). The use of dental care services has been found to be more dependent on ability to pay than on self-perceived need for care (Maharani and Rahardjo, 2012), which disadvantages those in lower SES groups. Having private dental insurance was positively associated with use of services (Drilea

et al., 2005; Goodman et al., 2005; Kaylor et al., 2010; Manski, 1995), as was being a white-collar worker (Gomes et al., 2008). In Sweden, financial limitations were the main reason for not seeking dental treatment (68% of men and 73% of women) (Wamala et al., 2006). Studies have shown that very low income adults experience "large indirect financial and/or opportunity costs in seeking and receiving treatment" (Oliver and Mossialos, 2004), and they may regard dental visits a luxury rather than a necessity (Muirhead et al., 2009). It has been found that higher social class patients have more restorative and preventive visits, whereas low SES groups are more likely to receive emergency services and extractions (Kyaw, 2001). Davies and colleagues (1987) found that oral health status, continuity of dental provider and beliefs in self-care reduced or eliminated socio-demographic effects on probability of use.

Perceived need and self-rated oral health were found to be significantly associated with utilisation of services (Muirhead et al., 2009; Pavi et al., 2010). Pavi and colleagues (2010) found that socio-economic variables mediate the effect between perceived oral health and dental service utilisation. Studies have found that lack of perceived need was a barrier to care among older adults (Lester et al., 1998), a low perception of need tended to reduce the likelihood of attendance (Hawley and Holloway, 1992), and perceiving a need for treatment increased the probability of attending the dentist regularly (Schwarz and Lo, 1994). Wilson and Branch (1986) found that both perceived need for treatment and use of dental services were influenced by dentate status, and that dentate status was a better predictor of use of services among the elderly than perceived need. In addition, the chance of reporting bad self-perceived oral health was found to be higher among those who only go to the dentist when there is a problem (vs. routine check-ups at least once a year) (Afonso-Souza et al., 2007).

Differences in use of dental services were found to be related to the perceived benefits of dental check-ups (Batchelor and Sheiham, 2002). Irregular dental attendance was found to be associated with high dental fear (Pohjola et al., 2007). Schouten and colleagues (2006) found that the less cynical and more motivated the patient, the stronger their preference for regular dental check-ups. Factors associated with visiting regularly for a check-up included social environment (deprived or affluent) (Pavi et al., 1995), high income (Sakalauskiene et al., 2009; Wu et al., 2007), a higher

level of education (Wu et al., 2007), being female (Sakalauskiene et al., 2009; Sugihara et al., 2010; Wu et al., 2007), frequent brushing (Sugihara et al., 2010), and tooth retention (Álvarez and Delgado, 2002; Sakalauskiene et al., 2009). Luzzi and Spencer (2008) found self-efficacy and past behaviour to be significant predictors of use of dental services. A greater number of functional limitations among those aged 65 and over were found to be associated with a lower likelihood of visiting the dentist (Brown et al., 2009b). Utilisation was also associated with experiencing toothache or oral discomfort (Tuominen and Paunio, 1987). The odds of visiting because of a complaint (vs. prevention/early detection) was found to be highest among those of lower income, lower education and males (Geyer and Micheelis, 2012). Manski and Goldfarb (1996) found that older adults who visited for relief of a problem were more likely to have more dental visits than those seeking preventive care.

Attitudes and beliefs are considered important since positive attitudes are said to increase the likelihood of seeking care (Locker, 1989). It has been found that dentally anxious individuals were more likely to have two or more years since their last dental visit (Dixon et al., 1999). Armfield (2012) found that avoiding visiting the dentist due to lack of time, inconvenience and not getting around to it was most common among those with the highest income. He also found that avoidance due to not getting around to it was greater among younger age groups, and that females were more likely to avoid the dentist because they did not like dentists while the main reason for males avoiding the dentist was apathy or indifference.

2.2.1. General observations on methods used in the studies

As with non-biological factors associated with tooth retention, the type of analysis most frequently used was logistic regression analysis. Count data models that have been used include the FMM (Okunseri et al., 2011), Poisson model (Celeste et al., 2011; Pavi et al., 2010; Zavras et al., 2004), and the two-part model (TPM) (Nguyen et al., 2005; Sintonen and Maljanen, 1995). Utilisation has also been examined within the framework of a three-part model, where contact, the choice between public and private dental sectors, and frequency was investigated (Nguyen and Hakkinen, 2006).

In the absence of a prior cut-point, common approaches to distinguish between high and low users of health services are to use the median split, or mean split techniques; however results cannot easily be compared between studies (Royston et al., 2006). In

a recent study, heavy consumption of dental services was defined as six or more dental visits in a year, and a low user was defined as having three or fewer visits (Nihtila et al., 2010), which is an improvement over the median split technique. Nonetheless, given that the empirical specification used in the analysis influences the conclusions (Deb and Holmes, 2000), analyses with count data, where available, may lead to a more accurate understanding of the association between explanatory variables and utilisation of services. Where the count of number of visits is available, an alternative to categorising people a priori is to use the finite mixture model (FMM) to categorise them as typical and frequent users (Okunseri et al., 2011). The FMM is explained in more detail in Section 3.3.3.

2.3. Trends in dental treatment provision

The electronic database PUBMED was searched in July 2012, with no time limits, using search terms (dental care [MeSH] OR "dental treatment") AND (trend* OR pattern* OR timetrend* OR time-trend*), limited to adults, adolescents, humans and the English language. The search retrieved 1,813 non-duplicate articles. Twenty nine studies met the inclusion criteria, in that they examined trends in treatment provision over time in adults. The search was repeated in February 2013, with a custom date range beginning in June 2012. This search retrieved 16 non-duplicate articles, of which three seemed relevant based on their titles, and these articles were included in the final review. One of the reviewers of Article IV indicated that similar studies had been conducted in the U.S. using Delta Dental, Metlife and Medicaid data. Therefore, for this topic, Google Scholar was also searched using search terms (dental treatment trend * adult * "Delta Dental" OR Metlife OR Medicaid), for which there were 5,040 links. This search added two more articles. Some of these articles are referenced in Article IV, and all are outlined in Appendix 3.

Some studies focused on examining trends in utilisation (Beazoglou et al., 1993; Lee et al., 2012; Suominen-Taipale et al., 2000; Wall, 2012; Wall et al., 2012). In the studies examining trends in the types of treatments provided, diagnostic and preventive treatments increased in most countries (Brennan and Spencer, 2006; Eklund et al., 1997; 1998; Elderton and Eddie, 1983b; Heloe, 1978; Heloe et al., 1988; Lacey, 2006), however they decreased among Canadian First Nations and Inuit people in Canada between 1994 and 2001 (Leake et al., 2005).

The general consensus among all articles was that provision of extractions decreased over time (Brennan and Spencer, 2006; del Aguila et al., 2002; Eklund et al., 1997; 1998; Elderton and Eddie, 1983b; Emphasis JADA, 1988; Heloe, 1978; Heloe et al., 1988; Schwarz, 1996b). Prosthetics also decreased (Eklund et al., 1997; Eklund, 2010; Emphasis JADA, 1988; Heloe, 1978; Heloe et al., 1988; Spencer et al., 1994b). The only exception was among handicapped adults in England and Wales between 1980 and 1990, for whom number of fillings, extractions, and general anaesthetics increased (Murray and Nunn, 1993). Orthodontic treatment increased in Washington (del Aguila et al., 2002). Periodontal treatments increased among insured Americans between 1980 and 1995 (Eklund et al., 1997), and mean number of periodontal services decreased among Canadian First Nations and Inuit people in Canada between 1994 and 2001 (Leake et al., 2005).

Fillings or restorations decreased in most studies (Brennan and Spencer, 2003; 2006; Eklund et al., 1997; 1998; Eklund, 2010; Emphasis JADA, 1988; Heloe et al., 1988; Leake et al., 2005; Schwarz, 1996b). Exceptions were found in earlier studies in Scotland, when cost of restorations increased between 1965 and 1981 (Elderton and Eddie, 1983a), and in Australia, where there was an increased work effort in advanced restorative and endodontic services between 1983 and 1988 (Spencer et al., 1994b). However, these studies would have been conducted when dentists were changing their treatment practice from extracting to restoring teeth.

Regarding types of restorative treatments, amalgams decreased (Brennan and Spencer, 2003; del Aguila et al., 2002; Spencer et al., 1994a), while crown and bridge services increased (Brennan and Spencer, 2006; Smith, 1983), endodontic treatment increased (Brennan and Spencer, 2006; Schwarz, 1996b), and composite restorations increased (del Aguila et al., 2002). An exception to the decrease in amalgams was found in the DTSS in Ireland, where Woods and colleagues (2009) found that extractions were substituted by amalgams following an increase in fees for amalgam restorations.

2.3.1. General observations on methods used in the studies

Although composition of treatment has been measured via surveys, this self-reporting method is considered less accurate than collection by observation or by extracting data from dental records (Manski and Moeller, 2002). When examining trends in treatments over time, analysis of administrative data is a less costly approach than

repeated representative sampling, and the use of this data overcomes the issues of low response rate and recall bias associated with survey data. Although dental claims databases have been used to analyse trends, most of the analyses were limited to selected years or focused on certain treatments (Appendix 3). Given the increased processing power of personal computers in the past few years, it is now feasible to perform detailed analyses of the treatments provided, as recorded in administrative/claims databases.

2.4. Comparison of epidemiologically-estimated need with treatment provided

The electronic database PUBMED was searched in August 2012, with no time limits, using search terms (dental treatment [MeSH]) AND (treatment need* OR "treatment provided" OR "dental treatment" OR "dental service treatment") AND (predict* OR compar* OR dispar*), limited to adults, adolescents, humans and the English language. The search retrieved 539 non-duplicate articles. Sixteen of these articles seemed relevant based on their titles, however just five studies met the inclusion criteria, in that they compared professionally estimated treatment need with treatment provided among adults. Three of these papers are referenced in Article III, and all studies are outlined in Appendix 4. The search was repeated in February 2013, with a custom date range beginning in June 2012. This search retrieved 12 non-duplicate articles, one of which seemed relevant based on its titles, but was not of significance on further reading. Findings from a thesis (McLoughlin, 1990), and a study focusing on restorations (Grembowski et al., 1997), are also presented, giving a total of seven studies.

McLoughlin (1990) used contingency table analysis to compare treatment estimated as needed in a survey with treatment provided to a sample of long-stay institutionalised psychiatric patients in the Mid-Western region of Ireland. She suggested that the agreement between predicted need and treatment provided may be a function of the disease profile and particular circumstances of the population, and that agreement can be achieved where the decisions are mainly related to disease status. Nuttall (1983) found that three years after a survey, 3.5 times as many surfaces had been filled than were predicted, although 44% of the need for restorations identified by the survey remained unmet. Naegele and colleagues (2010) found that 21% of patients had a greater number of teeth with treatment need than treated, 30%

had the same number of teeth with treatment need and treated, and 49% had a greater number of teeth treated than with treatment need. Wanman and Wigren (1995) found that more restorations were provided than professionally assessed as needed in the epidemiological sample. In Scotland, Eddie and Elderton (1983) found that 12.7% of the people who attended a dentist with a prosthetic need received the predicted treatment within one year and 21.3% received it within three years. Five percent of the sample received more treatment than predicted as needed, and one quarter received less than predicted as needed. Among American Indians and Alaskan Natives, Broderick and Niendorff (2000) found that between 1/3 and 1/2 of the need for complex restorations, endodontics, periodontal therapy, prosthodontics, and orthodontics were met.

2.4.1. General observations on methods used in the studies

Analysis of the relationship between estimated need and treatment provided is important to provide information on the efficiency of the dental care systems. Grembowski and colleagues (1997) stated that "systematic under-treatment represents a potential public health problem while over-treatment raises the cost of care and may have adverse effects on oral health or provide few health benefits". All studies found discrepancies between treatments provided and professionally assessed dental treatment need. There were no studies of comparisons between epidemiologically estimated treatment need and treatment provided in schemes serving different socio-economic groups.

2.5. Summary

This systematic literature review identified gaps in research of factors associated with tooth retention and utilisation of dental services, differences between epidemiologically-estimated need and treatment provided, and trends in treatment provided in Ireland. The review also identified the methods of analysis, data sources, variables measured, and theoretical framework used in previous research. Tooth loss during various time periods, or total tooth loss, were the dental status indicators most frequently used in previous studies. Measures of tooth retention included being dentate, number of natural teeth, retention of 20 or more teeth, 1-20 teeth and 1-19 teeth; number of sound teeth was only used in one study. The most commonly used measure of utilisation of dental services was visiting a dentist in the past year. Other

measures included utilisation in a 15-month period or three-year period, or frequency of use during a five-year period. Andersen's behavioural model of health care utilisation was the most frequently used theoretical framework for analysis of utilisation. Only a few studies have compared epidemiologically estimated need for treatment with treatment provided, and none have compared need with treatment provided by SES. The most detailed previous studies of trends in dental treatments provided used survey data, whereas analysis of administrative data provides a valuable description of treatment actually provided, using real-life data.

3. Data and methods

The literature review identified a dearth of information on factors associated with tooth retention and utilisation of dental services, differences between epidemiologically-estimated need and treatment provided, and trends in dental treatment provided in Ireland. In this chapter, the data sources used in the analyses of these topics are described in Section 3.1. The data sources, and methods used to create datasets, where relevant, are explained. The variables analysed in this study are described in Section 3.2. An overview is provided of the theoretical framework and model specifications used in the articles in Section 3.3 and a summary of the data and methods applied in the articles is provided in Section 3.4.

3.1. Data

This research drew on existing survey data and administrative data. The main study population are adults residing in Ireland. The data used are drawn from the 2000/02 NSAOH, SLÁN 2007, and the DTBS and DTSS claims databases. Data from the 1989/90 NSAOH was also used in Article IV.

3.1.1. 2000/02 National Survey of Adult Oral Health (NSAOH)

Articles I, III and IV use data from the 2000/02 NSAOH (Whelton et al., 2007). This was the most recent national survey of adult oral health in Ireland, and previous surveys were conducted in 1989/90 (O'Mullane and Whelton, 1992) and 1979 (O'Mullane and McCarthy, 1981). The survey of a stratified random sample of 2,888 adults was conducted by the Oral Health Services Research Centre, University College Cork. The three age groups targeted were 16-24 year-olds (n=1,196), 35-44 year-olds (n=978) and 65+ year-olds (n=714). The survey consisted of a clinical oral examination and an interview about oral health, general health, perception of oral health services and oral health related quality of life. The response rate was between 27% and 39%, depending on assumptions made; full details of the survey methods are provided in the survey report (Whelton et al., 2007). The sample was weighted (adjusted) according to gender, Medical Card status, and age to be representative of the population as a whole. Weighting was based on estimates of Irish population totals from the Quarterly National Household Survey (QNHS) in the 3rd quarter of 2001. The 32 clinical examiners were public service employees. Training in the clinical indices/criteria for the 32 dentists (30 teams) took place at the University

Dental School and Hospital, Cork. The fieldwork was conducted between October 2000 and August 2002 in health service clinics, with some home-based examinations.

3.1.2. 2007 National Survey of Lifestyle, Attitudes and Nutrition (SLÁN)

Article II uses data from SLÁN 2007 (Morgan et al., 2008). This was the third SLÁN survey, with previous surveys using postal questionnaires in 1998 (n = 6,539) (Friel et al., 1999) and 2002 (n = 5,992) (Kelleher et al., 2003). SLÁN 2007 was the first SLÁN survey to collect information on tooth brushing frequency, and frequency of visiting the dentist, although the question asking respondents to describe their teeth was also asked in SLÁN 2002 and SLÁN 1998. The most recent survey was a cross-sectional survey conducted in 2006/07 using face-to-face interviews with adults aged 18 years or over. The sampling frame was the *GeoDirectory*, a list of all addresses in the Republic of Ireland, compiled by An Post, which distinguishes between residential and commercial establishments. The sample (n=10,364) was selected by multi-stage probability sampling, and stratification was by percentage distribution across the country, age groups, social classes and urban-rural location. The response rate was 62%. The sample was representative of the general population in Ireland when compared with Census 2006 figures and was weighted to match the 2006 Census (full details in Morgan et al., 2008). Administered by trained interviewers in the respondents' own home, the questionnaire included information on health, health-related behaviours, use of health care services, and general household information. Reported use of dental services was determined by the question: "When was the last time you visited a dentist, dental hygienist or orthodontist on your own behalf?" Response categorises were 'In the last 4 weeks', 'Between 1 and 12 months ago', '1-2 years ago', 'More than 2 years ago' and 'Never'. For Article II, a dichotomous dependent variable was created from these categories, where 1 = 'In the last 4 weeks' or 'Between 1 and 12 months ago', and 0 = '1-2 years ago' or 'More than 2 years ago' or 'Never'.

3.1.3. DTBS data

Articles III, IV and V use data from the DTBS claims database. The Department of Social Protection (formerly the Department of Social and Family Affairs, and the Department of Social Welfare) maintain databases of treatments provided in the scheme. According to Card and colleagues (2011), access to administrative data "can

be achieved in a way that maintains the strictest standards of privacy while still allowing researchers direct access to individual records". To facilitate analysis of the data, while maintaining anonymity of the patients, their unique identifiers (PPS numbers) were scrambled prior to sending us the data.

The Department of Social Protection provided us with 90 codes referring to specific treatments, and treatment categories were created for Articles III, IV and V. Since dental health status could not be measured directly with the DTBS claims data, number of teeth was used as a dental health proxy.

Table 3.1 presents the variables recorded in the DTBS databases, made available to us by the Department of Social Protection, for this study. Although other information, such as whether the user is in paid employment, participates in a work scheme, or has a Medical Card are sometimes recorded on forms D1 (Appendix 5) and D2 (Appendix 6), the variables are not entered on the databases.

Table 3.1 Variables for this study

Variable	Description
Unique Identifier	This is in the same format as PPS numbers, but with the numbers and letters scrambled.
Spouse Indicator	Blank or 'Y' to indicate when a spouse had treatment.
Claim Date	Normally the date the treatment took place, but where the initial claim was an estimate (i.e. where the dentist is unsure whether or not the claimant qualifies, and estimate is keyed in, the claimant either qualifies or not and the dentist and claimant are notified), the actual treatment are carried out after this date, but normally within a month.
Treatment Code	See Table 3.2 for a list of treatments provided and Appendix 7 for obsolete codes.
Treatment Description	See Table 3.2
Date Of Birth	Claimant's Date of Birth
Gender	M - Male W - Female
Marital Status	C - Common Law/Cohabiting D - Deserted M - Married S - Single Z - Separated L - Legally Separated P - Divorced

	W - Widowed V - Unknown
Panel Number	Dentist's DSP ID Number.
Map Of The Mouth	X marks teeth that are missing.
Tooth Number (×12)	Tooth that was worked on. There are up to 12 on each treatment claim.
DSP Payable	Amount DSP pay to panelist (dentist) for the treatment.
Claimant Fee	Amount Claimant has to pay (-999.99 if there is no set amount).
Exam Date	Date of Examination (for oral exams only).

PPS: Personal Public Service; DSP: Department of Social Protection.

Table 3.2 provides a list of the treatments covered under the DTBS: the codes are recorded in the databases. Other obsolete codes are listed in Appendix 7.

Table 3.2 Treatments provided under the DTBS

Code	Treatment description
20	Oral Examination
30	Prophylaxis
51	Protracted Periodontal Treatment
Restorations	
71	Simple/Compound Amalgam Filling
74	Composite Fillings On Anterior Teeth
75	Pin-Retained Fillings
78	Restoration Of Incisal Angle Or Tip
Exodontics	
91	Extraction Of A Tooth Under Local Anaesthetic
96	Surgical Extractions
Endodontics	
80	Root Canal Therapy
210	Apicectomy/Amputation Of Roots
X-Rays	
61	Extra-Oral
62	Panoramic
Miscellaneous	
230	Biopsy - Excision Of Soft Tissue
240	Haemorrhage - Secondary
250	Pulpotomy
290	Dry Socket
300	Abscess - Pre-Treatment And Incising
310	Dressings
330	Pericoronitis
990	Other miscellaneous items not specified in this schedule.
Prosthetics	
122	Partial Acrylic Denture

123	Full Upper Denture
124	Full Lower Denture
125	Full Upper And Lower Denture
Relined Dentures	
131	Complete Upper Denture
132	Complete Lower Denture
133	Complete Upper And Lower Denture
140	Denture Repairs
Alternative Treatments	
971	White Filling on a Back Tooth (4 - 8)
	Glass Ionomers
974	Crown
	Porcelain Jacket Crown (PJC)
922	Partial Chrome Cobalt Denture or Bridge
923	Full Upper Chrome Cobalt Denture
924	Full Lower Chrome Cobalt Denture
925	Full Upper and Lower Chrome Cobalt Denture

All codes over 990, other than those in the table above, are miscellaneous codes and include items such as gingivectomy, re-cementing crowns, bite raising crowns, "Spill Overs" (S/O), root canal treatment, work done on baby teeth, removing sutures, and treatment of a supernumerary (extra) tooth.

3.1.3.1. Building the DTBS database

The size and complexity of the DTBS database, with over 15 million observations, warranted the help of a computer programmer/data manager to help process the data and create datasets for analysis. The computer used for processing the data, creating the datasets, and running the queries on treatments provided in the scheme had 250GB and 4GB RAM. It did not have sufficient processing power and so part of an external hard drive was used as virtual memory. It took over a year to concatenate the databases and clean the data. In preliminary data analysis, data was missing from the mid-1990s; therefore all analyses are restricted to 1997 onwards. Queries on treatments provided in the scheme varied in length from a few minutes to days, taking an average of 20 hours.

Claims data for the DTBS was obtained for the period 1987 to 2008 in 242 encrypted Comma Separated Values (CSV) files, which were then concatenated using the Java programming language, and cleaned using Java and SAS 9.2®. CSV files can be imported into statistical packages and most databases with no prior modification. Unlike excel files which have a limit of 65,536 rows and 256 columns, there is no limit on the size of CSV files, so they can be used for large databases. Figure 3.1 provides an example of the structure of a CSV file. While the first line contains

variable names to identify the data (ID, date of treatment and treatment code), the second and third lines are observations.

Figure 3.1 CSV file structure

```
ID, date of treatment, treatment code …
1234567A, 20070912, 20 …
7654321Z, 20070912, 71 …
```

The steps in building the database were as follows:

(1) Data was received in batches of encrypted CSV files and saved.

(2) Files were decrypted using *PrivateFile* and saved.

(3) All decrypted files were concatenated into one file using programmes created in Java.

(4) A header was added to the resulting concatenated file.

(5) Data was imported into statistical packages (SPSS 15.0 and SAS 9.2®).

(6) Files were checked manually for errors, and frequency distributions of variables in SPSS 15.0 revealed errors and codes which did not correspond to pre-defined codes.

(7) Files were "cleaned": after consultation with the Department of Social Protection, errors detected in Step 6 were corrected by the data manager (computer programmer) using the Java programming language and SAS 9.2®.

(8) Smaller files (with a sample of observations) were re-run to check for errors before all files were concatenated again and re-checked.

Details of the dates that the CSV files were received are outlined in Table 3.3.

Table 3.3 DTBS data received from the Department of Social Protection

Date	Number of encrypted CSV files	Number of observations/claims
July 14th 2008	19	1,224,598
August 1st 2008	24	1,546,130
August 25th 2008	27	1,674,499
September 12th 2008	36	2,262,507
October 1st 2008	62	3,744,755
October 17th 2008	15	851,068
January 8th 2009	41	2,618,791
July 13th 2009	18	1,114,868
Total	**242**	**15,037,216**

A list of headings inserted as the first line of the concatenated file enables statistical software to automatically name the variables contained in the data file. This header (Figure 3.2) was based on information received from the Department of Social Protection. When the data was imported into SPSS 15.0, there were errors with the types of variables imported (numeric or string). When values for variables were missing in the first record/observation, SPSS 15.0 automatically declared the variables as numeric. However, variables such as *spouseIndicator* and *toothNumber1* are strings, therefore, when imported, all further records with string values were missing. An additional line was added to the header to solve this issue (overwriting the data format for variables that were affected each time a CSV file was imported into SPSS 15.0 was time-consuming). This extra line contained a record with dummy codes in the correct format to force SPSS 15.0 to correctly initialise the variable types. Once data was imported successfully in SPSS 15.0 or SAS 9.2®, this first observation was subsequently deleted.

Figure 3.2 Header used for the concatenated files

```
id,spouseIndicator,claimDate,treatmentCode,treatmentDescription,dob,gender,marital
Status,panelNumber,A8,A7,A6,A5,A4,A3,A2,A1,B1,B2,B3,B4,B5,B6,B7,B8,C1,C2,
C3,C4,C5,C6,C7,C8,D8,D7,D6,D5,D4,D3,D2,D1,toothNumber1,toothNumber2,tooth
Number3,toothNumber4,toothNumber5,toothNumber6,toothNumber7,toothNumber8,
toothNumber9,toothNumber10,toothNumber11,toothNumber12,dswPayable,claimant
Fee,examDate
```

3.1.3.2. Cleaning the data

Data cleaning comprised communicating with the Department of Social Protection to learn how each variable had been defined, and whether the variables had changed over time. When building the database, and creating the datasets, the main focus was on confirming the accuracy of the variables, while noting and correcting errors. These errors included missing commas between the variables, redundant commas, invalid codes, claimants having more than one unique identifier (PPS number), duplicate claims, and incorrect (or incomplete) dates.

The concatenated file was imported into SPSS 15.0 and SAS 9.2®. In SAS 9.2®, logs showed several errors that prevented the concatenated file from being imported successfully. An example of an error is presented in Figure 3.3, where marital status is repeated in panelNumber (L9000, where L is marital status and 9000 is a panel

number). SAS 9.2® expects a numeric variable for panelNumber, so an error is logged because L9000 is a string variable.

Figure 3.3 Example of an import error generated in SAS

```
NOTE: Invalid data for panelNumber in line 23691 41-45.
RULE:    ----+----1----+----2----+----3----+----4----+----5----+----6----+----7----+----8----+--
23691
2311105I,,20060120,20,EXAM,19680124,M,L,L9000,,,,,,,,,,,,,,,,,,,,X,,X,,,,,,,,X,,,,,,,,,
    88  ,,,,,,2985,0,20050120 108
id=2311105I spouseIndicator= claimDate=20060120 treatmentCode=20
treatmentDescription=EXAM
```

As SAS 9.2® was used to create datasets and for data analysis, the concatenated file needed to be cleaned so that it could be imported into SAS 9.2®. Although it was possible to open the file in SPSS 15.0, any analysis of the data without cleaning it first would have produced erroneous output.

A visual check was performed on some of the original CSV files by opening them in a word processing application (to examine the arrangement of commas), and excel, to detect any issues with the data. Macro-editing was performed by examining the SPSS 15.0 output, where the frequencies of each variable were examined to detect errors or codes not provided in the original explanation of codes. Java programmes were created to correct errors such as:

- Comma missing between gender and marital status (e.g. *WW* instead of *W,W*)
- Repeated marital status (e.g. *W,W,W* instead of *W,W*)
- Repeated marital status and no separation with panel number (*M, L, L2244* instead of *M, L, 2244*) as in Figure 3.3.
- Codes not provided in the original explanation of codes, and typographical errors.
- Redundant commas.

Other errors detected in SPSS 15.0 included:

- Invalid tooth number codes
- Invalid marital status codes
- Invalid missing teeth codes

- Incorrect claim dates, dates of birth and exam dates.
- People having more than one PPS number.

Java programmes were written to correct the errors before the data could be imported successfully into SAS 9.2®. Most of the incorrect claim dates and exam dates were corrected in SAS 9.2®.

PPS numbers were used as unique identifiers (Table 3.1) in the DTBS database. Objectives of this research were to examine utilisation of, and treatments provided in, the DTBS over time; therefore unique identifiers were essential for accurate measurement of these outcomes. Two CSV files were received from the Department of Social Protection, containing the lists of PPS numbers in the Irish population. The first column was the current PPS number and the next three columns were any previous numbers that person had. The files contained a total of 110,757 sets (lines) of PPS numbers (109,111, 1,560 and 86 people had two, three and four PPS numbers respectively); not all of these people qualify for the DTBS. For people with more than one PPS number in the DTBS database, their PPS number was replaced with the first PPS number from the CSV files for each person.

Where a value in the claim date field could not be interpreted as a date (i.e. a typographical error), it was replaced with the exam date, as the claim date is usually within a month of the exam date. If the exam date value was greater than the claim date value, it was replaced with the claim date. There were excess zeros in some dates so these were removed (e.g. 200000303 was replaced with 20000303). However, there were instances where neither the claim date nor the exam date could be interpreted as dates, in which case a code "9999" was assigned. In checking claim dates against exam dates, some dates were missing '19', in which case, they were inserted (e.g. 950303 was replaced with 19950303). These changes were coded in SAS 9.2®.

Codes such as B (Batchelor), N (Never Married), T (Spinster) and U (Unmarried) had been used for marital status in the past. However, in recent years, S (Single) has been used, therefore, for consistency; B, N, T and U were re-coded as S (Single). Other letters that appeared in the dataset (each less than 1% of the overall frequency of marital status) were taken as typographical errors and changed to V (Unknown).

Thirty two variables recorded the presence or absence of a tooth, where X indicated a missing tooth, and blank indicated the presence of a tooth. In data entry, N, O, ?, and X had all been used to indicate missing teeth: these were all recoded as X in the final corrected file. A new variable (numberOfTeeth) was created based on these to calculate the number of teeth present: all the Xs were added and the total number of Xs subtracted from 32.

The tooth to which treatment was provided was recorded in the treatments database for treatments that were tooth-specific. Up to 12 teeth can be recorded on one claim form. The tooth identifier consisted of a letter referring to the quadrant in the mouth and a number referring to the tooth position within the quadrant. The mouth is split into four quadrants: the upper right quadrant is the first quadrant (A), the upper left is the second (B), the lower left is the third (C) and the lower right is the fourth (D). Within each quadrant, there may be up to eight teeth: these are numbered 1 to 8 from the front of the mouth to the back (Table 3.4 and Appendix 8). Anterior teeth are those in positions 1, 2 or 3; posterior teeth are those in positions 4, 5, 6, 7 or 8.

Table 3.4 Tooth identifiers in the DTBS databases

A8	A7	A6	A5	A4	A3	A2	A1	B1	B2	B3	B4	B5	B6	B7	B8
D8	D7	D6	D5	D4	D3	D2	D1	C1	C2	C3	C4	C5	C6	C7	C8

3.1.4. Database of dentists in the DTBS

A database of dentists who are registered to provide services under the DTBS was built from lists of dentists' names and addresses taken from the Department of Social Protection website. A file containing details of dentists who had been previously registered was received from the Department of Social Protection, and combined with this database. Variables such as urban/rural location and gender were created based on names and addresses of dentists. Dentists in Kilkenny City, Galway City, Cork City, Waterford City, Limerick City, and Dublin City and county were categorised as 'City' locations, all other addresses were categorised as 'Non-city'. Gender of the dentist was determined from the dentists' names.

This database was then merged with the DTBS database using the dentists' panel numbers as a primary key. Panel numbers can not be used as unique identifiers for individual dentists as dentists can have more than one panel number within, and between, practices; there are also panel numbers for practices which more than one

dentist may use. However, the availability of this data provided useful information on location and dentist gender.

3.1.5. DTSS data

Article III uses data from the DTSS administrative database. The Health Services Executive (Department of Health and Children prior to 2005) maintains a database of all dental treatments provided to adults with a Medical Card under the DTSS. Table 3.5 provides an overview of the treatments provided in the scheme, and their codes.

Table 3.5 Treatments provided under the DTSS

Code	Treatment description
Routine Treatments (Above the Line)	
A1	Oral Examination
A2	Prophylaxis
A3A	Restoration (Amalgam)
A3C	Restoration (Composite) six anterior teeth only
A4	Exodontics
A5	Surgical Extractions
A6	Miscellaneous (e.g. Biopsy, Haemorrhage, Dressings etc.)
A7	1st stage Endodontics
A8	Denture Repairs
Routine Treatments (Below the Line)	
B1	2nd stage Endodontics
B2	Apicectomy/Amputation of Roots
B3	Protracted Periodontal Treatment
B4	Extra-Oral Radiographs
B5	Prosthetics (other than edentulous persons)
Full Dentures	
A1	Oral Examination
B5	Full Upper Denture
B5	Full Lower Denture

'Above the line' treatments could be completed without prior approval from the HSE. Prior approval was required for all 'below the line' treatments (Health Services Executive Primary Care Reimbursement Service, 2006).

DTSS data was available from 1994 to 2006, and the research database had already been processed in an earlier study (Cronin, 2005). A new dataset was created from this database for Article III.

3.2. Dependent and explanatory variables

Table 3.6 summarises the dependent variables for Articles I, II and V. In Article I, six categories of tooth retention were used, all measured by the examining dentist. All

variables were self-reported in Article II, and all variables in Article V were recorded by the dentist when making a claim for treatment provided under the DTBS.

Table 3.6 Dependent variable definitions

Article	Variable	Definition
I	NT	Number of natural teeth present
	SUNT	Number of sound untreated natural teeth present
	Dentate	= 1 if at least one natural tooth present; = 0 if no natural teeth present
	21+NT	= 1 if 21 or more natural teeth present; = 0 if less than 21 natural teeth present
	28+NT	= 1 if 28 or more natural teeth present; = 0 if less than 28 natural teeth present
	18+SUNT	= 1 if 18 or more sound untreated natural teeth present; = 0 if less than 18 sound untreated natural teeth present
II	Utilisation of dental services	= 1 reported visit to dentists, dental hygienists, or orthodontists in the past year; = 0 visit longer than one year ago or never
V	Utilisation of dental services	= 1 if visit dentist in a five-year period; = 0 if do not visit in a five-year period
	Annual visits	Number of visits to a dentist in a five-year period = 1 if visit annually over a five-year period; = 0 if visit less often

Table 3.7 presents the explanatory variables that were used in the empirical models. In Article I, percentage lifetime exposure to water fluoridation was calculated from number of years living in fully-fluoridated areas, which was estimated by the interviewer, based on information provided regarding residence(s). All other variables were self-reported in Articles I and II.

Table 3.7 Explanatory variables used in the empirical analyses

	Article		
	I	**II**	**V**
Outcome of interest	**Number of teeth**	**Utilisation of dental services**	
Explanatory variables			
Age (in years) [a]		categorical	discrete
Gender[b]	categorical		categorical

Marital Status			categorical
Employment	categorical	categorical	
Education	categorical	categorical	
Disadvantage status	categorical		
Income		categorical	
Location of residence		categorical	
Use of a car		categorical	
Smoker	categorical		
Frequent snacks	categorical		
Frequent brushing	categorical	categorical	
Use of fluoride toothpaste	categorical		
Water fluoridation	continuous		
Visit dentist regularly	categorical		
Visit dentist for check-up	categorical		
Number of teeth		categorical	discrete

[a]Analyses were performed by age group for Article I. [b]Analyses were performed by gender for Article II.

3.3. Theoretical framework and model specifications

For each article, this section provides an overview of the theoretical framework and model specifications used. The rationale for including variables in the analyses is explained, and the types of analyses undertaken and model selection criteria, where appropriate, are described.

3.3.1. Non-biological factors associated with tooth retention

As outlined in Section 1.3.1, the aim of Article I was to analyse the influence of the use of services and other non-biological factors on tooth retention among Irish adults. People with different levels of tooth retention will have different profiles, and so when investigating factors associated with tooth retention, one needs to control for variables such as age, gender, SES and behaviour. Compared to younger adults, older adults are more likely to have full or partial dentures, fewer teeth, a greater numbers of restorations (and therefore fewer sound untreated natural teeth), and, given that water fluoridation was introduced to Ireland in the 1960s, they also have had less exposure to fluoride. Younger adults, on the other hand, are more likely to have a greater number of teeth, fewer restorations, and a greater proportion of their lives exposed to fluoride. Therefore, different outcome measures by age group (16-24, 35-44 and 65+) were selected, so that they reflect the clinical condition for the three age groups sampled.

Based on a literature review, explanatory variables included gender, SES, behaviour, and exposure to water fluoridation. Gender differences in tooth loss have been well established (Copeland et al., 2004), and studies have found females to be more concerned about the appearance of their teeth (Tin-Oo et al., 2011; Vallittu et al., 1996), and more sensitive to visible tooth loss than males (Carlsson et al., 2008). SES (as measured by income, occupation and education) has been found to be associated with tooth loss/retention (Bernabe and Marcenes, 2011; Haugejorden et al., 2003; Hescot et al., 1997). Income and occupation describe "access to and control over material resources", while education reflects "acquired levels of capital, knowledge and skills" (Sanders et al., 2006). Higher incomes can provide means for purchasing health care and better nutrition (Adler and Newman, 2002), and regular utilisation of dental services and diet have been associated with tooth retention (Atieh, 2008; Fan et al., 2006; Pearce et al., 2004).

Occupation in this research is measured as whether or not someone is in employment. Being in employment has been found to have a positive effect on health (Ross and Mirowsky, 1995). Education shapes future occupational opportunities and potential (Adler and Newman, 2002), and has been found to improve health directly and indirectly through work, economic conditions, social-psychological resources and lifestyle (Ross and Wu, 1995). According to Hammond (2003), the psychosocial outcomes of education play an essential role in "generating the practices, skills and personal attributes that have lasting effects on health". Behaviour factors such as tooth brushing, consumption of sweet snacks, dental visiting behaviour, and smoking have also been found to be associated with tooth loss/retention in other countries (Aida et al., 2011; Albandar et al., 2000; Atieh, 2008; Bole et al., 2010; Fan et al., 2006). Percentage lifetime exposure to water fluoridation was also included as water fluoridation has been found to reduce the incidence of caries, an important risk factor for tooth loss (Whelton et al., 2007).

A tooth was defined as present when at least part of it was visible: a tooth was considered sound if it showed no evidence of treated or untreated caries, or if it was at the doubtful stage. The number of teeth that were not decayed, filled, otherwise restored or traumatised on their coronal surfaces was counted by the examining dentists (Whelton et al., 2007). Mean NT for 16-24 year-olds was 28.2; the median

and 25th percentile were 28, and 75.2% of this age group had 28+NT, therefore 28+NT was used as a measure of dental health instead of the more frequently used 21+NT. In addition, dentate status was used instead of 18+SUNT for 65+ year-olds as 40.9% of this age group were edentulous and only 3.3% of dentate adults had 18+SUNT. More than 20 natural teeth (21+NT) was a binary variable (where 1 = more than 20 teeth, 0 = 20 teeth or less), and was modelled using logistic regression. The outcome measure in a logistic regression analysis is the log odds (Grytten, 2012). For 21+NT, the odds is a fraction where the numerator is defined as the probability of having more than 20 teeth, and the denominator is defined as having 20 teeth or fewer. Similarly, logistic regression was used to analyse factors associated with having 28+NT and 18+SUNT, and the odds of being dentate.

Number of sound untreated natural teeth (SUNT) and number of natural teeth (NT) are count variables. The commonly used models for predicting count outcomes include the standard Poisson and Negative Binomial Regression models. These models account for the fact that number of teeth is a non-negative variable. However, under the Poisson regression model, the conditional mean and variance of the dependent variable is constrained to be equal for each observation (Long and Freese, 2006). In practice, this assumption is often false since the variance can either be larger or smaller than the mean, i.e., both over-dispersion and under-dispersion can occur in count data. If the variance is not equal to the mean, the estimates in Poisson regression models are still consistent but inefficient (Long and Freese, 2006). The Negative Binomial Regression Model (NBRM) is considered more flexible than the standard Poisson model (Long and Freese, 2006), and is frequently used to study count data with over-dispersion, however it assumes that the variance is greater than the mean and is therefore not appropriate for under-dispersion. Model selection was guided by the Likelihood-ratio (LR) test, Vuong test, Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Further information on the types of models and model selection for NT and SUNT are provided in Appendices 9 and 10. Moderated multiple regression analysis, which examines whether the relationship between two variables depends on the value of a third (moderator) variable (Aguinis and Gottfredson, 2010) was also used, and is explained in Appendix 10. Relationships were considered statistically significant when $P \leq 0.05$.

3.3.2. Utilisation of dental services using survey data

As outlined in Section 1.3.2.1, the aim of Article II was to identify the factors associated with utilisation of dental care services by adults in Ireland. Andersen's behavioural model of health service utilisation, which suggests that people's use of health services is a function of predisposing, enabling and need factors (Andersen, 1995), was applied as the theoretical foundation to study socio-economic determinants of dental health care utilisation in Ireland. Logistic regression analysis was applied to explore factors affecting the utilisation of dentist services. Dental care service use in the past year, the outcome variable in the analyses, was elicited by the question 'When was the last time you visited a dentist, dental hygienist or orthodontist on your own behalf? To control for heteroscedasticity, the model was estimated separately for males and females.

The percentage of adults that used the dental services in the past year were obtained, and chi-squared tests were used to analyse the associations between pattern of attendance and explanatory variables. Predisposing factors were demographic (age, gender and marital status), social structure (level of education, employment status, country of birth, number of individuals in household), and beliefs (importance of oral health is reflected in frequency of brushing); and enabling factors were level of income, location of residence and access to a car. Health status was measured by a description of number of teeth present (whether the respondent had all 32 natural teeth, some missing but no dentures, partial dentures or edentulous). Need for dental treatment was not measured in the SLÁN survey. Only variables that were statistically significant at the 5% level were included in the final multivariate analysis. The effect of these variables on the outcome variable were analysed using multiple logistic regression. The adjusted Odds Ratios (OR) with their corresponding 95% Confidence Intervals (CI) were calculated in SPSS v. 15.0. Relationships were considered to be statistically significant when $P \leq 0.05$.

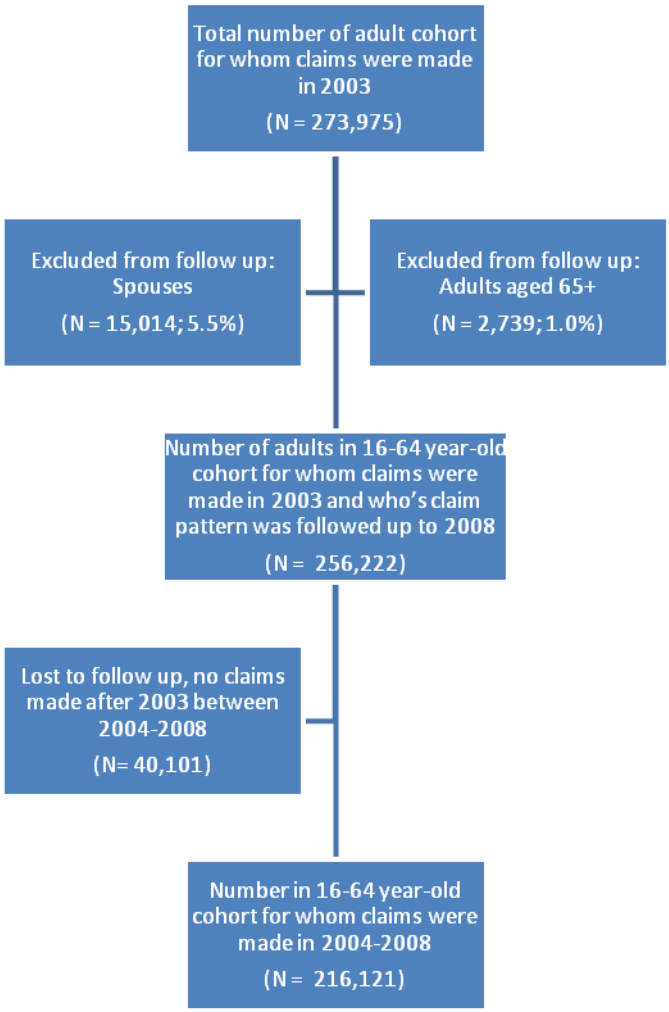
3.3.3. Utilisation of dental services using administrative (claims) data

In Article V, the utilisation rate of those who used the DTBS in 2003 was estimated, and patterns of attendance, distribution of treatments, and factors associated with utilisation for this cohort over the next five years (2004–2008), using different empirical models were investigated. A five-year period was chosen as it is often used

for measuring regularity in utilisation of dental services (Astrom et al., 2011b; Christensen et al., 2007; Clarkson et al., 2000; Eddie, 1984; Nuttall, 1984; Petersen et al., 2004; Schwarz, 1996a). The theoretical framework on the utilisation of medical care applies to dental care, and assumes that utilisation of dental care services is dependent on dental health status and other demographic variables (Álvarez and Delgado, 2002). Since dental health cannot be measured directly with the data, number of remaining teeth is used as a proxy. Demographic variables in this study are age, gender and marital status. The range of explanatory variables is limited by the number of variables recorded in the claim forms and database.

A cohort of adults aged 16-64 years was drawn from all those for whom treatment claims were made in 2003 (N=256,222), and their pattern of attendance was observed during 2004-2008. The original database had a separate entry (corresponding to a claim) for each type of treatment. New summary records were created to represent a five-year period in the person's history of utilisation of the DTBS. These were produced by manipulating and/or combining existing variables. Constructing the final sample for the analysis of utilisation in 2004-2008 began with those who claimed in 2003 (N = 273,975). Spouses were excluded as their date of birth is not recorded and therefore it was not possible to calculate age (N = 15,014; 5.5%). Those aged 65 and over were also excluded (N = 2,739; 1.0%) as the analysis was focused on employed adults. After these exclusions, there were 256,222 patients in the dataset. This dataset was used for analysis of count data. For the analysis of the composition of treatment provided in the five-year period, those for whom no claims were made in 2004-2008 were excluded (N = 40,101), resulting in 216,121 patients in the dataset (Figure 3.4).

Figure 3.4 Flow chart outlining data processing



Estimates of the utilisation of health care services depend on the empirical specification used in the analysis (Deb and Holmes 2000: 475), so it is important to be careful when choosing the empirical method and when interpretating results. Two key features must be considered when analysing utilisation of dental services. The first is that the decision-making process of utilisation involves different stages: contact (individuals decide whether to go to a dentist), the choice of a public or private dentist, and frequency (the number of visits and the amount and type of treatment received per visit) (Sintonen and Maljanen, 1995). Total demand for dental services depends on individual needs and the decisions of dentists. The second feature refers to the nature of the outcome variable: since number of visits (or treatments) is a non-negative integer, this requires the use of count data models.

Assuming a principal-agent framework, the decision to contact a dentist and the number of subsequent visits can be seen as the result of two separate decision-making

processes, and thus a hurdle model, or two-part model (TPM), can be estimated. The TPM is designed for data in which observations with an outcome of zero have been excluded from the sample (Long and Freese, 2006). The motivation for TPMs also comes from principal-agent theories of demand which suggest that the physician (agent) determines utilisation on behalf of the patient (principal) once initial contact has been made (Deb and Trivedi, 2002). While the patient is responsible for making initial contact, the dentist plays a role in determining subsequent treatments. There are separate equations to predict zero and positive counts, therefore zero is viewed as a hurdle that one must get past before reaching positive counts (Long and Freese, 2006). The advantage of the TPM over single equation models has been shown both theoretically and empirically (Sintonen and Maljanen, 1995).

Count measures of utilisation often display a higher proportion of zero observations than is consistent with typical count distributions. A finite mixture model (FMM) accommodates the problem of excess zeros. Empirical studies of utilisation of health services have found the FMM to fit the data better than the TPM (Bago d'Uva, 2006; Deb and Trivedi, 1997; Deb and Holmes, 2000; Deb and Trivedi, 2002). The main reason for the improved performance is that TPMs draw a strict distinction between users and non-users of a service, whereas some infrequent users might come from the same population as non-users (Zheng and Zimmer, 2009). The finite mixture specification relaxes this sharp dichotomy, and allows groups to be characterised according to mean utilisation, thereby allowing for additional population heterogeneity (Deb and Trivedi, 1997). However, it has also been shown that the TPM performs better for visits to specialists while the FMM is preferred for visits to GPs in 12 EU countries (Jimenez-Martin et al., 2002). To explore factors affecting the utilisation of dentist services (Article V), the two-part model (TPM) and the FMM (or, more specifically, the finite mixture negative binomial (FMNB)) were applied.

The NBRM was used in the TPM and FMM as it fitted the data better than the Poisson model. As in Deb and Trivedi (1997), the AIC and the BIC were used for model selection. Information on model selection is provided in Appendix 11. AIC and BIC favoured the TPM as the specification for estimating utilisation of the DTBS in this study. While the FMNB is difficult to interpret, its use allowed investigation of the independent effect of age group, gender, marital status and number of teeth

without dichotomising the outcome variable (high vs. low users) using cut-off values set *a priori*. By characterising the demand for dental services using a mixture distribution, the population was split into high and low users of dental services according to their individual latent health status and behaviour. In a study of Medicaid enrolees, Okunseri and colleagues (2011) referred to the groups in the FMM as frequent and typical users. According to Aguinis and Gottfredson (2010), statistical power is enhanced if predictor variables are not artificially dichotomised using a median split or similar methods resulting in high vs. low subgroups. Although results favour the TPM in Article V, FMMs are regarded as having wide appeal and applicability (Conway and Deb, 2005), and are a highly useful method of analysis in dental services research in which preset cut-off values may yield misleading results.

Factors associated with regular attendance between 2004 and 2008 were also analysed for the 2003 cohort. As in other studies (Clarkson et al., 2000; Schwarz, 1996a), it is defined as attending at least once a year (vs. less often), and is analysed using a logit model.

3.3.4. Trends in dental treatment provision

The theoretical framework for this article assumes that annual data provide an indication of changes in the expressed treatment need (actual treatment provided) of the population. It also assumes that oral health impacts expressed need for treatment (i.e., treatment provided). The resulting trend in treatments provided over a 12-year period in the DTBS will indicate the impact of greater tooth retention on expressed treatment need and oral health. As noted in Section 1.1, oral health in Ireland has improved in recent decades. One could argue that there are two possible treatment scenarios resulting from this. The improvements could either increase the amount of treatment required as more teeth are retained for life, and are therefore at risk of disease for longer (Joshi et al., 1996), or less treatment would be required because oral health is better. Monitoring trends in treatments helps to estimate the rate of change of practice in response to changing disease levels, monitor the rate of adoption of new materials and technologies as they emerge, predict future costs, and respond to developments through system design and restructuring.

New datasets were generated from the final DTBS database, with one entry per treatment for analysis of distribution of treatments and one entry per patient for mean

number of treatments per person. Treatments were categorised into oral examinations, prophylaxis, restorations, extractions, denture treatment, X-Rays and miscellaneous treatments. Restorations were categorised according to type of restoration as explained in Article IV. Other restorations such as bridges, re-cement of a crown, and other fillings (double, treble, single etch and pin etch fillings), compose a total of less than 0.01% of total restorations so they are not presented.

Information was derived on the number of patients and treatments, and mean number of treatments each year from 1997 to 2008. Availability of dental services was measured by a dentist per population ratio (number of dentists per 100,000 eligible adults). Only dentists that claimed for treatment were included in the calculation of dentist density as it is considered a more accurate measure of availability than overall number of dentists (Lynch, 2008). For each variable, ordinary least squares regression analyses of the natural log of the values were computed ($\ln Y = a + bt$), where time (t) was the independent variable (coded 1 to 12; where 1 = 1997 …12 = 2008). A log transformation is said to provide realistic results because it "flattens" the series of rates (Rosenberg, 1998). These logarithmic equations were then used to determine the average annual rate of change over 12 years (by computing the inverse of the log of time from the regression and multiplying by 100) (Mason et al., 1999).

3.3.5. Comparison of epidemiologically-estimated treatment need with treatment provided in two dental schemes in Ireland

Treatment need, as estimated in an epidemiological survey, is often used to plan future services. The model used in this paper to compare epidemiologically estimated treatment need with treatment provided, incorporated age and SES in its framework as these factors have been found to be associated with dental health (Donaldson et al., 2008; Eklund and Burt, 1994; Thorstensson and Johansson, 2010) and need for dental treatments (Brennan et al., 2008; Ekanayake et al., 2001b; Rice et al., 1980; Roberts-Thomson et al., 2008; Zitzmann et al., 2007).

In this article, eligibility for the DTBS (employed adults) and the DTSS (less well-off adults) are used as proxies for SES. Information on the proportion of adults and mean number of teeth with estimated treatment needs was obtained from a clinical examination conducted as part of an epidemiological national survey (2000/02 NSAOH), and information on treatment provided amongst matched groups was

obtained from administrative (claims) data. To compare the survey estimates of treatment need with the dental treatment provided to employed (DTBS) and less well-off (DTSS) adults who used the schemes, extractions and restorations provided to 16-24, 35-44 and 65+ year-olds between October 2000 and August 2002 were analysed. The chi-square test was used to compare proportions, and the student t-test was used to compare means between the survey and claims databases.

Although it was not possible to determine the differences between estimated need and treatment provided for the same group of people, measures were used to ensure that the population groups were the same. These measures included ensuring that only eligible adults and those who attend regularly were included in the calculation of epidemiologically estimated need, and comparing with administrative data for the same time period during which the survey was carried out (October 2000 and August 2002).

3.4. Summary of data and methods

Table 3.8 summarises the data sources, specific purpose, and the types of analyses used for each of the articles included in this thesis.

In general, the same population (Irish adults) was studied in Articles I and II, and although the NSAOH and SLÁN surveys differ in methods used, they are both nationally representative samples. Article III focuses on low-income, or disadvantaged, adults (those eligible for, and users of, the DTSS) and employed or retired adults in certain occupations (those eligible for, and users of, the DTBS), using data from the 2000/02 NSAOH, and from the DTBS and DTSS databases from October 2000 to August 2002. Articles IV and V use data from the DTBS database. Article IV also uses data from the 2000/02 NSAOH and the 1989/90 NSAOH, and presents results from Central Statistics Office (CSO), the 1979 survey of adult oral health, and the 1961-63 (Minister for Health, 1966), 1984 (O'Mullane et al., 1986) and 2002 (Whelton et al., 2006) surveys of children's dental health.

Table 3.8 Data and methods applied in the studies

Article	Data/year	n/N	Age in years	Dependent variable or specific purpose	Model specification
I	NSAOH 2000/02	2,888	16-24, 35-44, 65+	Tooth retention	· Logistic regression · Negative binomial · 2-parameter log-gamma · Zero-inflated negative binomial · Moderated multiple regression
II	SLÁN 2007	10,364	18-99	Utilisation of dental services	· Logistic regression
III	NSAOH 2000/02	1,486	16-24, 35-44, 65+	Comparison of need and utilisation	· Chi-square test and t-test
	DTBS 2000/02	238,942			
	DTSS 2000/02	167,141			
IV	DTBS 1997-2008	1,271,937	16-100	Trends in treatment provision	· Time series analysis (linear regression analysis)
V	DTBS 2003	256,222	16-64	Utilisation of dental services	·Logistic regression ·A two-part model (1: logit, 2: zero-truncated negative binomial) ·Finite mixture negative binomial

NSAOH: Irish National Survey of Adult Oral Health. SLÁN: Survey of Lifestyle, Attitudes and Nutrition in Ireland. DTBS: Dental Treatment Benefit Scheme data. DTSS: Dental Treatment Services Scheme data.

4. Results

Having applied the methods described in Chapter 3, this chapter summarises the results of the five articles. Section 4.1 describes the sample and presents an overview of the results from Article I, which examined factors associated with being dentate, retention of natural teeth (NT) and sound untreated natural teeth (SUNT), as measured by dental examiners in the 2000/02 NSAOH. Section 4.2 presents results from Articles II and V. Article II examined factors associated with the odds of self-reported use of dental services in the past year, using SLÁN data, and Article V examined factors associated with the odds of visiting a dentist and number of visits to a dentist over a five-year period, using data from the DTBS database. The SLÁN sample and the DTBS cohort are described. A summary of findings from an analysis of trends in treatment provided in the DTBS between 1997 and 2008 (Article IV) is provided in Section 4.3. The results from the comparison of epidemiologically-estimated need and actual treatment provided in the DTBS and DTSS schemes (Article III) are summarised in Section 4.4.

4.1. Non-biological factors associated with tooth retention

Table 4.1 presents the characteristics of the sample from the 2000/02 NSAOH (Article I) by age group. Retention of natural teeth and sound teeth decreased with increasing age group, for example, 90.0% of 16-24 year-olds had 18 or more sound untreated natural teeth, compared to 36.8% of 35-44 year-olds and 3.3% of 65+ year-olds.

In terms of SES, among 35-44 year-olds, 76.1% were in employment and 4.6% had primary education only; among 65+ year-olds, 37.9% had primary education only and 71.1% had Medical Cards. Smoking and frequent snacking were highest among the 16-24 year-olds, and frequent brushing, use of fluoride toothpaste, regular visits, and visiting for a check-up were highest among 35-44 year-olds.

Table 4.1 Characteristics of the 2000/02 NSAOH sample

	16-24 (n = 1196)		**35-44 (n = 978)**		**65+ (714)**	
	n	**%**	**n**	**%**	**n**	**%**
At least one natural tooth present	1194	100.0	968	99.1	422	59.1
No natural teeth present	0	0.0	9	0.9	292	40.9

21 or more natural teeth present	1192	99.8	842	87.3	104	13.3
Less than 21 natural teeth present	2	0.2	134	12.7	608	86.7
28 or more natural teeth present	877	75.2	361	40.0	18	2.5
Less than 28 natural teeth present	317	24.8	615	60.0	694	97.5
18 or more sound untreated natural teeth present	1045	90.0	344	36.8	28	3.3
Less than 18 sound untreated natural teeth present	151	10.0	634	63.2	686	96.7
Male	511	50.5	367	49.4	331	43.4
Female	685	49.5	611	50.6	383	56.6
Employed or self-employed	502	48.0	687	76.1	61	7.1
Unemployed, homemaker, retired or student	667	52.0	258	23.9	602	92.9
Primary education only	8	0.7	45	4.6	260	37.9
Left education during second level, after second level, third level, or if still in full time education	1173	99.3	913	95.3	432	62.4
Disadvantaged (Have a Medical Card)	263	19.0	197	17.4	456	71.1
No Medical Card	920	81.0	761	82.6	242	28.9
Percentage lifetime exposure to fluoride (continuous variable)	809	80.2	782	85.9	555	84.0
<1 years exposure to fluoridated water	314	19.8	176	14.1	142	16.0
Smoker	376	32.1	285	29.7	112	17.4
Non-smoker	798	67.9	661	70.3	580	82.6
Sweet snacks at least three times/day	363	31.1	184	19.3	41	11.2
Sweet snacks less often or never	808	68.9	759	80.7	349	88.8
Brush teeth twice/day or more	851	68.5	695	70.9	209	52.0
Brush teeth less often or never	336	31.5	258	29.1	192	48.0
Always use fluoride toothpaste	802	71.3	685	73.4	194	50.7
Use fluoride toothpaste less often	383	28.7	264	26.6	205	49.3
Visit the dentist at least once a year	377	32.1	389	39.8	123	17.7

Visit the dentist less often	796	67.9	560	60.2	566	82.3
Visit the dentist for a check-up	547	48.4	532	54.2	159	27.9
Visit the dentist when in need or in pain	560	51.6	401	45.8	408	72.1

Percentages are weighted to match the total Irish population.

Results indicated that visiting the dentist regularly and/or for a check-up are significantly associated with retention of natural teeth and sound untreated natural teeth (Table 4.2). Visiting the dentist regularly (at least once a year) had a negative effect on retention of NT, SUNT, 28+NT and 18+SUNT among 16-24 year-olds. It also had a negative effect on retention of 18+SUNT among 35-44 year-olds. However, visiting the dentist regularly and attending for a check-up instead of when in need or pain, had positive effects on retention of NT and 21+NT among 35-44 year-olds and 65+ year-olds and on being dentate among 65+ year-olds (Table 4.2).

In terms of SES, being in employment had a positive effect on NT among 16-24 and 35-44 year-olds, and 21+NT among 35-44 year-olds and 65+ year-olds (Article I). Being disadvantaged was negatively associated with retention of 28+NT or 18+SUNT among 16-24 year-olds, and NT and 21+NT among 35-44 and 65+ year-olds. Having primary education only had a negative effect on retention of 18+SUNT among 16-24 year-olds, NT and 21+NT among 35-44 year-olds, and NT, 21+NT and being dentate among 65+ year-olds.

Being a smoker was negatively associated with retention of SUNT among 16-24 year-olds, NT and 21+NT among 35-44 year-olds, and NT, 21+NT and being dentate among 65+ year-olds. Consuming sweet food, or drinking sweet drinks at least three times/day had negative effects on NT and SUNT among 35-44 and 65+ year-olds, and 21+NT among 35-44 year-olds.

Brushing teeth twice a day or more had positive effects on retention of SUNT among 16-24 year-olds, and retention of NT among 35-44 and 65+ year-olds. Use of fluoride toothpaste also had a positive effect on NT among 35-44 year-olds.

Percentage lifetime exposure to water fluoridation had positive effects on retention of SUNT and 18+SUNT among 16-24 and 35-44 year-olds, and NT and 21+NT among 35-44 year-olds.

Table 4.2 Factors associated with retention of natural teeth (NT) and sound untreated natural teeth (SUNT), and the odds of having 21+NT, 28+NT, 18+SUNT or being dentate

	Empirical direction of the effect*											
	16-24 year-olds				35-44 year-olds				65+ year-olds			
Variable	**NT**	**SUNT**	**28+NT**	**18+SUNT**	**NT**	**SUNT**	**21+NT**	**18+SUNT**	**NT**	**SUNT**	**21+NT**	**Dentate**
Male	+	+	+			+			+	+	+[a]	+[a]
Employment	+				+		+				+[a]	+[a]
Disadvantaged			-	-	-[a]		-[a]		-		-[a]	-[a]
Primary education only				-[a]	-		-[a]		-		-[a]	-[a]
Smoker		-			-		-		-		-[a]	-[a]
Frequent snacks					-[a]	-	-		-[a]	-		
Frequent brushing		+		+[a]	+[a]		+[a]		+		+	
Use of fluoride toothpaste					+[a]							
Visit dentist regularly	-	-	-	-	+[a]		+	-	+[a]		+[a]	+[a]
Visit dentist for check-up					+[a]		+[a]		+[a]		+	+
Water fluoridation		+		+	+	+	+	+				

* The direction of the effect of the independent variable on the dependent variable. +(-) = statistically significantly positive (negative) at $p \leq 0.05$. [a]significant for bivariate regression analysis only.

4.2. Utilisation of dental services

In Article I, 32.1% of 16-24 year-olds said that they visited the dentist at least once a year, and corresponding figures for 35-44 and 65+ year-olds were 39.8% and 17.7%. Table 4.3 presents the characteristics of the sample from the SLÁN survey (Article II) by gender. Females had greater self-reported use of dental services in the past 12 months than males (55.7% vs. 48.3%; P<0.0001). Forty five percent of males and 43.0% of females had second level education, and 32.9% of males and 27.0% of females had a household income of €50,000 or more per year. Almost three quarters of males (72.4%) and just over half of females (51.8%) were in employment. Females were more inclined to brush their teeth frequently (twice a day or more) than males (80.7% vs. 39.1%). In terms of dentition status, 12.0% of females and 7.6% of males were edentulous.

Table 4.3 Characteristics of the 2007 SLÁN sample

	Males (n = 4,369)		**Females (n = 5,995)**	
	n	**%**	**n**	**%**
Dental care visit in the past year	2006	55.7	3305	48.3
Age				
18-24	481	14.7	567	14.1
25-34	804	23.4	1196	22.4
35-44	882	19.4	1287	18.7
45-54	704	16.3	1013	16.0
55-64	630	13.0	831	12.8
65+	868	13.1	1101	16.0
Education				
Primary	847	20.1	994	19.2
Second level	1970	45.0	2700	43.0
Third level	1552	34.9	2301	37.8
Household Income				
Less than €20,000	820	15.4	1481	23.4
€20-30,000	676	15.9	958	18.7
€30-40,000	675	17.6	816	15.7
€40-50,000	644	18.3	760	15.3
€50,000+	1138	32.9	1247	27.0
Employment				
In employment	2912	72.4	3014	51.8
Not in employment	1405	27.6	2851	48.2

Urban/Rural location				
Rural/village/town (<1,500 inhabitants)	2837	63.7	3999	64.5
City/Dublin city and county	1464	36.3	1906	35.5
Use of a car				
Yes	3435	80.5	4484	75.5
No	790	19.5	1320	24.5
Brushing:				
Twice a day or more	2462	39.1	4660	80.7
Less often or never	1748	60.9	1122	19.3
Dentition Status:				
All 32 teeth	1388	37.8	2209	40.9
Some missing but no dentures	1663	38.3	1915	30.8
Teeth and partial dentures	809	16.4	1027	16.3
Edentulous	439	7.6	769	12.0

Percentages are weighted to match the total Irish population.

Table 4.4 presents the characteristics of those who used the DTBS in 2003 (2003 cohort), from the DTBS database (Article V). The majority of those who used the DTBS in 2003 were aged between 25 and 44 years (70.2%). More females than males used the DTBS in 2003 (57.9%), and continued to use it in the next five years (60.0%). Almost one-fifth (18.0%) of the 2003 cohort who used the DTBS over the next five years visited the dentist annually. A large proportion of the cohort had 21 or more natural teeth present (92.9%) and 0.3% were edentulous.

Table 4.4 Characteristics of 16-64-year-olds who visited the dentist through the DTBS in 2003 and those who received further treatments in 2004-2008

	2003 cohort (N = 256,222)	**2003 cohort who were treated in 2004-2008 (N = 216,121)**
16-24	15.0	13.3
25-34	39.0	39.5
35-44	31.2	32.2
45-54	10.7	11.0
55-64	4.1	4.1
Mean age	34.7(9.5)	35.0 (9.4)
Male	42.1	40.0
Female	57.9	60.0
Married/ Cohabiting	58.9	60.5

Other	41.1	39.5
Number of teeth		
Edentulous	0.3	0.2
1-10	1.3	1.2
11-20	5.5	5.5
21+	92.9	93.1
Mean teeth	27.3(4.7)	27.2 (4.5)
Annual visit		18.0
Less often		82.0
Annual oral exam		1.7
Less often or none		98.3

Table 4.5 presents the factors associated with the odds of using dental services and number of treatments. The odds of a self-reported visit in the past year was less for older adults than younger adults (Article II), however the odds of a cohort of 16-64 year-old patients who used the DTBS in 2003 visiting again in the next five years was greater for older adults, and there was a positive relationship between number of treatments and age (Article V). Among the 16-64 year-olds who used the DTBS in 2003, those who were married/cohabiting had greater odds of visiting again over the next five years, or having annual visits. They were also more likely to be low users, and there was a negative relationship between marital status and number of treatments.

There was a positive relationship between visiting in the past year and level of education and income, however there was a negative relationship between visiting and employment for males (Article II). Visiting in the past year was positively associated with living in a city, having use of a car and brushing teeth frequently.

There was a positive relationship between number of teeth and visiting in the past year (Article II) or visiting the dentist annually (Article V), however there was a negative relationship between number of teeth and number of treatments, and being a low or a high user of dental services (Article V).

Table 4.5 Factors associated with the odds of using dental services and number of treatments

	Empirical direction of the effect*						
	Visit in the past year (II)		Adults aged 16-64 who used the DTBS in 2003 (V)				
	Males	Females	Annual over next 5 years	Visit again in next 5 years	Number of treatments	Low users	High users
Female			+	+	+	+	+
Age		-	+	+	+	+	+
Married/Cohabiting			+	+	-	+	-
Education	+	+					
Income	+	+					
Employment	-						
Living in a city	+	+					
Use of a car	+	+					
Frequent brushing	+	+					
Number of teeth	+	+	+	+	-	-	-

* The direction of the effect of the explanatory variable on the dependent variable.
+(-) = statistically significantly positive (negative) at $p \leq 0.05$.

4.3. Trends in dental treatment provision

Table 4.6 presents the number of adults who used the DTBS from 1997 to 2008, and their composition by gender and age group. The majority of users were consistently female (ranging from 57.8% of users in 1997 and 1998 to 60.8% in 2006) and aged between 25 and 34 years (ranging from 28.1% of users in 2008 to 37.4% in 2004 and 2005).

Table 4.6 Composition of those who used the DTBS from 1997 to 2008

Year	N	Male	Female	16-24	25-34	35-44	45-54	55-64	65+
1997	292,166	41.8	58.2	13.9	31.4	24.7	16.1	8.3	5.2
1998	318,146	42.2	57.8	13.2	30.1	25.3	17.0	8.8	5.2
1999	330,149	42.2	57.8	12.8	29.5	25.5	17.4	9.1	5.4
2000	314,823	41.8	58.2	13.3	30.8	26.8	15.9	8.3	4.6
2001	254,739	40.5	59.5	16.7	36.6	32.7	9.1	3.6	1.1
2002	222,049	39.9	60.1	15.1	36.5	32.9	10.1	4.0	1.1
2003	273,975	40.0	60.0	14.0	37.0	32.2	11.2	4.4	1.1
2004	307,127	39.8	60.2	12.0	37.4	31.8	12.7	4.8	1.1
2005	327,627	39.3	60.7	10.5	37.4	31.2	14.3	5.2	1.2
2006	349,481	39.2	60.8	9.2	36.5	31.0	15.9	5.8	1.3
2007	445,184	40.1	59.9	7.8	29.6	27.5	19.3	11.3	4.5
2008	462,112	40.2	59.8	7.5	28.1	27.3	19.7	12.2	5.1

On average, number of adults using the scheme increased between 1997 and 2008, and mean number of treatments per patient decreased. Changes in treatments over time are summarised in Table 4.7. As a proportion of overall treatments, dentures, and extractions decreased, and oral examinations and prophylaxis increased between 1997 and 2008. Proportion of restorations decreased for all categories except those aged 55 and over. Mean number of restorations, extractions and dentures per person decreased across all categories, as did mean number of oral examinations and prophylaxis per person, and mean number of X-Rays and miscellaneous treatments per person increased.

Table 4.7 Changes in treatments between 1997 and 2008

	Restorations	Oral Exams	Prophyl	Extractions	X-Rays	Misc	Denture Treatments
Proportion:							
Overall/Gender/ 16-54/Dentists	↓	↑	↑	↓	↑	↑	↓
55-64/65+	↑	↑	↑	↓	↑	↑	↓
Mean:							
All categories	↓	↓	↓	↓	↑	↑	↓

Categories included overall, males, females, age groups 16-24, 25-34, 35-44, 45-54, 55-64, and 65+, dentist gender, and dentist practice location.

Changes in restorations over time are summarised in Table 4.8. As a proportion of total restorations, composites on anterior teeth, pin-retained fillings and restorations of incisal angle or tip decreased, whereas white fillings on back teeth/glass ionomers, crowns and endodontic treatment increased.

Table 4.8 Changes in restorations between 1997 and 2008

	Amalgam	Comp Anterior	White Fillings Back Teeth/ Glass Ionomer	Crown	Pin-Ret	Incisal Angle or Tip	Endo
Proportion:							
All other categories	↓	↓	↑	↑	↓	↓	↑
45-54/ 55-64	↑	↓	↑	↑	↓	↓	↑
Mean:							
All categories	↓	↓	↑		↓		

Comp Anterior = Composites on anterior teeth. Pin-Ret = Pin-retained fillings. Endo = Endodontic treatments.

Proportion of amalgams provided decreased for all categories (Table 4.8) except for those in the 45-54 and 55-64 age groups. Mean number of amalgams, composites on anterior teeth and pin-retained fillings decreased, and white fillings on back teeth/glass ionomers increased.

4.4. Comparison of epidemiologically-estimated need with treatment provided

Table 4.9 presents the number of adults included in the comparison of epidemiologically-estimated need, from the 2000/02 NSAOH, and treatment provided, extracted from the DTBS and DTSS databases, by age group and socio-economic group (employed and less well-off adults).

Table 4.9 Number of adults included in the comparison of epidemiologically-estimated need with treatment provided

	16-24	35-44	65+
Employed adults:			
Survey regular	103	211	28
Administrative data	100,971	134,198	3,773
Less well-off adults:			
Survey regular	103	65	94
Administrative data	58,702	48,491	59,948

Number of adults analysed from the survey data are those who stated that they attend the dentist at least every two years. Employed adults refer to those eligible for, and who used, the DTBS. Less well-off adults refer to those eligible for, and who used, the DTSS.

Table 4.10 presents the direction of the differences between treatment provided and epidemiologically-estimated need for treatment. Among employed adults (DTBS), the proportion of 35-44 year-olds that had restorations provided was significantly greater than estimated as needed in the 2000/02 NSAOH. The proportion of 35-44 year-olds and 65+ year-olds provided with advanced restorations and denture treatments was significantly less than estimated by dentists in the survey. Among less well-off adults (DTSS), the proportion of 16-24- and 35-44-year-olds that had extractions provided was greater than estimated as needed in the survey. The proportion of 35-44 year-olds provided with denture treatments was significantly less than estimated by dentists in the survey for those eligible for the DTBS and DTSS. The proportion of denture treatments provided was also significantly less for 65+ year-olds eligible for the DTBS.

Table 4.10 Summary results for comparing proportion of adults estimated as needing treatment with the proportion who received treatment

	Extractions		Restorations		Advanced Restorations		Denture Treatments	
	DTBS	DTSS	DTBS	DTSS	DTBS	DTSS	DTBS	DTSS
16-24	>	>*	>	>	<	>	<	<
35-44	<	>*	>*	>	<*	<*	<*	<*
65+	>	<	>	<	<*	<	<*	<

> indicates treatment provided greater than estimated need. < indicates treatment provided less than estimated need. * indicates significant difference at least at the 5% level based on the chi-square test to compare two proportions.

Among employed adults (DTBS), mean number of teeth extracted was significantly less than estimated as needed for 35-44 and 65+ year-olds (Table 4.11). Mean number of restorations provided was significantly greater for 35-44 year-olds, and mean number of advanced restorations provided was significantly less than estimated as needed in the survey for all age groups. For less well-off adults (DTSS), mean number of extractions provided was greater than estimated as needed for 16-24 year-olds and less than estimated as needed for 65+ year-olds. Mean restorations provided were significantly greater than estimated as needed in the survey for all three age groups. Mean number of advanced restorations provided was significantly less than estimated as needed for 35-44 year-olds.

Table 4.11 Summary results for comparing mean number of teeth per person estimated as needing treatment with the mean number of teeth per person that received treatment

	Extractions		Restorations		Advanced Restorations	
	DTBS	DTSS	DTBS	DTSS	DTBS	DTSS
16-24	>	>*	>	>*	<*	>
35-44	<*	>	>*	>*	<*	<*
65+	<*	<*	>	>*	<*	>

> indicates treatment provided greater than estimated need. < indicates treatment provided less than estimated need. * indicates significant difference at least at the 5% level based on the student t-test.

The gap between epidemiologically-estimated treatment need and treatment provided seems greater for those disadvantaged (DTSS) than those in employment (DTBS) among 16-24 year-olds and 65+ year-olds.

5. Discussion

This thesis describes the development of a new method to provide a comprehensive picture of oral health status and changes in oral health over time among Irish adults. The data generated for analysis of trends in treatments provided were previously unattainable. Statistical analyses and current technologies were applied to oral health service and survey databases to generate information on oral health outcomes for health policy makers. The focus of this research was to determine the value of a public dental claims database to provide information on use of services. Survey data were used to contextualise the research by describing the socio-demographic influences on oral health and utilisation of services in the adult population in Ireland. The potential of the DTBS database to provide information on the utilisation of services was determined, and factors associated with utilisation of dental services over a five-year period by a cohort of users from 2003 was investigated. The extent to which the DTBS data could yield information on the impact of reported improvements in oral health on the volume and types of treatment provided to Irish adults was established, and trends in treatments provided over a 12-year period were extracted from the data. The DTBS and DTSS claims databases were further exploited to determine the validity of epidemiologically-defined dental treatment need in estimating treatment provided to Irish adults. While the data analyses have provided important information, they also have some limitations. In Section 5.1, the key dimensions, or characteristics, of the data sources are discussed. The results are discussed in the context of previous research in Section 5.2.

5.1. Data

In this section, the key dimensions of the survey and administrative data are explored. The survey data, which were used to describe the context within which the remainder of the research was carried out, are discussed in Section 5.1.1, and the administrative data, the main focus of this research, are discussed in Section 5.1.2.

5.1.1. Survey data

Three of the articles (I, III and IV) used data from the 2000/02 NSAOH. Although the response rate of the survey seems low (less than 40%), the profile of the sample in terms of household size was similar to the general population. Subsequent weighting for gender and Medical Card ownership ensured the representativeness of the results

as far as possible (Whelton et al., 2007). There is no scientifically-proven minimally acceptable response rate to surveys (Johnson and Wislar, 2012), although a response rate of 60% has been used as a "rule of thumb" (Johnson and Wislar, 2012), and less than 15% is considered very low (Groves, 2006). Participation in surveys has declined in recent years (Galea and Tracy, 2007; Korkeila et al., 2001), however, according to Galea and Tracy (2007), this is unlikely to substantially influence point estimates of measures of interest.

The 2000/02 NSAOH is the most recent survey of adult dental health, and number of teeth (Article I), and need for treatment (Article III), were recorded by clinicians. However, people need to perceive a need for treatment to visit for treatment in the first instance, and there are often gaps between people's perceived need and dentist-defined need (Gooch and Berkey, 1987). According to Schicke (1981), generally, "perceived need is less than or equal to demand, which, in turn, is less than the professionally determined need, which is not equalled by the supply of services".

The utilisation of dental health services in Article I (2000/02 NSAOH) and Article II (SLÁN 2007) was assessed by means of self-reporting, which could affect the validity of the information as the respondents may have difficulty recalling exact attendance (Bellon et al., 2000; Nitschke et al., 2001; Sjöström et al., 1998). Administration data, as used in Article V, may provide a more accurate measure of utilisation since it is recorded at the time the treatment is provided, so it is not affected by the recall errors associated with a survey. Nonetheless, survey data represents a useful method for gathering information on clinical status as well as sociological and demographic determinants of utilisation, and provides a wide range of variables. In Article II, the aim was not to calculate the absolute level of dental care utilisation but to explore differences according to socio-demographic characteristics, and so self-reported utilisation is unlikely to have biased the conclusions. Similarly, in Article I (2000/02 NSAOH), the analysis investigated whether use of services influenced tooth retention. Therefore, although dental service use was self-reported, its collection as part of the survey enabled an estimation and exploration of its influence on clinically-assessed tooth retention and sound teeth.

In Article II, the question relating to use of services does not differentiate between visits to an orthodontist, general dentist and dental hygienist as they are combined in

one question, although they provide different services. Thus, it was not possible to use the SLÁN data to establish whether a visit had been made for preventive reasons or for treatment of problems. Therefore, a report of a visit in the past year could mean that the respondent had either good preventive practices or a serious problem. However given that the SLÁN data were representative of the population and had a response rate of 62% (Morgan et al., 2008), they provided a useful indication of the percentage of individuals who reported a dental visit in the past year. The SLÁN survey also collected information on income level, which was not collected in the NSAOH, or recorded in the DTBS and DTSS databases. This enabled an analysis of the relationship between reported use of dental services in the past year and income level. However, given the limitations of survey data as discussed, it has been suggested that claims data provide "more accurate and detailed information than do self-reports of dental use recalled for the past year" (Davies et al., 1987).

5.1.2. Administrative data

For Articles III, IV and V, the data were derived from requests to the Department of Social Protection for claims for treatments provided to adults eligible for the DTBS. In Article III, data on provision of treatments were also derived from requests to the HSE for claims for treatments provided to adults eligible for the DTSS. Because the administrative databases were not collected for research purposes, extensive cleaning was required before any analysis could be performed. The DTSS research database had already been developed in the Oral Health Services Research Centre (Cronin, 2005).

Although the DTBS administrative data files constituted a potentially rich source of information, they needed to be linked longitudinally at the patient level before their full value could be appreciated. In Article V, a single cohort of participants within the DTBS claims database (those who had treatment in 2003) was assembled, and subsequent treatments for these individuals from 2004 to 2008 were identified. A major unexpected advantage of examining patterns of treatment over time per person for one cohort (Article V) was that errors in the database were flagged (such as differences in date of birth) which may otherwise have gone unnoticed. Although treatments received in the reference period could be part of a course of treatment from a previous year, this does not adversely affect the aims of the research. This is

because the analyses focus on factors associated with annual attendance for any reason and number of treatments in 2004-2008.

The service data are of high quality; however the issue of attrition between 2004 and 2008 is inevitable, and patients may be lost to the system for a number of reasons. Attrition in administrative data arises from death, emigration, or loss of eligibility through unemployment or change in the type of employment. The unemployment rates in 2004, 2005, 2006, 2007 and 2008 were 4.5%, 4.4%, 4.5%, 4.7% and 6.4% respectively, and the death rate among 20-69 year-olds, based on population estimates, in both 2007 and 2008 was 0.3% (Central Statistics Office, 2013). Assuming eligibility of approximately 40.5% of 16-64 year-olds in 2003, a death rate of 0.3% for each of the five years, and a total increase of 1.9% in the unemployment rate over the five years, an estimated 1.4% of people were lost to the scheme in 2004-2008 due to death and unemployment $(((0.3 \times 5) + 1.9) \times 0.405)$.

Patients may also be lost to the database if they choose to seek care privately or to obtain care in another country. Although the attrition effect is not quantifiable, the approach to analysing utilisation of a cohort over a five-year period required use of the DTBS in 2003, and the second part of the TPM required at least one other claim in 2004-2008, which minimised the effect. Ultimately, future development of this approach to outcomes-based research should attempt to link databases to better track individuals. As well as providing a rich range of variables, linking individuals across schemes (for example the DTBS and DTSS) could also greatly increase the value of the information available for analysis. In Ireland this approach is hindered by lack of a common unique patient identifier. For example, patients' PPS numbers are recorded when they use the DTBS; however their Medical Card number is used as an identifier when they use the DTSS. Plans to introduce such an identifier in the future will be very beneficial to health services research. Additionally, it must be acknowledged that there are inevitable opportunities for recording or transcription errors to result in an apparent change of identity. While many of these were dealt with during the data cleaning phase, some may have been undetectable and the rate of such errors is unknown.

The analysis of the DTBS data in Article V is constrained by the limited range of variables in the administrative database. Although the data are rich in information

necessary for financial transactions, they lack socio-economic variables, which are essential for answering many dental health services research questions. Lack of specific detail about the services that patients receive has previously been discussed as a problem in using administrative databases to measure quality of care (Garnick et al., 1994). Combining databases (for example, survey data and administration data, or linking across schemes) would result in a richer data source with a wider range of variables. However, confidentiality issues and obtaining agreements to perform links represent potential barriers to developing more comprehensive data systems (Holtz et al., 1998). Matching claims and survey data would allow analyses of patients' characteristics, which would be very useful in identifying policy implications.

The main advantages of using administrative data was that the treatments provided represent real-life patterns of dental care, and it was possible to link longitudinal data and analyse patterns of utilisation with a large number of patients annually over a 12-year period (Article IV), and for a cohort during a five-year period (Article V). The analyses provided useful information on patterns of attendance and factors associated with utilisation (Article V). Real-life data were successfully harvested from administrative databases, which provide a more accurate picture of service utilisation than survey data.

5.1.2.1. Key dimensions of survey and administrative data

Holtz and colleagues (1998) provide a detailed report of the key dimensions of survey and administrative data, and these are summarised in Table 5.1.

Table 5.1 Key dimensions of survey and administrative data

Survey Data	Administrative Data
High cost of locating individuals, and good response rate crucial.	Low cost relative to a representative sample.
Samples are representative of general population.	Large sample size.
Flexible method for gathering information.	Detail and accuracy of scheme information.
Can collect a broad range of information, including outcome and background information, and indicators of well-being.	Variables limited by the primary purpose for which the records exist, i.e. only records outcome and background information directly relevant to the claim.

Does not require a person to participate in a scheme to obtain information.	No information when a person is "off the scheme".
May refuse to answer certain questions and responses subject to recall error.	More accurate information on utilisation of services because information is recorded at the time transactions occur.
Repeated representative samples are costly.	Longitudinal data through matching.

Compiled based on information in Holtz and colleagues (1998).

Although Holtz and colleagues (1998) did not explicitly include the validity of survey data as one of their key dimensions, they noted that respondents may refuse to answer certain questions and have difficulty recalling exact information. This weakness of survey data was further described by Tomar and colleagues (1998), who suggested that the validity of survey results may be affected by the respondent's honesty and accuracy in interpreting questions and recalling past behaviour. Respondents may not say they are eligible for a scheme because of socially-desirable responding, or they may not realise that they are entitled to receipt of care in a scheme. Other limitations of administrative data, in addition to those mentioned by Holtz and colleagues (1998), include coverage and benefit restrictions, lack of coverage continuity (Riley, 2009), and inability to estimate the rates of participation in a scheme (Holtz et al., 1998). Lack of coverage continuity, or loss of eligibility, in the DTBS due to lack of contributions arises through unemployment or changes in the type of employment, which, as mentioned earlier in the discussion, leads to attrition. Eligibility rates are not always available for schemes; however the Department of Social Protection provided the numbers eligible for four years, which enabled a calculation of DTBS participation rates for those years.

Holtz and colleagues (1998) suggested that a comparison of the relative strengths and limitations of administrative and survey data should include an examination of their similarity and differences with respect to the populations they sample, or cover. It should also include the types of outcome and "background" variables they measure, the quality of these measurements, and the periods for which information is available in each data source (Holtz et al, 1998). Table 5.2 uses these headings to summarise the key dimensions of the administrative and survey data used in this study. The headings 'errors', and 'cost and time' are also added. In terms of obtaining outcome measures and background variables, data acquisition and validity and reliability of

data could be added as sub-headings. Acquisition of administrative data can be an obstacle to research as Government departments are understandably cautious about releasing their data. Acquiring the DTBS data for this research was achieved by agreeing to have the PPS numbers scrambled, using encrypted files, and agreeing to limit access to the raw data to just two people on password-protected computers. Nonetheless, due to a shortage of manpower, access to the data was not granted for claims beyond 2008. In terms of validity and reliability, as noted in Table 5.2, self-reported use of dental services is subject to recall errors and socially-desirable responses, whereas real data on treatments provided is recorded in administrative databases.

Because the survey data and the DTSS data had already been collected and processed (Cronin, 2005; Morgan et al., 2008; Whelton et al., 2007), the only relevant aspect for these data, in terms of cost and time, in this thesis, was analysis of the data. Costs of the survey data include salaries for administrators and researchers, and the cost of incentives, printing, envelopes, postage and travel costs. Costs of the administrative data are limited to time spent cleaning and analysing the data, i.e. researcher salaries. As noted in Section 3.1.3, substantial time was spent preparing the DTBS data for this study; however the overall costs would still be significantly lower than for repeated nationally representative surveys.

Table 5.2 Key dimensions of administrative and survey data used in this study

Survey data		**Administrative data**	
NSAOH 2000/02	**SLÁN 2007**	**DTBS**	**DTSS**
Population represented:			
Irish adults aged 16-24, 35-44, 65+ years.	Adults aged 18-99 years living in private households. It included both Irish citizens and non-Irish national residents.	Adults in certain types of employment (and retired persons) with sufficient social insurance contributions, and their spouses, aged 16 and over.	Low income or unemployed adults, or adults eligible under EU regulations.
Obtaining outcome measures and background variables and their quality:			
Utilisation of services subject to recall errors and socially-desirable responding.		Accurate information on scheme participation and real data on treatments provided.	
894 variables, including information recorded by	Questionnaire recorded 550	Data on individuals or	Limited number of variables

clinical examiners and via questionnaires during face-to-face interviews. Variables include socio-demographic information, but exclude income level.	variables during face-to-face interviews. Variables include socio-demographic information. One question records utilisation of dental services generally.	households that are not directly relevant to the needs of the scheme either tend not to be kept at all, or not recorded. Limited number of variables available (14), with 90 codes for treatments provided.	available (22) with 22 codes for treatments provided.
Time frames for which information is available:			
In 2000/02, subjects were asked to recall dental visiting behaviour in the past few years, however there is a risk of recall error and socially-desirable responses.	In 2006/07, subjects were asked to recall when was the last time they visited the dentist, orthodontist or dental hygienist, however there is a risk of recall error and socially-desirable responses.	Data recorded on computers from 1986. Data missing from 1993 to 1996 (inclusive). Longitudinal analysis possible from 1997 to 2008.	Data available from 1994 (when the scheme was introduced) to 2006.
Errors:			
Key-in errors, non-responses, socially-desirable responses.		Key-in errors, missing data, duplicate records. Please see Section 3.1.3.2 for a list of errors in the DTBS data.	Key-in errors, duplicate records.
Cost and time:			
Design, locating individuals, data collection, data entry and analysis.		Data cleaning and processing, creation of datasets, and analysis.	Creation of dataset and analysis.

NSAOH = National Survey of Adult Oral Health 2000/02, DTBS = Claims data for the Dental Treatment Benefit Scheme, DTSS = Claims data for the Dental Treatment Services Scheme, SLÁN = Survey of Lifestyle Attitudes and Nutrition in Ireland 2007.

5.1.2.2. Recommendations for recording, and use of, administrative data

The time spent cleaning the DTBS data could be reduced, and the data would be more amenable to statistical analysis, if software with mandatory fields for data entry, or electronic health records (EHRs), were used to record the data in the dentists' practice and/or in the Department of Social Protection. EHRs, or computer-based patient records, are "designed to provide clinicians with access to complete, comprehensive, and accurate data about patients" (Committee on Improving the Patient Record Institute of Medicine, 1997). They are considered key tools in supporting healthcare (Schleyer et al., 2011), for research efficiency and innovation (Thwin et al., 2007), and can provide valuable knowledge about diseases and treatments (Safran et al., 2007). EHRs provide more detailed information than can be obtained from surveys, and it is therefore possible to examine the distribution, and trends, of symptoms, disease, and treatment outcomes (Schleyer et al., 2011; Stark et al., 2010). According to Atkinson and colleagues (2002), they play an important role in enhancing evidence-based decision-making in dentistry and improving clinical effectiveness through assessment of outcomes of care.

The use of EHRs helps to eliminate the manual task of extracting data from charts. When compared with paper-based data collection, computerised data collection has been found to reduce operating costs, save time, and increase the accuracy and reliability of data by reducing the possibilities for human errors (Weber et al., 2005). Computer-generated clinical records have also been found to achieve a higher compliance rate with statutory regulations than handwritten records (McAndrew et al., 2011). They are said to have the potential to "serve as a catalyst for more effective co-ordination between public health departments and primary care providers in maintaining healthy communities" (Calman et al., 2012). The use of EHRs by governments and dentists should be considered to record administrative data for dental care schemes to enrich the amount of data available to researchers, and to support effective and informed policy decisions.

The key dimensions of the DTBS database were outlined in Table 5.2. It provides real data on a population of patients who use the DTBS; however it does not capture characteristics of patients, which would provide a more complete picture of people's dental health. To improve the utility of the service data, the range and quality of the

information captured needs further development. Hayden (1997) suggested that one of the greatest deficits is the absence of a diagnostic code that would provide researchers with some reason for provision of treatment. This information is currently not recorded on the DTBS and DTSS claim forms. The introduction of this field would provide useful information on dental health (for example, whether a restoration was provided due to caries, trauma or for aesthetic reasons) and quality of care. In practice, a balance must be achieved between the information researchers would like to have, and what is feasible for practitioners to record. Therefore, there is a need to focus on recording the most valuable information. This information could be identified through collaborations between health services researchers and the departments responsible for the administration of the schemes. Identification of the ideal database required for collection should consider the value of international comparisons. The ability to use real outcomes data would facilitate international comparisons of the impact of services on oral health outcomes. Although the services are delivered in different cultural and system contexts, the information would be of value in identifying best practice in service design.

In terms of processing and analysing administrative data, with file sizes of approximately 2GB, space on the computer and RAM play a vital role in efficient analysis of data. Furthermore, if one is to consider analysing administrative data, although it provides a wealth of otherwise unavailable information, it is important to plan for sufficient time spent processing and analysing the data, and creating datasets. Running analyses on smaller subsets of data is useful in exploratory analysis to ensure that all the information required has been included, before performing the analysis on the entire dataset.

5.2. The empirical results

The directions of the effects of the explanatory variables in the empirical models are largely in accordance with expectations, and are in agreement with previous studies of the topics. This section discusses the results of the five articles. Sections 5.2.1 to 5.2.5 mainly discuss the results relating to objectives one, two and three. Tooth retention, utilisation of dental services, and socio-demographic influences on these are discussed. Section 5.2.6 discusses results relating to objective four, that is, the trends in the treatments provided to Irish adults over a 12-year period. Finally, Section 5.2.7

discusses results relating to objective five, that is, the gap between epidemiologically-estimated need and treatment provided in the DTBS and DTSS. The shortcomings of normative need as a measure of need are outlined, and perceived need and the socio-dental approach to needs assessment are explored.

5.2.1. Tooth retention

Overall, almost 10% of the 2007 SLÁN sample was edentulous (Article II), which is similar to the overall level found in the 2000/02 national survey of adult oral health (11.6%) (Whelton et al., 2007). Article I (NSAOH 2000/02) reports edentulousness levels of 0.9% among 35-44 year-olds and 40.9% among 65+ year-olds. Article I also reports mean number of natural teeth per person among 16-24 year-olds, 35-44 year-olds and 65+ year-olds as 28.2, 25.2 and 8.5 respectively. Mean number of sound teeth for these three age groups were 23.3, 15.3 and 5.2 respectively (Article I). In Article III, the mean number of teeth reported as present is similar between survey and administrative data for 35-44 year-olds and 65+ year-olds eligible for the DTBS. For example, among 35-44 year-olds mean number of teeth present was 26.6 in both survey and administrative data, and among 65+ year-olds, mean number of teeth per person in the survey sample was 18.4 and in the DTBS data was 17.2.

Results from Article V showed that 0.3% of the 2003 cohort of 16-64 year-olds were edentulous and 92.9% had 21 or more teeth. For every extra tooth present, there was a 1.5% decrease in total number of treatments. Mean number of oral examinations was greater for those with more teeth, ranging from 1.7 per edentulous person to 2.2 for those with 21 or more teeth. Mean number of prophylaxis per person also increased with greater tooth retention, whereas mean number of extractions per person decreased. Mean number of restorations was greatest for those with 11-20 teeth (3.5). In an aging population, where levels of tooth retention are increasing, these findings have important implications for future planning of services.

5.2.2. Utilisation of dental services

Approximately half of the adults surveyed (48.3% of males and 55.7% of females) had used dental services in the year prior to the SLÁN interview (Article II). This compares favourably with countries such as Catalonia (Spain) (34.3%) (Pizarro et al., 2009), Turkey (40.4%) (Mumcu et al., 2004) and Greece (39.6%) (Pavi et al., 2010),

but is less than Finland (Suominen-Taipale et al., 2000), Denmark (Christensen et al., 2007) (64%) and the U.S. (63%) (Sohn and Ismail, 2005). Analysis of the DTBS data revealed that approximately 15.2% of the 2003 cohort who used the DTBS attended annually over the next five years (Article V), however in the 2000/02 NSAOH, 31.5% of 16-24 year-olds and 52.4% of 35-44 year-olds, eligible for the DTBS, said they visited at least every year (Whelton et al., 2007). Corresponding figures for those who reported that they attended the dentist at least every two years (Article III) were 52.0% and 68.7%. This discrepancy between the survey and administrative date emphasises the value of measuring utilisation using administrative data, when real, as opposed to estimated, rates are required. The considerable difference between the results of survey and administrative may be due to socially-desirable responding, or optimism, on the part of the patient, and/or difficulty in recalling exact attendance. Reporting regular use of dental services may also signify an intention to visit, which is associated with a positive dental attitude (Luzzi and Spencer, 2008). This intention to visit, however may not necessarily translate into an actual visit. Further research to determine what motivates adults in Ireland to seek dental care would be useful.

5.2.3. Utilisation of dental services and tooth retention

The importance of number of teeth in predicting dental care utilisation (II and V) is supported (Álvarez and Delgado, 2002; Kiyak and Reichmuth, 2005; Nguyen et al., 2005; Suominen-Taipale et al., 2000). In Article I, visiting the dentist regularly was negatively associated with retention of teeth for 16-24 year-olds; however, less than one third of this age group visited the dentist regularly and just over half of visits were when in need or due to pain. This age group also had the greatest need for restorations among employed adults (Article III) and had the greatest mean number of restorations provided in the DTBS, although it decreased over time (Article IV).

Attending for a check-up had a very large positive effect on having 21+NT or being dentate among 65+year-olds (Article I). The 35-44 year-olds had the highest proportion attending at least once a year and for a check-up, however this age group had the greatest proportion of people in employment, many of whom would be eligible for the DTBS (Article I). As explained in Section 1.2, this scheme entitles adults (and their spouses) who have sufficient PRSI contributions to a free oral examination once a year. Having a greater number of teeth was associated with

visiting the dentist annually in the DTBS, but number of treatments decreased as number of teeth increased (Article V). Attending for a check-up/oral examination moderated the relationship between disadvantage status and tooth retention (NT) for 35-44 year-olds (Article I). This means that although being disadvantaged was negatively associated with NT, when those who were disadvantaged visited for a check-up, instead of waiting until they felt a need or were in pain, their expected number of NT increased. The justification for visiting for a check-up is to deal with conditions such as calculus deposits before they have caused disease, or to detect disease early and treat it with minimal interventions (Locker, 1989).

Those who attended annually for an oral examination received a greater mean number of restorations and fewer extractions than those who attended less often (Article V). The greater number of restorations among those who attend frequently is supported by Burke and colleagues (2005), who found a strong relationship between attendance frequency and survival time. The greater number of restorations may either represent evidence of moral hazard, which arises because neither the patient nor the dentist have incentives to contain costs as the system is "fuelled on entitlements to care and reimbursement through a fee-for-service" (Goodwin et al., 2006), or perhaps those who need more treatments visit the dentist more often. This may be a signal that dental professionals are failing to effectively address the underlying cause of oral disease and to prevent recurrence. Although it is encouraging that there were fewer extractions among those who attended frequently, the high number of restorations may also be a sign that the services are too restoratively-orientated rather than adopting a preventive approach. If dentists keep treating the symptoms of caries without tackling the cause, caries will continue to recur. Most oral disease is preventable so this problem could possibly be addressed in system design with a sliding scale of remuneration for recurring disease and greater rewards for prevention. This is a good example of the kind of information that the database can give us that could be useful when considering system design. Clearly other factors must also be considered.

Ettinger (1992) proposes that a fundamental principle that drives any individual to seek health services is that s/he must believe that they need health care. The difference between potential access and realised access is bridged by the realisation

that a person needs treatment. Whelton and colleagues (2007) found that lack of perceived need was the main reason for not visiting a dentist regularly among Irish adults. For example, among dentate 16-24, 35-44 and 65+ year-olds, proportions who felt they did not need to visit a dentist were 47.1%, 31.5% and 62.1% respectively (Whelton et al., 2007). However, as already noted, for 65+ year-olds, waiting until a need is felt may not be conducive to keeping teeth, as visiting the dentist for a check-up (vs. when in need or due to pain), is associated with being dentate or having 21+NT (Article I).

Self-perceived need depends on people's understanding of 'normal' health, tolerance of pain and discomfort, and on their personal priorities (Davis, 1982). Recent pain experience and concern about oral health and appearance have also been found to be predictors for perceived need (Tickle and Worthington, 1997). According to Giddon and colleagues (1976), the perception of need may differ considerably among groups with similar objective clinical findings, depending on various psychosocial and economic factors. In a study to determine the relation of clinical DMF scores to perceived need for treatment, Giddon and colleagues (1976) found that females were more acute in their perceptions of the need for treatment of decayed teeth and the state of those decayed teeth than males. This may explain why utilisation rates were lower among males than females (II and V), and why males had more extractions once care was sought (Article V).

5.2.4. SES and tooth retention/utilisation of dental services

Socio-economic differences were observed in tooth retention (Article I), reported use of dental care services (Article II), and in need for treatment and treatments provided (Article III). These findings concur with other studies where SES was found to be an important determinant of dental health (Donaldson et al., 2008; Petersen et al., 2004; Thomson et al., 2000) and utilisation of dental health care services (Christensen et al., 2007; Manski et al., 2001; Suominen-Taipale et al., 2000). In a Swedish study, Wamala and colleagues (2006) found that every instance of increasing levels of socio-economic disadvantage was associated with worsened oral health and with decreased utilisation of dental care services.

Tooth retention was negatively associated with SES factors such as lower educational attainment and having a Medical Card (being disadvantaged), and was positively

associated with being in employment (Article I). This is in agreement with several studies outlined in Appendix 1 for example: (Ahlqwist et al., 1991; Bernabe and Marcenes, 2011; Sanders and Spencer, 2004; Suominen-Taipale et al., 1999; Tsakos et al., 2011). Higher educated groups make more use of dental services than less educated groups (Article II). This concurs with findings in the U.S. (Anderson and Kim, 2010; Bloom et al., 1992), Australia (Australian Research Centre for Population Oral Health, 2010), Sweden (Bagewitz et al., 2002), Canada (Bhatti et al., 2007; Brothwell et al., 2008), Denmark (Christensen et al., 2007), Germany (Ugur and Gaengler, 2002), and many other countries, outlined in Appendix 2.

In Article II, higher income levels had a positive effect on utilisation. This is in agreement with studies in Greece (Pavi et al., 2010; Zavras et al., 2004), Brazil (Baldani and Antunes, 2011), Canada (Bhatti et al., 2007; Kosteniuk and D' Arcy, 2006; Millar and Locker, 1999), the U.S. (Bloom et al., 1992; Brown et al., 2009a; Brown et al., 2009b; Evashwick et al., 1984; Goodman et al., 2005), Denmark (Christensen et al., 2007) and Finland (Nguyen and Hakkinen, 2006). People with higher incomes have been found to be more likely to use preventive, restorative, and aesthetic dental services than lower income people (Nguyen, 2008).

Access to services has improved for those on low incomes since the introduction of the DTSS in 1994; however, as suggested by the results of Articles II and III, there are those who may not be aware of their entitlements. Therefore, there is a need to make Medical Card holders better aware of the availability of the DTSS, and their entitlements to free treatment.

5.2.5. Other variables and their relationships with tooth retention and utilisation of dental services

Retention of teeth is dependent on behaviour. The negative relationship between smoking and tooth retention is consistent with other studies (Dietrich et al., 2007; Morita et al., 2006; Yanagisawa et al., 2009; Ylostalo et al., 2004). The results show that tooth retention was positively associated with frequent brushing (Article I), which concurs with the findings of Kressin and colleagues (2003) and Aida and colleagues (2011).

Water fluoridation may be responsible for the greater chance of having more teeth and more healthy teeth (Article I). The effectiveness of water fluoridation in controlling dental caries, one of the greatest risk factors for tooth loss, has been well established (Clarkson et al., 2003; Newbrun, 2004; Spencer et al., 2008; Whelton et al., 2007), and it has been found to reduce the socio-economic inequalities in oral health (Peres et al., 2006; Riley et al., 1999).

Age was significant for females but not males in reported utilisation of dental services (Article II). The finding of a positive association between age and attendance (Article V) concurs with other studies of utilisation of dental services (Moon and Shin, 2006; Nguyen et al., 2005; Sintonen and Maljanen, 1995).

Gender differences (II and V) in utilisation of dental services have also been established in other countries (Álvarez and Delgado, 2002; Christensen et al., 2007; Grytten and Holst, 2002; Millar and Locker, 1999; Mumcu et al., 2004; Pizarro et al., 2009; Suominen-Taipale et al., 2000). Males who had used the DTBS in 2003 were less likely to visit a dentist under the scheme again, but had more extractions than females once care was sought (Article V).

In Article V, being married or cohabiting was positively associated with visiting again in the next five years. This positive effect of marital status on utilisation of dental services is supported (Anderson and Kim, 2010; Christensen et al., 2007; Manski et al., 2012; Osterberg et al., 1995).

5.2.6. Trends in dental treatment provision

Article IV examined trends in the volume and types of treatments provided to adults in the DTBS over 12 years. The design of the study does not permit the establishment of a direct causal relationship using the results presented (i.e. presenting number, percentage and mean number of treatments). Changes in patterns of dental care may reflect patient and provider preferences and the influence of reimbursement policies (del Aguila et al., 2002). Factors related to the types of treatments provided include advances in dental materials, changes in the dentist per population ratio, increased utilisation, a more conservative practice, the increasing danger of malpractice suits, a change in fees, and the decline in the incidence of caries (Simard et al., 1988). As in the UK (Randall et al., 2002), changes in dental care in Ireland may be a consequence

of developments in policy, adjustments to methods of remuneration, the introduction of new procedures and techniques, and changes in patient needs and expectations. The findings may also be biased by the potential for patients to obtain care outside the DTBS. People may not have realised that they were entitled to free or subsidised treatments, forgot to claim for treatments under the scheme, or they may have sought dental treatment abroad.

The number of adults treated in the DTBS increased over time. One possibility for this, especially in 2007, is that Irish economy was buoyant, with 2.1m people in employment in the 3rd quarter of 2007 (Central Statistics Office, 2007), and consequently eligibility for the DTBS increased to 1.9m (from 1.3m in 2005). Several studies have shown demand for, and use of, dental services to change with changes in the economy (Brown, 2001; Suominen-Taipale and Widstrom, 1998). There may also have been a substitution effect between the DTBS and the DTSS, which provides free dental care to less well-off adults. In 2007, approximately 0.4m adults were eligible for treatment in both schemes (The Competition Authority, 2007), when a dispute meant that some dentists withdrew from the DTSS (Lynch, 2008). Prevalence of caries has been found to be greater among adults with Medical Cards (and therefore those eligible for the DTSS) (Whelton et al., 2007). Treatment needs of lower income groups are different (Article III), and an increase in employment during the period of study may have shifted people who would need extractions in the DTSS to receive treatment in the DTBS. This immigration of unhealthy patients to the DTBS may dilute the impression of improvements in dental health among those with higher incomes. Therefore, in addition to changing trends in disease, trends in employment may also influence trends in the types of treatments provided. The linkage of databases with a unique patient identifier would allow this theory to be tested; unfortunately this is currently impossible as there are no identifiers to link the DTSS and DTBS databases.

The number of treatments provided in the DTBS increased over time. According to Schwarz (1996b), this could indicate an increase in utilisation (increase in dental services holding the population constant) or an increase in demand (increase in the proportion who used dental care, holding dental services constant), or a combination of both. In this case, it largely reflects an increase in demand, as mean number of

treatments per patient decreased. The utilisation rate of those eligible was 20.7% in 2003, 25.5% in 2005 and 23.6% in 2007.

Decreases in extractions, restorations and dentures (Article IV) may be due to reductions in caries, which may be a consequence of increased patient exposure to fluoridation, changes in diet, preventive treatments, and improved oral health habits (Beazoglou et al., 1993). Eklund and colleagues (1997) suggested that decreases in restorations, extractions, and denture treatments, and increases in oral exams and prophylaxis, are "profound" and reflect "a combination of competent treatment, effective prevention and rising expectations of healthy dentition on the part of both dentists and the public". They also state that "these favourable trends while partly the product of past dental treatment, also may change dental treatment in the future". As found by Eklund and colleagues (1997), the effect of the caries decline in children (Whelton et al., 2006) has moved into adulthood. In agreement with Brennan and Spencer (2006), the trends are consistent with increased tooth retention and improved oral health.

The consequence of the downward trend in provision of restorations, extractions and denture treatments for younger adults is that need for more advanced restorations and denture treatments decrease, thus lowering future cost of dental care. However, because the DTBS no longer provides subsidised treatments, the future of adult oral health is uncertain. Although oral examinations accounted for approximately one fifth of treatments, they are now the only treatment provided in the DTBS. Because oral examinations are free, patients may opt to receive prophylaxis during the same visit, however if the dentist diagnoses a need for extractions or restorations, there is no guarantee that the patient will return until they feel pain. Recent cutbacks in the DTBS may reduce utilisation of dental services generally and threaten the oral health of those eligible for the DTBS. Furthermore, with increased unemployment, people become ineligible for the DTBS and eligible for the DTSS, for which there has also been a reduction in cover. The impact of the reductions in cover on utilisation of dental services was recently noted by the Irish Dental Association. In a 2012 survey of adults (n = 1,004), they found that the restrictions in dental benefit caused 29% of those eligible for the DTSS and 26% of those eligible for the DTBS to postpone dental treatment in the past year (Irish Dental Association, 2012).

Dentist density has been found to be related to utilisation of dental services (Grytten, 1992). According to Grytten (1992), supplier inducement may operate by increasing the number of patients requesting care (demand) and by increasing the amount of care provided per patient (utilisation). He suggested that dentists are more likely to be able to influence existing patients rather than potential patients. As noted in Article IV, the dentist per population ratio in the DTBS changed from 1:1,075 in 2003 to 1:933 in 2005 and 1:1,323 in 2007, meaning that there were more patients per dentist in 2007 than any other year for which this information is available. Dentist density was found to be significant in utilisation of services in a Finnish study (Nguyen and Hakkinen, 2006) but not in Spain (Álvarez and Delgado, 2002), however the samples and dependent variables were very different. In the Finnish study, the dependent variable was the probability of visiting a dentist in the past year among a sample of dentate 20-40 year-olds eligible for subsidised dental care. In the Spanish study, the analysis focused on number of visits to the dentist in the past three months among working men and women age 16-65 years, a large majority of whom (>88%) paid out-of-pocket at their last dental visit.

Yule and Parkin (1985) suggested that availability of more dentists may be capturing the effect of lower costs (such as travel costs and waiting times) on demand. Parkin and Yule (1988) suggested that dentists may influence the type and amount of services consumed, and availability may also have an effect on access costs. Although use increased with changing dentist per population ratio, there is no evidence of supplier-induced demand as mean treatments per patient decreased progressively over time (for example, from 4.1 in 2003 to 3.6 in 2008). Hence, it is unlikely that the changes in dentist density are responsible for the shift in mean number of treatments. Nonetheless, as suggested by Álvarez and Delgado (2002), inducement may manifest through the recommendation of more costly treatment alternatives, for example, by recommending crowns instead of amalgam restorations.

Improvements in dental health, reflected in increased tooth retention, means that "there are more tooth surfaces available for decay and therefore for preventive and repair work" (Parkin and Yule, 1988). Although restorations as a proportion of overall treatments decreased, they composed approximately one third of treatments in 2008. This is greater than Washington (17.6%) (del Aguila et al., 2002) and Canada

(21.1%) (Leake et al., 2005). With the reduction in caries (Whelton et al., 2007), there should be a decrease in the need for dental services to treat it. The consequence of the decrease in caries in children (Whelton et al., 2006) is that young adults require fewer large restorations than older adults do as their teeth are less damaged by earlier caries. They may have fewer existing restorations, thereby requiring fewer re-interventions. The increase in the proportion of restorations among older adults reflects their increasing tooth retention. Older adults are also more likely to have greater numbers of existing restorations, and they differ from younger adults regarding diet and medication, and have had less exposure to fluoridation (Burke et al., 2005).

Those who have experienced caries will require continued management of its effects, and may require re-interventions on the restorations. Randall and colleagues (2002) state that "a restoration should be viewed as a phase in the life-long care or management of a diseased or traumatised tooth". Ideally, Ireland should be aiming for a situation similar to Denmark (Schwarz, 1996b) where dental services changed from largely restorative/extraction to diagnostic/preventive. One of the commitments in the 1986 Ottawa Charter for health promotion (World Health Organization, 1986) was to reorient health services and their resources towards the promotion of health. The results of Articles IV and V indicate that the Irish system is too focused on restorative services, and is therefore more curative-oriented than prevention-oriented. This needs to be addressed, possibly through education of the public and changes in system design, where dentists are rewarded more for preventive treatments than invasive treatments.

Females had more restorations and more white fillings than males (Article IV). Lucarotti and colleagues (2005) found that there is generally a greater proportion of female patients than males attending for dental restorations. Lucarotti and Burke (2009) suggested that this may reflect both the greater number of females in the population and, perhaps, more concern for the aesthetics of their teeth, or awareness of health issues generally. Males had both a greater proportion, and mean number, of amalgams than females (Article IV). This is supported by Lubisich and colleagues (2011), who found that amalgam placement was more likely when the patient is male.

From the patient's viewpoint, the most important aspect of quality, other than the cosmetic aspect, may be the durability of the treatment (Kostlan, 1979: 109). According to Burke and Lucarotti (2009), one measure of the performance of a dental restoration is the time interval from restoration placement until the next intervention on the same tooth: the longer the interval, the better the perceived performance. According to Forss and Widstrom (2004), over 60% of all restorative dentistry is replacement of previous restorations, and, in the DTBS, 18.3% of restorations were re-interventions on the same tooth (Article IV). Repairs may have been recorded as restorations in the DTBS database, therefore the re-intervention rate of 18.3% does not mean that the restorations failed, only that a re-intervention was performed on the same tooth. According to Anusavice (1995), replacement should only be considered in the case of cavitation or more progressive breakdown involving poor aesthetics, loss of function, poor anatomic form, pain, or sensitivity. According to Hickel and colleagues (2010), "localized defects with sufficient clinical access can be repaired instead of replaced, e.g. sealing of gaps, adding new material to chipping fractures, partial removal and veneering of stained areas of the restorations". Cavity size increases significantly during re-restoration (Forgie et al., 2001), and the tooth becomes weaker (Tyas, 2005). Repeated restorations have been found to display a pattern of progressively reduced survival (Gilthorpe et al., 2002), and can result in irreversible pulpitis requiring endodontic treatment or extraction (Berkowitz et al., 2000).

Restorations composing of pin-retained fillings decreased by, on average, 14.8% annually over the 12-year period. The use of a pin within a restoration is associated with a reduced survival of the restoration (Burke and Lucarotti, 2009). One possibility for the high proportion of amalgam restorations (Article IV) is that they have been found to last longer than composites (Forss and Widstrom, 2004; Tyas, 2005). However, Tyas (2005) found that amalgam was associated with more tooth fracture than resin composite, and Opdam and colleagues (2010) found a better 12-year survival rate of large posterior composite restorations compared with amalgam. According to Christensen (2007), patients should be advised of longevity differences and the availability of metal restorations for the non-visible locations in the mouth. Bharti and colleagues (2011) stated that amalgam should "remain the material of choice for economic direct restoration of posterior teeth".

There are generally two treatment options for severely damaged teeth: a restoration that involves placing the material directly onto the patient's tooth, or a crown made indirectly that covers the entire coronal tooth structure (Janus et al., 2006). In agreement with del Aguila and colleagues (2002), provision of crowns, which have been found to outperform amalgam restorations (Lucarotti and Burke, 2009), increased, especially among females and 55-64-year-olds. The difference in cost between direct and indirect restorations is quite large, for example in Ireland, an amalgam restoration costs approximately €85, whereas a crown costs approximately €800, and the contribution from the government in the DTBS was much less for crowns than direct restorations (approximately 5% vs. 41% in 2008). Although provision of crowns increased in later years, possibly due to the 'Celtic Tiger' effect, crowns were more expensive than amalgam or composite restorations so perhaps many patients may still have found the cost prohibitive.

Spencer and colleagues (1994a) found that changes in the provision of restorations varied according to the number of surfaces covered, and Lubisich and colleagues (2011) found that restoration selection depends on tooth type and which surfaces are being restored. Number of surfaces restored was not recorded when a restoration was provided in the DTBS. Recording the surface(s) and reason(s) for restorations would offer a more complete picture of treatment patterns. It would also be interesting to study which restorations survive longer in the DTBS. Cronin (2005) found that gender, attendance pattern, and position of the tooth in which the restoration was placed were associated with restoration survival in the DTSS, and that amalgam restorations appeared to have better survival than composite restorations. Differences between Ireland and other countries may indicate a different pattern of dental disease and/or treatment philosophy. A survey of dentists' practice in Ireland would be of value in extending knowledge and understanding of the provision of restorations and dental treatments generally.

Preventive treatments, such as pit and fissure sealants, which are regarded as an effective means of preventing caries (Irish Oral Health Services Guideline Initiative, 2010), have yet to be subsidised in Ireland, although Brennan and Spencer (2006) found that they composed a large proportion of treatment provided in Australia. According to Anusavice (1995), if the public are educated about the value of modern

caries-preventive and remineralisation measures, they will demand them. If the range of services cannot be restored to 2009 levels, subsidised provision of fissure sealants and topical fluoride treatments to those with greatest disease risk may reduce the burden of dental disease on society (in terms of costs of restorations, extractions, dentures, and sick-days) in the future.

5.2.7. Comparison of epidemiologically-estimated need and treatment provided

Grembowski and colleagues (1985) suggested that the gap between dental needs and the demand for care is one of the reasons why dental disease is a serious public health problem. The implications of this gap are that unmet needs impact quality of life, and treated cases are not representative of the population as a whole in need of dental treatment (Locker, 1989). There was a lack of agreement between mean epidemiologically-estimated treatment need (normative need) and mean treatment provided in all age groups, especially among 16-24 and 65+ year-old less well-off adults and 35-44 year-old employed adults (Article III). More restorations and extractions were provided than estimated as needed among 16-24 year-olds, and fewer extractions and more restorations were provided than estimated as needed among 65+ year-olds.

The gap between epidemiologically-estimated treatment need and treatment provided seemed greater for those less well-off (DTSS) than those in employment (DTBS) among 16-24 year-olds and 65+ year-olds (Article III). According to Bago d'Uva and Jones (2009), barriers to access may contribute to different levels of utilisation for those with equal need, depending on factors such as income or education. Furthermore, Thomson and colleagues (2000) suggested that it is possible that adults of lower SES (such as those eligible for the DTSS) do not have the same value for an intact dentition as those of higher SES (such as those eligible for the DTBS). This may explain why extractions are higher among those eligible for the DTSS (Article III).

Although treatments were provided at a subsidised rate in the DTBS, many people may still have considered the cost to be prohibitive, especially for advanced restorations such as crowns. This may explain why the proportion of adults receiving advanced restorations was significantly less than epidemiologically estimated as needed for 35-44 and 65+ year-olds (Article III).

Compared to employed adults (DTBS), a greater proportion of less well-off adults (DTSS) had extractions provided across all age groups (Article III). They also had a greater mean number of extractions and restorations per person (Article III). Many of those eligible for the DTSS (less well-off adults) have a low level of income or are unemployed. Very low income adults face large indirect financial and/or opportunity costs in seeking and receiving treatment (Oliver and Mossialos, 2004), and they may regard dental visits a luxury rather than a necessity (Muirhead et al., 2009). Millar and Locker (1999) found that people in lower income households were less likely than those in high-income households to mention preventive reasons for visiting a dentist. They may also be from a background of casual symptomatic dental attendance (Richards and Ameen, 2002).

Differences have been found between normative (professionally-defined) need and perceived need for fillings, extractions, and prosthetic treatment (Colussi et al., 2009; Robinson et al., 1998; Smith and Sheiham, 1980). Perceived need has been found to be an important factor influencing use of dental services (Brodeur et al., 1987). According to Schicke (1981), low self-perceived need may cause "different backlogs of professionally determined need which influence the supply of care and ensuing costs". In 1963, Last (1963) referred to the discrepancy between perceived need and demand in healthcare as the 'Clinical Iceberg', as "disease known to the general practitioner represents only the tip of the iceberg". In a more recent interview, he stated that "some of what's submerged below the surface is serious and important in that, if detected early, it can be treated effectively; otherwise it will eventually cause serious trouble, and cost much more in medical expenses and shortened lives" (Last, 2010). This remark can be generalised to dental care: if patients perceive a need and visit their dentist regularly for a check-up, and if the dental care system is oriented to reward prevention of progression of early stage disease, most advanced and costly treatments may be prevented.

Schicke (1981) suggested that closing the gap between need and demand for dental care depends on social values and financial resources. Davis (1982) identified two strategies for converting need into demand: raising the level of perceived need, through attitude change, and increasing the rate at which perceived needs are converted into demands by reducing organisational barriers. Suggested changes

include ones to payment systems, and improving the relationship between dentists and patients.

Normative need, as measured by dentists in the NSAOH, is considered most useful in the case of restorations (Sheiham et al., 1982), but not so useful when measuring need to replace missing teeth or extract third molars (Sheiham and Tsakos, 2007). Although dentists are trained to examine, diagnose and treat based on scientific principles, they are influenced by their values, beliefs and skills about health and disease, and by the features of the organisation under which they operate (Mosha and Scheutz, 1993). Therefore, objective need (such as normative or evaluated need) is not free of subjective judgements (Sheiham et al., 1982). This lack of objectivity was noted by Sheiham and Tsakos (2007) as one of the shortcomings of normative assessment of need. Other shortcomings are that it does not consider quality of life, health behaviours, perceived symptoms, patient compliance, or that there are limited resources. Differences between subjective and objective need have been noted, especially among the elderly (Gooch and Berkey, 1987).

Attitudes and behaviours of patients can influence the effectiveness of treatments (Tsakos, 2008), and defining need solely in terms of ill-health is considered inadequate as it does not consider how much benefit the health care is likely to bring (Cookson and Dolan, 2000). In the 2000/02 NSAOH, need was assessed solely by examining dentists, where their only consideration was oral health status. The patient's financial situation, or whether s/he wanted treatment, was not taken into account. According to Sheiham and Tsakos (2007), the presence of clinical impairment alone is "neither a necessary nor sufficient basis for need". Defining need as the ability to benefit in some way from health care is considered one of the most appropriate measures of need (Stevens and Gabbay, 1991). Williams (1979) suggested that need can be 'objective' only if we translate the assertion 'Individual A needs Intervention X' into 'If Individual A had Intervention X then, in everybody's opinion, Individual A would be better off'. Among the benefits sought from health care services are that they will enhance health or prevent its depreciation (Culyer, 2001). Ability (or capacity) to benefit can be influenced by incidence and prevalence of disease and effectiveness of interventions (Asadi-Lari et al., 2003). According to Cookson and Dolan (2000), incorporating the concept of a capacity to benefit

"introduces the importance of effectiveness of health interventions and attempts to make explicit what benefits are being pursued". The amount of treatment needed is "that sufficient to exhaust capacity to benefit" (Culyer, 2001). According to Wright and colleagues (1998), if health needs are identified, then "effective interventions must be available to meet these needs and improve health".

To overcome these deficiencies of normative need, a new 'socio-dental approach' to needs assessment has been proposed, influenced by the definition of need as the capacity to benefit (Gherunpong et al., 2006; Sheiham and Tsakos, 2007; Tsakos, 2008). This approach proposes the incorporation of normative assessment of need with general health status, subjective perceptions (including perceived treatment needs and oral impacts in relation to functional, psychological, and social dimensions), propensity to adopt health-promoting behaviours, and scientific evidence of the effectiveness of treatments (Sheiham and Tsakos, 2007). Since oral health-related quality of life was already included in the 2000/02 NSAOH (Whelton et al, 2007), the socio-dental approach could easily be adopted in future surveys, with the addition of questions on, for example, general health status and perceived treatment need for specific treatments.

The socio-dental approach has been used to estimate oral health needs among children (enamel defects, dental anomalies, periodontal diseases, malocclusions and prosthodontic treatment) (Gherunpong et al., 2006), and has been proposed for orthodontic treatment need (Tsakos, 2008). Using this method, needs can be prioritised according to the level of disruption caused in a person's daily life. This method is also useful in a time of scarce resources, where the subjective indicators identify those who would gain most from treatment (Locker and Jokovic, 1996). The socio-dental approach would be especially useful for older adults who may prefer an extraction over endodontic treatment, or may not want a partial denture. Since normative need for extractions, restorations and advanced restorations in Article III was mostly indicated in the case of caries, one could assume that it was a largely appropriate measure of need in this instance. Sheiham and Tsakos (2007) suggest that where there is active caries, treatment is essential even without an assessment of the impact of the condition on the patient's life. The socio-dental approach to assessing treatment need should however be considered in future surveys, especially in the case

of restorations for aesthetic purposes, or partial dentures, where the patient may not perceive a need for treatment.

One of the questions in the 2000/02 NSAOH asked why respondents did not attend, and one of the responses was that they did not feel there was a need. It would be interesting to assess the relationship between those who had a clinically-assessed need and those who perceived that there was no need for treatment, that is, compare objective and subjective need. Perceived need for treatment (such as whether a person feels they need extractions, restorations or dentures) and self-rated oral health should also be assessed in future surveys of adult oral health. This should provide insight into why people are not visiting the dentist in the first instance. In addition to assessing the perceived need for treatment, Sheiham and colleagues (1982) suggested assessing factors that will predict whether a person will comply with treatment and with oral health instructions. Although dental diseases can be largely prevented by having preventive treatment, little is known about what factors influence the propensity of individuals to undertake preventive care or their response to health education (Sheiham et al., 1982).

6. Conclusions

The main aim of this research was to develop a method of generating valid information for health policy makers by applying statistical analyses and current technologies to oral health service and survey databases. The research highlights the importance of epidemiological surveys to assess dental health, reported utilisation, and need for dental services. It also highlights the value of administrative databases in quantifying real use of services and monitoring the ever-changing nature of dental treatments provided. The DTBS database was designed to serve the needs of a paymaster, and focuses on recording treatments and payments to dentists. Use of the database required extensive data cleaning and restructuring, however the resulting datasets enabled an invaluable analysis of otherwise unavailable trends in treatment provision. This research illustrates the feasibility of extracting important trends data from such sources, and the lessons learnt during this exercise could be applied to administrative databases in other countries. Such analysis could be the first step in international comparisons of the impact of systems design on the nature of treatment provided. This research should also help to guide the development of future databases and help determine what variables should be recorded for future research. The information presented in this thesis should prove useful for policy-makers in formatting their decisions on service delivery, and for researchers considering using administrative data to analyse patterns of health care utilisation. Although the data refer to specific schemes in Ireland or to Irish adults generally, similar schemes are in place worldwide for which the findings and recommendations of this research can be applied.

The initial literature reviews identified a dearth of research in Ireland on utilisation of services, factors associated with tooth retention, comparisons of treatment need with treatment provided, and trends in treatment provided, which was later extended and supported by systematic literature reviews. The results of the analyses present the first glimpse of the volume and types of treatments provided in an Irish social insurance scheme over time, the extent of the gap between epidemiologically estimated need and treatment provided, and the bi-directional relationship between tooth retention and utilisation of services in the Republic of Ireland.

Inequalities were found in tooth retention, with education, occupation, and disadvantage status (having a Medical Card) associated with number of natural teeth and sound teeth (Article I). The study highlighted the relationships between retention of teeth and water fluoridation, diet and SES, and the importance of good oral hygiene, regular dental visits, and visiting for check-ups instead of waiting until a need is perceived or there is pain. Visiting for a check-up increased the expected number of NT for those who were disadvantaged. Low SES may serve dentists/hygienists as a marker for increased risk of tooth loss. Individuals of lower SES may benefit from more frequent visiting and more intensive efforts at education on the importance of a well-maintained dentition.

Evidence of inequalities were also found in the self-reported use of dental care services (II), and in the gap between epidemiologically-estimated need and treatment provided (Article III). The association between SES (education, employment, and income) and self-reported utilisation of dental services persisted even after controlling for other factors, and number of teeth was significantly associated with self-reported use of dental care services in the past year. In an analysis of utilisation of a cohort of DTBS users (Article V), age and being female were positively associated with utilisation, and number of teeth was positively associated with visiting annually but negatively associated with number of treatments. Those who attended annually for an oral examination had fewer extractions than those who attended for an oral examination less often.

Significant differences were found between epidemiologically-estimated need for dental treatments and treatment provided, as measured from administrative databases for selected treatments for services targeted mainly at employed and less well-off adults (Article III). The gap between need and treatment provided seemed greater for the less well-off than for those in employment. Trends in treatments provided in the DTBS between 1997 and 2008 somewhat mirror improvements in dental health, evidenced by a decrease in restorations, extractions and dentures (Article IV).

The research indicates that a survey of dentists' practices in Ireland would be useful in extending knowledge of treatment provision. Research into dentists' beliefs and practices with respect to tooth extractions is needed to provide a comprehensive understanding of why teeth are extracted. Health promotion has become an important

means of improving general health behaviour among adults but has received less attention in dentistry. There is a need to make people more aware of the availability of the DTBS and DTSS and their entitlements, and to encourage them to obtain dental care. Perhaps provision of information in areas such as waiting rooms at doctors' surgeries or community centres may encourage adults to visit the dentist regularly, and inform them of their entitlements under the schemes.

Future surveys of dental care utilisation should include questions on perceived dental treatment need. It may provide a better indication of whether there is unmet demand, or whether people perceive that they do not need treatment, or if there are other factors affecting utilisation. Attitudes and beliefs towards visiting the dentist should be analysed. It would be interesting to assess the relationship between those who had a clinically-assessed need and those who perceived that there was no need for treatment. In future research, it would be useful to estimate the time to re-intervention of previously restored teeth for different types of restorations to determine which material performs better, and also investigate factors associated with restoration survival. It would also be interesting to investigate the effects of the reduced cover by the DTBS on dental health and utilisation of services.

Administrative databases provide real-life data, however, there is a deficiency of variables, such as SES, and many databases were not designed for research. The development of guidelines and standards should be prioritised to ensure that comparable and high quality data is collected by Government departments. A crucial issue is the current unavailability of universal identifiers to enable administrative records to be linked across schemes, which would greatly enrich the variable set for the Irish population. In addition, reasons for treatment provision, and/or how many surfaces were restored, were not recorded in the DTBS or DTSS databases; the introduction of these fields in a claim form would provide a more complete picture of treatment patterns and invaluable information about dental health. The use of software with mandatory fields for data entry at the dentist or agency level would reduce the time spent processing the data, and EHRs should be considered. Given limited research funding, administrative data can provide a useful cost-effective resource with which to study and assess the impact of policy changes. If Ireland is to increase its profile as a knowledge economy, more use of administrative data needs to

be facilitated, and researchers and database designers need to collaborate to increase the quality of the recorded data.

7. Summary of recommendations

Further analysis of administrative data would prove beneficial by enhancing evidence-based decision-making in dentistry and improving clinical effectiveness through assessment of outcomes of care. The cost of analysing administrative data is significantly less than for surveys of nationally representative samples. To improve the utility of administrative data, the range and quality of the information captured needs further development. The ability to use real data would facilitate international comparisons of the impact of services on oral health outcomes, and identification of the information captured should consider this.

Communication between government departments, responsible for administrative data, and epidemiologists in future administrative database and survey design should prove beneficial in identifying the most valuable information. The introduction of universal identifiers to enable matching across databases for different schemes, and with survey data, would enrich the information available for analysis, support better tracking of individuals, and would be very useful in identifying policy implications. The use of software with mandatory fields for data entry at the dentist or agency level would be beneficial in reducing recording or transcription errors and the time spent entering and processing the data. It would also enrich the amount of data available to dentists and researchers, and support effective and informed policy decisions.

In addition to bridging the information gap between periodic surveys, use of administrative data should help to reduce the long-term costs of dental treatment, as funding for treatments and dental education could be more focused, and issues can be addressed in a timely fashion. For example, recording the reason for a restoration would indicate whether restorations are largely provided for aesthetic purposes or due to caries.

It would be useful to estimate the time to re-intervention of previously restored teeth to determine which material is most effective, and also investigate factors associated with restoration survival. Recording the tooth surface that is provided with a restoration would be beneficial in determining the life of a restoration. It would also be worthwhile to investigate the effects of the reduced cover in the DTBS on dental health and utilisation of services. If the range of services in the DTBS cannot be restored to 2009 levels, subsidised provision of fissure sealants and topical fluoride

treatments to those with greatest disease risk may reduce the burden of dental disease on society (in terms of costs of restorations, extractions, dentures, and sick-days) in the future.

A survey of dentists' beliefs and practices would provide a comprehensive understanding of reasons for treatment provision. The high number of restorations in the DTBS may indicate that the service is too focused on restorative services rather than adopting a preventive approach. This could possibly be addressed through education of the public and changes in system design, with a sliding scale of remuneration for recurring disease and greater rewards for prevention. If patients perceive a need and visit their dentist regularly for a check-up, and if the dental care system is oriented to reward prevention of progression of early-stage disease, most advanced and costly treatments may be prevented.

Future surveys of dental care utilisation should include questions on attitudes and beliefs towards visiting the dentist, self-rated oral health and perceived dental treatment need. The socio-dental approach to needs assessment should be considered, especially in the case of restorations for aesthetic purposes, or partial dentures, where the patient may not perceive a need for treatment. It would be interesting to assess the relationship between those who have a clinically-assessed need and those who perceive that there was no need for treatment. There is a need to increase awareness of the availability of the DTBS and DTSS and people's entitlements, and to encourage them to obtain dental care. Individuals of lower SES may especially benefit from more frequent visiting and more education on the importance of preventive treatments and a well-maintained dentition.

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Appendix 1 Non-biological factors associated with tooth retention

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Adegboye et al.	2012	Data from a longitudinal study (beginning 1982/83) of 30-, 40-, 50-, and 60-year-old men and women living in Copenhagen County. Health examination and questionnaire. Analysis of 432 individuals.	Number of teeth lost (from 1987/88 to 1993/94).	Negative binomial regression analysis.	Dietary calcium intake from dairy protects against tooth loss.
Adegboye et al.	2010	Prospective Danish observational study from 1982/83 to 1993/94 of 1,602 adults (30-60 years) with information on number of teeth, and a subset of 511 with information on tooth loss from 1987/88 to 1993/94.	Number of teeth (26-32, 1-25, 0) and tooth loss of 10+%.	Multinomial logistic regression, logistic regression.	Calcium intake below recommendations was significantly associated with fewer teeth in males and females, and negatively associated with tooth loss among males (after adjusting for age, education, smoking, alcohol and sucrose consumption, subjective oral dryness, and time since last dental visit).
Ahlqwist et al.	1991	Questionnaire and medical study of 1,462 women (38-60 years) in Gothenburg, Sweden, examined using panoramic radiographs in 1968/69 and 1980/81.	Number of teeth present and edentulousness.	Correlation based on non-parametric permutation test.	Education level associated with number of remaining teeth in 38 and 50-year-olds in 1968/69 and 1980/81. For 50-year-olds, husband's profession was associated with number of remaining teeth in both studies, and with edentulousness in 1968/89; education level was associated with edentulousness in 1968/69, and number of children was associated with edentulousness in both studies.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Ahlqwist et al.	1989	Questionnaire and medical study of 1,462 women (38-60 years) in Gothenburg, Sweden, examined using panoramic radiographs in 1968/69 and 1980/81.	1-9, 10-19 and 20 teeth or more, edentulousness.	Chi-square tests of independence and t-test.	In all age groups, there were higher percentages of non-smokers (vs. smokers) who still had 20 teeth or more in the last study. Edentulousness was more common among smokers. Smokers lost more teeth between the studies.
Ahlqwist et al.	1999	Longitudinal study of women's health, beginning in 1968/69 with women aged 38, 46, 50, 54 and 60 participating in medical and dental examinations. They were re-examined in 1980/81, and new groups aged 38 and 50 years were invited to participate. A 24-year follow-up study was performed in 1992/93, and new groups of 38 year-olds and 80-year-olds were invited to participate (n = 850 in all 3 studies).	Percentage edentulous, number of remaining teeth, number of restored teeth.	t-test.	The percentage of edentulous women decreased. Among females aged 38, 50 and 62 years, number of remaining teeth increased significantly over time, number of restored teeth increased for 50 and 62-year-olds, but decreased between 1980/81 and 1992/93 for 38 year-olds.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Aida et al.	2011	Self-completed questionnaires to community-dwelling individuals (65+ years) in Ohsaki, Japan, (n = 21,736) in 2006.	Having 20+ teeth.	Logistic regression.	28.5% had 20+ teeth. Those living in an area with the highest neighbourhood educational level (vs. low), medium sports and hobby network (vs. low), or highest friendship network (vs. lowest), and those who brushed twice daily (vs. less often), spent longer than 3 minutes brushing their teeth, used dental floss, or attended for a check-up at least once a year had greater odds of having 20+ teeth.
Albandar et al.	2000	Data from the Baltimore Longitudinal Study of Aging. 21+ year-olds (n = 705).	Number of missing teeth.	Multiple regression analysis.	Age, race, being a current smoker and number of years smoking were significantly associated with tooth loss.
Al-Bayaty et al.	2008	2,506 persons 15-64 years were examined in Yemen. The status of every permanent tooth was assessed (excluding third molars).	Total mean tooth loss.	t-test.	Mean tooth loss was higher among smokers than non-smokers across all age groups, except 45-54 year-olds. The central incisors, lateral incisors and first molars were the most common missing teeth in smokers vs. non-smokers.
Al Shammery et al.	1998	Epidemiological study of 7,000 children and adults in Saudi Arabia.	Mean number of missing permanent teeth.	Compared means	Tooth loss increased with age and differed by gender and socio-economic status (housing conditions).

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Arora et al.	2010	Data from the 45 and Up Study, New South Wales, Australia (n = 103,042).	Edentulism.	Logistic regression.	Current and former smokers had higher odds of edentulism vs. non smokers. Among former smokers, the risk of edentulism declined with increasing time since smoking cessation.
Astrom et al.	2011 a	1992 questionnaire study of 6,346 50-year-olds, 4,143 completed postal follow-ups at ages 55, 60 and 65 (2007).	Tooth loss over 15 years (change from all teeth 1992 to tooth loss in 2007 versus persistent all teeth)	Logistic regression.	The prevalence of having lost at least some teeth increased from 76% at age 50 to 85.5% at age 65. Refraining from dental care because of financial limitations was a major risk factor for tooth loss. Other risk factors were being single, going from having no pain in 1992 to having pain in 2007 or vice-versa, and having pain both in 1992 and 2007 (vs. no pain in either year).
Atieh	2008	Study (clinical exam and self-administered questionnaire) in Eastern Province of Saudi Arabia 2006/07 of 14-19 year-olds (n = 484).	Loss of at least one tooth.	Logistic regression.	Prevalence of tooth loss was 40.9%. Sweet consumption more than 3 days per week, tobacco use, never brushing teeth, not visiting the dentist regularly, and having fair/poor self-rated oral health increased the odds of losing at least one tooth.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Barbato & Peres	2009	Brazilian Oral Health Survey 2002/03 of 15-19 year-olds (n = 16,833).	Loss of at least one tooth.	Poisson regression.	The prevalence of at least one tooth loss was 38.9%. Living in a rural location, being older, having a higher income increased the odds of tooth loss. Being female and not having a fluoridated water supply increased the odds of tooth loss in the South. Having at least one year gap of schooling compared to that expected for the age increased the odds of tooth loss in the SouthEast.
Beal & Dowell	1977	Survey of adults (15+ year-olds) in England and Wales 1968 (n = 2,932) and 1977 (n = 1,873)	Percentage of adults edentulous.	% edentulous by gender, age, and social class.	Edentulousness decreased between 1997 and 1968, the largest improvements are found in those in the higher social groups.
Bernabe & Marcenes	2011	2008 Behavioral and Risk Factor Surveillance System, a telephone survey of US non-institutionalised 18+ years (n = 386,629).	Factors associated with tooth loss due to caries or gum disease (missing 1-5 teeth, 6+ teeth but not all, and missing all teeth vs. missing no teeth).	Ordered logit models.	There was a relationship between income inequality (Gini coefficient) and tooth loss. Being female, having a higher education level (vs. less than high school), and income level (vs. < $15k) decreased the odds of tooth loss. Being previously married (vs. married) and having the last dental visit more than 1 year ago increased the odds of tooth loss.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Bernabe et al.	2010	Study of 5,401 dentate adults who participated in the Health 2000 Survey in Finland.	Number of teeth.	Linear regression analysis	A strong sense of coherence was related to having more teeth.
Bernabe et al.	2012	Study of 5,401 dentate adults who participated in the Health 2000 Survey in Finland.	Number of natural teeth including third molars and tooth remnants.	Structural equation modelling.	Childhood (parental education) and adulthood socioeconomic position (education and household income), and adult oral health-related behaviours were associated with tooth retention in adulthood.
Bole et al.	2010	Postmenopausal women (n = 1,341) were recruited in New York between 1997 and 2000 and completed dental examinations and interviews. Five years later, 1,021 women repeated the examinations and questionnaires.	Tooth loss.	Logistic regression.	28.7% of women lost at least one tooth. Diabetes history, gum disease history, smoking, previous tooth loss, high BMI, and other clinical factors were risk factors for tooth loss in the 5 year period.
Burt et al.	1990	Longitudinal study over 28 years (dental examinations in 1959 and 1987, and some telephone surveys in 1989) (n = 500).	Probability of becoming edentulous.	Logistic regression.	A higher education level decreased the odds of becoming edentulous.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Casanova-Rosado et al.	2005	14-30 year-olds attending the University of Campeche. Oral exam and questionnaire.	At least one tooth lost (vs. 0)	Logistic regression.	Females, those older than 19 years, having an unfavourable lifestyle, and having high levels of stress increased the likelihood of having lost at least one tooth.
Chatrchaiwiwatana	2007	Oral exam and interview in Thailand. 30-89 year-olds in 1990/91 (n = 1,484) and 31-86 year-olds in 1992/94 (3,471).	Number of teeth lost	Poisson regression.	In 1990/91, smoking, being older and being single were positively associated with number of lost teeth. In 1992/94, smoking and being older were positively associated with number of lost teeth
Chung et al.	2011	Data from the Korean National Oral Health Survey 2006.65+ year-olds (n = 1,193).	Number of missing teeth.	Multiple regression.	There was a positive association between age and number of missing teeth. Number of missing teeth was lower among those with more education, and higher among those residing in cities. Those who thought they were normal or unhealthy (vs. healthy) were more likely to have missing teeth. Those who had not had a dental check-up in the last 2 years were more likely to have missing teeth. Brushing teeth once or twice/day was negatively associated with number of missing teeth. Smoking was positively associated with number of missing teeth.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Copeland et al.	2004	Baltimore Longitudinal Study of Aging, ages 30-69 years (n = 94) and the VA Dental Longitudinal Study in Boston, consisting of 481 males in the same age range. Baseline and follow-up exams over a 10-year period.	Rate of tooth loss.	Generalised Linear Models Regression.	Being a smoker, age, having a greater % of teeth with restorations, and being male were positively associated with tooth loss. Drinking 2+ alcoholic drinks/day was negatively associated with tooth loss.
Cunha-Cruz et al.	2007	1972, 1991 & 2001 National Health and Nutrition Examination Surveys. Number of teeth assessed by dentists during an examination. Age 25-74 years.	Trends in socio-economic disparities in edentulism (28 missing teeth excl. 3rd molars).	Two-sample t-tests.	Disparities in edentulism did not change significantly. Utilisation of dental care and smoking avoidance reduced disparities.
Daly et al.	2003	Survey of a convenience sample in Cork Dental School and Hospital, Ireland, of 49 patients (25-74 years).	Number of teeth.	Pearson's correlation coefficient.	Poor diet and impaired food choice was associated with less teeth.
De Marchi et al.	2012	Cohort study (interviews and oral exams) of dentate 60+year-olds in 2004 in Brazil. Follow-up in 2008 (n = 273).	Number of teeth lost in a 4-year period.	Negative binomial regression analysis.	Being male, age 70 or older, living in a rural area, being married (vs. single, married, divorced), having 4 or more years of schooling, dissatisfied with access to health services, or being a current smoker were positively associated with tooth loss.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Dietrich et al.	2007	Longitudinal study of US male health professionals (Health Professionals' Follow-Up Study, every 2 years). Participants were 40-75 years at baseline (1986) (n = 43,112).	Incidence of tooth loss.	Cox proportional-hazards models.	There was a strong dose-dependent association between cigarette smoking and risk of tooth loss. Among former smokers, risk of tooth loss decreased with increasing time since cessation.
Dixon et al.	1999	Postal questionnaire to 15+ year-olds (n = 324) in the West Coast of the South Island of New Zealand	Edentulism	Logistic regression.	Being older increased the odds of being edentulous, as did having less than third level education.
Dogan and Gokalp	2012	Interview and clinical exam of 65-74 year-olds (n = 1,545) in Turkey in 2004/05.	Edentulism	Logistic regression.	Being in the 70-74 age group (vs. 65-69) and not having health security (health insurance through occupation) increased the odds of being edentulous.
Dolan et al.	2001	Florida Dental Care Study of adults 45+ years (n = 5,254). 873 completed a baseline interview and dental examination.	Edentulous.	Logistic regression.	19% of subjects were edentulous. Being older (vs. 45-54 years) increased the odds of being edentulous, as did having self-perceived general health less than excellent (vs. excellent), being poor (household income less than 150% of poverty level).

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Donaldson et al.	2008	1998 UK Adult Dental Health Survey (n = 2,329) (mean age = 43).	Investigate association between SES and number of sound teeth in adults.	Structural equation modelling. Covariance matrix, Maximum Likelihood estimation and Generalised least squares.	Association is partially explained by the pathway [SES (social class and weekly household income) - barriers-to-dental-attendance (perceived importance of visiting regularly, anxiety, cost, wanting simple instead of intricate treatment) - dental attendance profile (regular check up vs. occasional or only when in trouble) - number of sound teeth]. A direct relationship between SES and number of sound teeth was also found. The most important determinant of the number of sound teeth were aging, SES and attendance.
Drake et al.	1995	Sample of Black (n = 263) and White (n = 228) 65+ year-olds in North Carolina, U.S. Interviews and exams at baseline, 18 months and 3 years.	Loss of at least one tooth during a 3-year period	Logistic regression.	Among whites, having oral pain now, sensitive teeth, and being higher on the prestige scale were negatively associated with tooth loss. Having taken calcium, number of alcoholic drinks/week, higher income and number of negative life events were positively associated with tooth loss. Among blacks, high blood pressure, number of times needed help from others in the past year, and number of depression symptoms were negatively associated with tooth loss.
Eklund & Burt	1994	Longitudinal data: data collected in 1971-75 and 1982-84 in the National Health and Nutrition Examination Survey in the U.S. For this study, focus on 25-74 year-olds (n = 3,854).	Incidence of tooth loss.	Logistic regression.	Age, and having a lower level of income and education increased the odds of tooth loss, and number of remaining teeth and being non-white reduced the odds among 25-59 year-olds. Number of remaining teeth reduced the odds of tooth loss among 60-74 year-olds.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Fan et al.	2006	Longitudinal study of 581 male narcotics addicts admitted to California Civil Addict Program in 1962-64 tracked until 1996/97. 108 surviving participants completed oral exam and survey in 1998.	Number of remaining teeth.	Multivariate poisson regression.	Age, ethnicity, income, smoking status and dental visits during the 12 months prior to the survey were related to tooth retention.
Finlayson et al.	2009	California Behavioral Risk Factor Survey 1995, 1997, 1999, 2000, 2002, 2004 & 2006. Adults age 18+ years.	Number of missing teeth removed because of gum disease or tooth decay. No missing teeth, 1-5 missing teeth, 6+ teeth (but not all), edentulism.	Ordered probit regression models.	The likelihood of missing teeth due to disease increased with age. It decreased with increasing education level and increasing income level. Smoking is associated with loss of teeth due to disease.
Forslund et al.	2002	Cross-sectional study of 3 groups (normal weight (94), obese (32), and severely obese (83)) of middle-aged women in the South West of Sweden. Physical examination (for weight) and self-administered questionnaire.	Number of teeth	Linear regression analysis.	A lower number of teeth were associated with age, higher BMI, lower education, irregular dental care (less than once a year), high dental anxiety, higher energy intake and lower iron intake.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Fukuda et al.	1997	In 1992, 1,248 persons 50-80 years who received dental treatment at dental clinics in an urban area in Japan. Number of teeth recorded by dentists and questionnaire.	Number of teeth present.	Stepwise multiple regression analysis.	For those aged 50-64 years, having received prompt dental treatment when any discomfort was felt, using a toothbrush with nylon tufts, changing the toothbrush within 3 months were positively related to number of teeth present. Age and frequent dental visits in childhood and middle age were negatively related to number of teeth present. For those 65-80 years, changing the toothbrush within 3 months and receiving scaling were positively related to number of teeth present, while age and frequent dental visits in middle age were negatively related to number of teeth present.
Geyer and Micheelis	2012	Data for 35-44 year-olds from the 1989 (n = 500), 1997 (n = 655) and 2005 (n = 921) surveys in Germany.	Number of caries-free and unrestored healthy teeth.	Ordinary least-squares regression.	In 2005, having lower levels of education, or lower levels of income, had a negative effect on the number of caries-free and unrestored healthy teeth. In all years, every one-unit increase in age decreased the number of caries-free and unrestored healthy teeth, and there was a positive relationship between being female and number of healthy teeth.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Gilbert et al.	1999	The Florida Dental Care Study of dentate 45+ year-olds. In-person interview and clinical exam at baseline and 24 months after baseline, with 6-monthly telephone interviews in-between.	Tooth loss in 24 months.	Logistic regression.	24% lost one or more teeth. Having a perceived need for dental care, having self-reported toothache and/or abscessed tooth one or more times, aware of cavities one or more times, aware of having a loose or broken tooth one or more times, being frustrated about dental care at baseline, being 65+ (vs. 45-64), black (vs. white), female and having less than 25 teeth at baseline increased the odds of tooth loss.
Hanioka et al.	2007 b	Data from the 1999 National Nutrition Survey and Survey of Dental Diseases were linked. 3,999 records of subjects aged 40+ years were analysed.	Having less than 19 teeth	Logistic regression.	Being a current smoker increased the odds of having less than 19 teeth among males and females.
Hanioka et al.	2007 a	Data from the 1999 National Nutrition Survey and Survey of Dental Diseases were linked. 2,200 records of subjects aged 60+ years were analysed.	Total tooth loss.	Logistic regression.	Being 70+ (vs. 60-69) increased the odds of tooth loss, as did being a current smoker. Having less than 100mg of Vitamin C/day increased the odds of tooth loss among males. Currently drinking alcohol reduced the risk of tooth loss among females.
Haugejorden et al.	2003	Interviews in 1999/2000 among Norwegian adults aged 20-79 years (n = 2,520).	Odds of self-reported tooth loss during the last 12 months.	Logistic regression.	Those with 12+ years of education had lower odds of having lost teeth during the last 12 months than those with less education.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Heegaard et al.	2011	2004/05 study of 783 65-95 year-olds in Copenhagen, Denmark. Clinical exam and questionnaire.	Odds of having less than 20 teeth.	Logistic regression.	Being a moderate or heavy drinker reduced the odds of having less than 20 teeth among women (vs. abstainers). Analysis by type of alcohol showed that having more than 6 units of wine reduced the odds of having less than 20 teeth, but beer or spirits were not significant.
Heloe et al.	1988	Personal interviews in 1973, 1977, 1979, 1981, 1983, 1985 (n=1,500 each year) of the Norwegian population age 15+.	Percentage edentulous, with 1-19 teeth, or 20+ teeth.	Percentages overall and by age group.	The percentage with 20+ teeth increased steadily, and those with 1-19 teeth or edentulous decreased.
Hescot et al.	1997	1994 national study of 35-44 year-olds (n = 1,000) in the Rhone-Alpes area of France, using WHO assessment forms.	Mean number of teeth present, edentulous, more than 20 natural teeth, DMFT.	Mann Whitney U-test and Chi-square test.	None of the 35-44 year-olds were edentulous, 97% had > 20 natural teeth present, mean number of teeth was 27.1. Mean number of missing teeth was greater among those in low occupations, and these also had the greatest proportion of dentures. Males required significantly more fillings than females.
Hesser & Jiang	2008	Data from Rhone Island's 2004 Behavioral Risk Factor Surveillance System. 18+ year-olds (n = 3,999).	Teeth removed because of tooth decay or gum disease (1-5 teeth lost, 6+ but not all, edentulous).	Logistic regression.	Being in the 45-64 and 65+ age categories increased the odds of tooth loss, as did a lower level of education, or being a current smoker. Having no leisure time activity or having diabetes increased the odds of losing 6+ teeth or all teeth. Having a very low income level increased the odds of being edentulous.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Holm	1994	1979/80 epidemiological survey of adults living in the county of Gavleborg (Sweden), and another epidemiological survey 10 years later (n = 273).	Teeth lost in a 10-year period.	Logistic regression.	Age and smoking were positively associated with tooth loss.
Hugo et al.	2007	2002/03 study (dental examinations and interviews) of 65-74 year-olds (n = 5,349) in Brazil (SB Brasil survey).	Edentulous, 1-19 teeth, 20 or more teeth.	Chi-square tests, one-way analysis of variance or Krustal-Wallis tests, logistic regression. Oral Health Belief Model.	54.8% were edentulous, 35.6% had 1-19 teeth, and 9.6% had 20+ teeth. For age, gender, education, income, car ownership, individual perceived need, and dissemination of preventive information, there was a significant difference between subjects in the 3 dental status categories. Edentulous subjects perceived a need for care less frequently than others. Age, being female, not owning a car, visiting the dentist more than 2 years ago, classifying oral health as good, not perceiving a need for dental treatment, having an oral mucosa lesion, classifying chewing ability as not good, classifying speech ability as not good, and classifying appearance of teeth and mouth as good increased the odds of being edentulous. Being female, visiting the dentist more than 2 years ago, classifying oral health as good, having an oral mucosa, and classifying chewing ability as not good increased the odds of having 1-19 teeth (vs. 20+ teeth).

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Jack & Bloom	1988	1986 US National Health Survey (relevant here: adults aged 22+ years).	Edentulous.	Percentages.	The higher the education level, the lower the percent edentulous.
Jansson & Lavstedt	2002	Dentate individuals examined in 1970 and 1990.	Number of teeth lost and marginal bone loss over 20 years.	Stepwise multiple regression analysis.	Age was negatively associated with tooth loss. Being a former smoker was correlated with marginal bone loss.
Joshi et al.	1996	Interviews and oral exams of 70+ year-olds in the 6 New England states in 1988-1991 (n = 718 with 1+ natural teeth).	Number of teeth (1-10, 11-24, 25-32).	Chi-square test and analysis of variance.	A higher level of education and income was associated with having more teeth. Other factors associated with having more teeth were brushing and flossing frequently, receiving dental care less than one year ago, and reason for last dental visit being regular maintenance or conservative treatment.
Jung et al.	2011	Data from 65+ year-olds (n = 1,091) from the 2005 South Korean National Health and Nutrition Examination Survey.	Tooth loss.	Logistic regression.	Being over 75 years (vs. 65-69 years), residing in a rural area, being illiterate (vs. secondary school or higher), brushing teeth less than twice daily, and being a former or current smoker increased the odds of tooth loss.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Kim et al.	2007	National Health Insurance Corporation dataset of 822,325 dentate 18-74 year-old Korean government employees' dental exam results and questionnaire responses in 2000.	Missing teeth with unmet needs (vs. having no missing teeth with unmet needs).	Logistic regression.	Age and income were the strongest predictors of having missing teeth with unmet needs. People residing in rural areas, with lower income, low occupation, older adults and persons who smoked, and adults visiting a dental clinic in the past year were more likely to have at least one missing tooth with unmet needs. Females, people who brushed their teeth at least twice a day or who had a cleaning in the past year were less likely to have at least one missing tooth with unmet needs.
Koltermann et al.	2011	Rio Grande do Sul State, Brazil 2002/03. 35-44 year-olds (n = 10,407). Clinical exams and structured interviews.	Presence of at least 20 teeth	Logistic regression.	Factors increasing the odds of having at least 20 teeth included being in the 35-39 age group (vs. 40-44), being male, having a medium or high family income, having medium of high years of schooling, having visited the dentist in the previous 12 months, and having received information on prevention.
Kressin et al.	2003	Longitudinal study of 736 males recruited through the Boston Veterans Affairs Outpatient Clinic in 1961-70 (mean initial age 47.7). Since 1969, triennial clinical oral exams. They receive private-sector care.	Factors associated with tooth retention.	Cox proportional-hazards models.	Higher education (vs. high school or less) and recommended oral hygiene behaviours (consistently brushing, flossing and regular prophylaxis) reduced the risk of tooth loss. Smoking increased the risk of tooth loss.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Koyama et al.	2010	2006 Ohsaki cohort study. Self-administered questionnaires from 25,078 40-64 year-olds.	Tooth loss (<10 teeth, <20 teeth, <25 teeth)	Logistic regression.	Green tea consumption associated with decreased odds for tooth loss.
Lawton et al.	2008	Women's Lifestyle Study: face-to-face interview of 51-74 year-old women (n = 1,817).	Number of teeth present, edentulism	Poisson regression and logistic regression.	Age, BMI < 20.0, smoking, and having no education had a negative effect on number of teeth present and a positive effect on edentulism. Maori women had greater odds of being edentulous.
Li et al.	2011	Data from four surveys of non-institutionalised Danes aged 15+ years in 9 birth cohorts from 1975-2005 (n = 4,330).	Edentulous.	Logistic regression.	The odds of being edentulous increased with age, and were higher for those of lower SES. The odds were lower among those who received dental care in childhood in all grades, who received dental care regularly over the past 5 years, and among males.
Lopez & Baelum	2006	Survey (questionnaire and clinical examination) of Chilean high school students age 12-21 years(n = 9,163)	Tooth loss.	Logistic regression.	Being female, and having a father with a lower level of income, or lower education level, or mother with a lower education level increased the odds of having one or more missing teeth.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Lundgren et al.	2010	Data from the Danish MONICA (MONItoring trends and determinants of Cardiovascular disease). 30-60 year-olds (n = 2,217). Data collected in 1982/83, 1987/88 and 1993/94.	Number of missing teeth	Negative binomial regression analysis.	Being younger (vs. 60-69), not smoking, not being a nocturnal eater, and not having diabetes were negatively related to number of missing teeth. Having level 9-12 education (vs. level 18 or more) was positively associated with number of missing teeth.
Marcenes & Sheiham	1993	Clinical examination and personal interview in Brazil. 164 families, parents aged 35-44 years.	T-Health (weighted average of sound, filled and teeth with some decay), T-Health modified (different weights to T-Health; 4,1,1 instead of 4,2,1), and number of functioning teeth (filled + sound).	Linear regression analysis	FS-T, T-Health and T-Health modified indicators were more efficient than the DMFT indicator in revealing social and behavioural factor as significantly related to oral health status. For fathers, level of education had a positive effect on T-Health and FS-T, and sugar consumption had a negative effect on them. Dental attendance had a negative effect on FS-T. Among mothers, level of education and socio-economic status had a positive effect on T-Health and FS-T.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Marcus et al.	1996	Data from Phase 1 of the third National Health and Nutrition Examination Survey in 1988-91 in the US. Oral exam and questionnaire among 18+ year-olds (n = 8,366).	Mean number of teeth, percent dentate.	t-test; Logistic regression.	Gender was not associated with tooth retention. Race-ethnicity was associated with tooth retention.
Miller and Locker	1994	Mail survey in Ontario of 18+ year-old dentate adults (n = 500).	Loss of one or more teeth in the previous year.	Chi-square test; Logistic regression.	Those who only attended the dentist when in pain or trouble were more likely to have experienced tooth loss in the preceding year. In logistic regression, age was associated with tooth loss.
Mumghamba & Fabian	2005	Mtwara's rural population aged 40+ years (n = 206). Interviews and clinical exams.	Mean number of missing teeth	t-test.	Tooth loss was higher among those who brushed once vs. twice or more/day. Mean number of missing teeth was lower among those who brushed at least before breakfast vs. those who reported not to brush before breakfast.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Mundt et al.	2011	Health Survey (medical and oral exams, interview and self-administered questionnaire) in North-East Germany. Baseline data of adults 20-81 years collected between 1997 and 2001 (n = 4,310). Between 2000 and 2006, follow-up study (n = 3,300). 25-59 year-olds analysed (n = 1,071).	Tooth loss.	Negative binomial regression analysis.	Low education and low income were associated with tooth loss among males and females. Tooth loss was more likely among single men than single women.
Mundt et al.	2007	Study of Health in Pomerania, Northeast Germany, of 25-59 year-olds (n = 2,501).	Number of missing teeth (15% of individuals with the highest number of missing teeth, each losing at least 5 teeth vs. the remaining 85% of individuals)	Logistic regression.	Unemployment, current and former smoking, poor general health status and a last dental visit more than 6 months ago were significant risk indicators for missing teeth. Consuming alcohol, use of interdental cleaning products and checkups as the reason for the last dental visit reduced the risk of missing teeth. Women with low education and low income were a high-risk group for missing teeth. Being single was a risk indicator for men but was protective for women.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Musacchio et al.	2007	Survey of adults 65+ years in Northern Italy (n = 3,054). Home interview and examination at an outpatient clinic.	Edentulous, number of teeth.	Analysis of variance to compare means, Chi-square test to compare proportions. Logistic regression.	44% were edentulous, and the rate was higher in women (45.3%) than men (41.3%). Difficulty in chewing and swallowing was greater for those with less teeth, and those with less teeth tended to have less education and more of them had lower income. Edentulism was associated with age. For women, edentulism was associated with more than 23 years since menopause, having more than 3 children and living alone. For men, edentulism was associated with former and current smoking.
Nikias et al.	1977	Study of 1,290 members of a prepaid Health Insurance Plan in New York City in 1971-73.	Six or more missing teeth.	Percentages.	The percentage with 6+ missing teeth decreased with increasing education level
Ojima et al.	2007	1999 Japan National Nutrition Survey and Survey of Dental Disease linked by household identification code, 1,314 records of individuals aged 20-39 years.	Tooth loss.	Logistic regression.	Being a smoker increased the odds of tooth loss among males and females. Brushing less than twice a day and having a BMI of 25+ increased the odds of tooth loss among females.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Okoro et al.	2012	Non-institutionalised adults, 18+ years, in 16 states who participated in the 2008 Behavioral Risk Factor Surveillance System (n = 80,486). Data collected via interview.	Tooth loss: having had at least one tooth extracted due to gum disease or tooth decay, excluding injury or orthodontics.	Logistic regression; adjusted prevalence ratios.	Adults with current depression, lifetime diagnosed depression, and lifetime diagnosed anxiety, were more likely to have at least one tooth removed than those without depression, after adjusting for age, gender, race/ethnicity, education, marital status, employment status, adverse health behaviours, chronic conditions, BMI, assistive technology use, use of oral health services, and perceived social support.
Osterberg et al.	2006	Five cohorts of 70-year-olds examined in 1971/72, 1976/77, 1981/82, 1992/93, and 2000/01 (total n = 2290) in Goteborg, Sweden,	Factors associated with being dentate or having 20 or more teeth.	Logistic regression.	Higher education than elementary school was positively associated with proportion of dentate subjects and having 20 or more teeth. Smoking, higher waist circumference, being unmarried and physical inactivity were negatively associated with the dependent variables.
Osterberg et al.	1991	Interviews of 16-74 year-old adults in Sweden in 1975 (n = 11,582), 1977 (n = 11,699) and 1980/81 (n = 14,964).	Edentulous.	Logistic regression.	Among men and women age 45-64 and 65-74, age was positively associated with being edentulous, as was urbanisation. A higher occupation level was negatively associated with edentulism. Level of income was negatively associated with being edentulous, and marital status was positively associated with being edentulous for women aged 65-74. Smoking was positively associated with edentulism among men. Level of education was negatively associated with edentulism for all except men aged 65-74.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Pallegedara & Ekanayake	2005	Survey (interview and clinical examination) of free-living Sri Lankan adults age 60+ (n = 630).	Number of missing teeth	Chi-square test.	17% were edentulous. Age, gender, income level were associated with number of missing teeth.
Palmqvist et al.	1991	Questionnaire study (postal) of 3,000 individuals 45-69 years in Sweden.	Edentulous, number of teeth remaining (excluding third molars), prevalence of dentures.	Percentages overall and by gender and age group.	9% were edentulous, 18% had all their teeth remaining. The percentage of subjects having all teeth decreased with increasing age. Married men had better dental conditions than other men. Widowed women had poorest dental conditions compared with married and unmarried women. Subjects in lower income groups reported poorer dental conditions than those in higher income groups.
Paulander et al.	2004	Sample of 50-year-olds in Sweden examined at baseline and after 10 years (n = 309).	Edentulous, alveolar bone loss.	Logistic regression.	Tooth loss was more common in the molar than anterior tooth regions. Education level was associated with tooth loss.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Pearce et al.	2004	Self-completed questionnaires and clinical examination of 49-51 year-olds in the UK (n = 102 men and 138 women).	Number of retained teeth.	Multiple linear regression.	Adult socio-economic position and lifestyle (cigarette smoking, alcohol consumption, socio-economic status, total daily dietary sugar intake) accounted for most of the variation in the number of retained teeth (17.2% for men and 21.9% for women). Contribution of early life variables was 8.1% for men and 12.9% for women. Infant and childhood experience accounted for 3% or less of the variance, and birth weight and socio-economic and housing position at birth accounted for less than 2% of the total variance in the number of teeth.
Petersen et al.	2004	2000 survey of 22,486 Danish citizens 16+ years (personal interviews).	Factors associated with being edentulous or having 20 or more teeth, or having removable dentures.	Logistic regression.	The odds of having 20+ teeth was lower for persons with low incomes, with less than high school education, who visited the dentist not regularly or at all (vs. regular). Persons receiving regular dental care during childhood were twice as likely to have 20+ teeth as those who received no dental care. The odds of being edentulous were greater for those with 7 to 9 years of education, and who were not regular attendees, and was less for those who received dental care in childhood. The odds of having removable dentures was greater for those with lower income, 7 to 9 years education, who were not regular attendees, and was less for those who received dental care in childhood.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Pihlgren et al.	2011	Survey of 35-, 50-, and 65 year-olds in 1990 (n = 9,051) and 35-, 50-, 65 and 75-year-olds in 2002 (n = 11,324) living in Vasterbotten, Sweden.	Factors associated with being edentulous or number of teeth (dichotomised into < mean and >=mean).	Logistic regression.	In 1990, women had twice the risk of being edentulous, and those without university education had a 7-fold risk of having fewer teeth than the mean for their age. Education and number of teeth were also significantly associated in 2002. Low income was positively associated with being edentulous and those with low income also had a lower mean number of teeth. Smoking and visiting regularly for check-ups were also associated with edentulousness and number of teeth.
Richards & Ameen	2002	1998 survey of adults 18+ years (n = 643) in Swansea.	% edentulousness, 1-20 teeth, and 20+ teeth	Chi-square tests of independence.	No significant difference between regular (visit within a 2 year period), irregular and new patients and edentulousness, 1-20 teeth, and 20+ teeth.
Ringland et al.	2004	Data from the NSW Older People's (65+) Health Survey 1999 (n = 8,881).	Edentulism.	Logistic regression	Being female increased the odds of edentulism, as did being a health concession card holder (bivariate only), not being financially comfortable, not a home owner, living in a rural area, and being unable to travel alone. Factors that decreased the odds of edentulism were having private dental insurance and leaving school at 15 years or older.
Sakki et al.	1994	Examination and questionnaire among 55-year-olds (n = 533) in Finland 1990/91.	Mean number of retained teeth	Analyses of variance and Tuckey's studentised range method.	Number of teeth was associated with occupation status rather than lifestyle. Those with lower occupational status (workers) had fewer teeth than those with higher occupations (lower and upper white collar).

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Sanders & Spencer	2004	Participants, aged 18-91 years, from the 1999 National Telephone Interview Survey who completed a mail survey (n = 3,678).	Tooth loss.	Linear regression.	Being in the 45-64 and 65+ age categories were positively associated with tooth loss, as were having a low household income, secondary level or less (vs. third level) education, blue collar occupation (vs. upper white collar), and living in a high disadvantage area.
Sanders et al.	2007	Postal questionnaire among 43-57 year-olds in Adelaide, Australia in 2003 (n = 2,915).	Tooth loss: retention of fewer than 20 teeth.	Logistic regression.	Being deprived, having had the last dental visit 1+ years ago, usual reason for a visit being in pain or problem (vs. check-up), brushing teeth less than 7 times/week, being a current or former smoker increased the odds of retaining < 20 teeth.
Sheiham et al.	1985	Dental exam and questionnaire among a sample of 336 dentate men and 110 dentate women (16-64 years) randomly selected from employees of two industrial plants in England in 1980.	Number of missing teeth	Multiple regression analysis.	More frequent visits to a dentist are associated with fewer missing teeth. Manual workers have one more tooth missing than non-manual workers. Sugar consumption influences number of missing teeth for women less than 35 years. Age is positively associated with number of missing teeth.
Slade et al.	1997	Interviews and oral exams of 911 dentate 60+ years in 1991, and among 693 of them 2 years later.	Loss of 1+ teeth in 2 years.	Incidence rates and relative risks. Logistic regression.	19.5% had lost one or more teeth during the 2-year period. Males, people with an extraction less than 2 years ago, smokers and those who brushed once a day or less had a greater risk of tooth loss. Current and former smokers had almost twice the incidence of tooth loss as non-smokers.

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Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Steele et al.	2000	1998 Adult Dental Health Survey of adults over 16 years (n = 3,817).	Edentate, dentate, reasons for losing last remaining teeth.	Percentages.	The percentage dentate decreased with increasing age. Social class differences in total tooth loss was greater among men than women, especially among older men. The main reason that people lost their last remaining teeth was due to caries.
Suominen-Taipale et al.	1999	Annual mailed questionnaires from 1978 to 1997 to Finnish adults of working age (15-64 years) (n ranged from 5,000 to 6,027).	Edentulous.	Logistic regression.	Age increased the odds of being edentulous, as did a lower level of education, having a history of smoking, and fair or poor perceived status (vs. good). In 1978, being female increased the odds of being edentulous.
Suominen-Taipale et al.	2001	Postal questionnaire, health examination, and an interview among 65-74 year-olds in two areas of Finland (North Karelia and The Helsinki area) in 1997 (n = 1,500).	Number of extracted teeth (0-5, 6-10, 11-27, 28-32)	Cumulative logistic regression model.	41% had lost all their teeth. Risk indicators for extractions were higher age, occupation of guardian in childhood was white-collar (vs. blue-collar), history of smoking, and a longer time since last dental visit. Lower household income, being female, single (vs. married), lower household income were significant only in North Karelia.
Susin et al.	2005	Clinical exam and interview of a sample of 974 subjects (30-103 years) in Brazil.	Tooth loss (7-13 missing teeth or 14 or more missing teeth vs. 6 or fewer missing teeth).	Logistic regression.	Being female increased the odds of 7-13 or 14 or more missing teeth, as did middle or low socio-economic level (vs. high), and being a heavy smoker (vs. non-smoker).

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Susin et al.	2006	Clinical exam and interview of a sample of 14-29 year-olds (n = 612) in Brazil.	Tooth loss (at least one, or at least 4 vs. no tooth loss)	Logistic regression.	Being 25-29 years increased the odds of having missing teeth, as did being in a low socioeconomic level (vs. high) and being a heavy smoker (vs. non smoker). Being in the 20-24 age group increased the odds of missing at least one tooth (vs. 14-19 year-olds) as did being in the middle socioeconomic level (vs. high).
Taiwo & Omokhodion	2006	Study (interviews and oral examinations) of 690 65+ year-olds living in the South East Local Government Area in Ibadan, Nigeria.	Number of teeth lost and retained by tooth type, and age distribution of tooth loss.	Chi-square test.	48% had not lost any teeth. Mandibular teeth had a higher rate of retention than maxillary teeth. The percentage with tooth loss increased with age.
Telivuo et al.	1995	Postal questionnaire to 15-64 year-olds in North Karelia, Finland in 1990/91 (n = 1,200).	Missing teeth (< 5 missing teeth, 5+ missing teeth).	Logistic regression.	Missing teeth were associated with age, tooth brushing frequency, frequency of sugar in coffee/tea per day, but was not associated with daily smoking.
Thomson et al.	2000	Longitudinal study of a birth cohort of children born in New Zealand in 1972/73 (n = 821), dental examination and interview at ages 15, 18 and 26.	Risk factors associated with tooth loss due to caries (excluding 3rd molars) between the ages of 18 & 26.	Logistic (tooth loss incidence) and Poisson regression (number of teeth lost).	Being male, an episodic dental visitor (only visiting when they had a problem), and being in a low SES group (based on occupation, vs. medium SES) increased the odds of tooth loss. Those who were episodic visitors (vs. regular) or in a high (vs. medium) SES group lost more teeth.

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Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Thorstensson & Johansson	2010	Octogenarian Twin study 1995-1998 of 357 individuals aged 82+. Interviews and information on number of teeth taken from dental records.	Retaining 20 or more teeth.	Logistic regression.	Never smoking or being a former smoker, high education and being married were associated with having 20+ teeth (vs. edentulous). Never having been married was associated with having 20+ teeth (vs. 1-10 teeth).
Tsakos et al.	2011	English Longitudinal Survey of Aging of community-dwelling 50+ year-olds. Baseline interview 2002/03, interview and exam in 2004/05, interview 2006/07 (n = 6,634).	Edentulous.	Logistic regression	Factors associated with a higher odds of edentulousness were having no education or education less than a degree or equivalent, being in a lower occupation class (vs. managerial and professional), earning intermediate or poorest tertile (vs. wealthiest tertile in total weekly income), having a lower total net wealth, lower subjective social status (vs. highest).
Turunen et al.	1993	Questionnaire and clinical examination of 909 35-64 year-olds in Finland.	Edentulous.	Logistic regression.	Age and level of education were positively associated with edentulousness, and being female was negatively associated

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Unell et al.	1998	Postal questionnaire to 50-year-olds in Sweden (n = 6,343) in 1992.	Number of remaining teeth, edentulous, and all teeth remaining.	Multiple regression analysis (for number of remaining teeth) and logistic regression.	Being single, born outside Sweden, not working or shift work (vs. full-time), being a tobacco user, appearance and function being important, and fear of dental treatment had negative effects on the number of remaining teeth. Having secondary education (vs. primary only), having good general self-perceived health, being satisfied with dental care, and regular utilisation reduced the odds of being edentulous, and being born outside Sweden, and appearance and function being important increased the odds of being edentulous. Being a white-collar worker (vs. blue collar), having higher levels of education, having good self-perceived general health, being satisfied with dental care and having good oral hygiene decreased the odds of being edentulous and having almost no teeth left (vs. all others), and born outside Sweden, not working (vs. full-time) increased the odds.
Wu et al.	2012	Data on adults aged 50+ in five ethnic groups in the US, from the National Health Interview Surveys between 1999 and 2008.	Edentulous.	Logistic regression.	There was a downward trend in edentulism rates between 1999 and 2008. Age, smoking, having memory problems, diabetes, hypertension, coronary heart disease, a heart attack were positively related to being edentulous. Being female, married, and having a higher level of education decreased the odds of being edentulous.

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Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Wu et al.	2012	Qingdao University Chinese Aging Study of 50-74 year-olds in 2009 (n = 2,009).	Number of teeth lost	Zero-inflated poisson.	For every increase of 10 years, three were 1.06 times increase in the rate of tooth loss.
Yanagisawa et al.	2010	Oral exams and self-completed questionnaires of Japanese men 40-75 years (n = 1,088).	Mean number of teeth present, more than 8 missing teeth (retained fewer than 20 teeth).	Chi-square test, t-test, negative binomial regression, logistic regression.	Subjects with more than 8 missing teeth were older, had a lower frequency of tooth brushing, lower prevalence of using interdental tools, lower experience of tooth brushing instruction, and lower self-check of teeth and gums with a mirror. Smoking is positively associated with missing teeth. There was an increasing trend in the adjusted mean number of teeth present with an increase in the number of smoking cessation years. The odds of having more than 8 missing teeth in those who never smoked was similar to that of those who reported stopping smoking >11 years ago.
Yiengprugsawan et al.	2011	Self-administered questionnaire completed by 15-87 year-old adults enrolled in an Open University in Thailand (n = 87,134).	Less than 20 teeth.	Logistic regression.	Being female, older age, having low income, having lower education, being a lifetime urban resident, being a regular smoker (vs. never smoked), consuming soft drinks daily, no formal education by mother, and not breastfed as a child were associated with less than 20 teeth.

Appendix 1 continued

Author(s)	Date	Data source & population	Dental status indicators	Type of analysis	Findings
Zitzmann et al.	2008	1992/93 and 2002 Swiss Health Surveys of those aged 15 years and over (n = 14,326 [upper age limit 74] and 16,141 respectively)	Mean number of missing teeth.	Reported mean number of missing teeth.	Mean number of missing teeth decreased between 1992/93 and 2002. Mean number of missing teeth was greater among women, those with less education, lower income, ex-smokers, and those with a higher BMI.

Appendix 2 Factors associated with utilisation of dental services

Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Ahlberg et al.	1996	Male workers age 38-65 years from an oil refinery in southern Finland, eligible for subsidised treatment (n = 325), and control group from three other companies not eligible for subsidised treatment (n = 174).	Dental visit within the past two years.	Logistic regression.	A dental visit within the past two years was positively associated with access to an employer-provided dental scheme, tooth brushing, and number of teeth, and negatively associated with number of carious teeth.
Alvarez & Delgado	2002	Data from the 1993 Spanish Health Survey. 16-65 year-old working individuals (n = 6,258).	Number of visits to the dentist in the previous 3 months.	Poisson, Negative binomial model, Hurdle Negative binomial model.	Use of dental services was greater for those retaining more than half of their teeth than those who have all their teeth. Aging was negatively associated with use of dental services for females. There was a positive relationship between attendance and years of education among males.
Alvesalo & Uusi-Heikkila	1984	Interviews of patients visiting University of Connecticut dental clinics in Finland (n = 94) in May 1980.	Number of visits to University dental clinic in previous 12 months.	Spearman and Pearson correlations.	Number of visits is positively associated with general satisfaction with care, opinion about dental costs in general and number of remaining teeth. It is negatively associated with opinion about treatment time.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Anderson & Kim	2010	65+ year-olds in the US who participated in the Health and Retirement Studies in 2004 and 2006 (n = 9,617).	Dental care utilisation for any reason in the last two years.	Logistic regression. Andersen & Newman's model of health services utilisation.	Immigrants were more likely to use dental services than natives. Bring female, married, having more years of education, living in an urban environment, and having dental insurance increased the likelihood of visiting the dentist. Having poor self-reported health decreased the likelihood of visiting.
Armfield	2012	Nested within the 2008 National Dental Telephone Survey of 18+ year-olds (n = 1,511).	Avoid going to the dentist.	Anova.	Over two thirds (67.1%) said that they avoided going to the dentist or went less often than they felt they needed to. Females were more likely to avoid the dentist because they did not like dentists while the main reason for males avoiding the dentist was apathy or indifference. Avoidance due to not getting around to it was greater among younger age groups. Avoidance due to lack of time, inconvenience and not getting around to it was most common among those with the highest income. Avoidance due to cost was lowest for those with the highest income. Those with postgrad education were more likely than those with 10 years of education to state lack of time as a reason for avoidance. Those who avoided the dentist had greater anxiety than those who did not avoid visits.
Australian Research Centre for Population Oral Health.	2008	Data from the 2004/06 National Survey of Adult Oral Health. Dentate Australian population aged 15 years and over (n = 12,609).	At least 5 years since last dental visit.	Logistic regression.	Lack of dental insurance had the largest effect on likelihood of non-attendance. Presence of fewer than 16 teeth, being male, aged 25-34 (relative to 45-54), and having poor self-rated oral health, low level of education, being a smoker, reporting difficulty paying a $100 bill, and dental anxiety were associated with non-attendance in the last 5 years.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Australian Research Centre for Population Oral Health.	2010	Data from the 2008 National Dental Telephone Survey of 60+ year-olds (n = 2,486).	Dental attendance within the last 12 months; usually visit for check-up; 1+ extractions in the last 12 months.	Percentages and confidence intervals.	52.1% made a visit within the last 12 months. The percentage who visited was higher among dentate than edentulous adults, younger adults, females, capital city, those with more education, ineligible for public care, and those insured. 41.7% usually visit for a check-up. The percentage usually visiting for a check-up was higher among dentate than edentulous adults, insured, females, those in capital cities, more years of education, and ineligible for public dental care. 17.5% had 1+ extractions in the last 12 months. The percentage having 1+ extractions was greater among those outside capital cities, eligible for public care, and those uninsured.
Arcury et al.	2012	Survey of multiethnic sample of community-dwelling 60+ year-olds in rural communities in North Carolina (n = 635). Face-to-face interviews and in-home oral assessment.	Visit the dentist on a regular basis vs. only when a problem or never; visit the dentist in the past year.	Logistic regression. Behavioural Model of Health Services.	Approximately one quarter (27.1%) reported receiving regular dental care, and 36.7% visited the dentist in the past year. Having less than high school education (vs. greater than high school) was associated with lower odds of regular dental care. Having excellent or good self-rated oral health was associated with higher odds of regular visiting or recent dental care. Having a greater level of dental anxiety or no filled teeth were negatively associated with odds of regular visiting or recent dental care.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Bagewitz et al	2002	Questionnaire for adults in Southern Sweden, aged 50-75 years (n = 1,278) in 1998.	Visit the dentist less than once a year.	Logistic regression.	Twelve percent used dental care less than once a year. Men had a higher probability of using dental care less than once a year, as did those with fewer teeth or edentulous, many teeth missing, or where cost is a barrier to obtaining care even where there is a perceived need, or if they have refrained from dental care because of costs once or more. Those who felt it was too expensive had lower odds of visiting a dentist less than once a year, as did those with a "high" level of education.
Baldani & Antunes	2011	Survey of all persons in area covered by the Family Health Strategy, Parana State, Brazil, 2007/08 (n=747).	Used dental services in the previous year.	Logistic regression. Andersen & Newman's model of health services utilisation.	Younger people were more likely to have used dental services in the previous year (compared to those aged 60+), as were those who owned a home, those with higher income, and those who were referred to a regular dentist.
Beal & Dowell	1977	Survey of adults (15+ year-olds) in England and Wales 1968 (n = 2,932) and 1977 (n = 1,873).	Self-reported attendance frequency.	Percentages.	Adults attend more frequently in 1997 compared to 1968.
Bhatti et al.	2007	Adults aged 25 years and older interviewed (telephone) in the 2003 Statistics Canada Canadian Community Health Survey (n = 108,861).	Number of dental visits in the last 12 months.	Two-part model: probability of receiving dental care, and proportional change in number of visits among those receiving dental care.	The probability of receiving any dental care over the course of a year increased with dental insurance, household income, and level of education. Among those receiving at least some dental care, a person's general oral health largely determined visit frequency.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Bloom et al.	1992	1989 US National Health Interview Survey, persons aged 2 years and over (n = 109,603)	Number of dental visits in the past year.	Mean number of dental visits per person.	Dental visit rates increased with income and level of education. Persons with private dental insurance had higher dental visit rates.
Brodeur et al.	1987	Interview and dental exams of a sample of 1,478 65+ year-olds in Quebec, Canada.	Time since last dental visit.	Multiple regression. Andersen & Newman's model of health services utilisation.	Need factors (number of teeth, prosthetic condition and perception of needs) were the most important determinants of use, and, of these, perceived need was most important. Age, mobility and perception of need positively affect use. Dentist/population ratio, monthly income, dental insurance and number of teeth were negatively associated with use.
Brodeur et al.	1988	Interviews and exams of 405 dentate 65+ year-olds in Quebec in 1980/81.	Number of years since last use and natural log of that delay.	Multiple linear regression.	A variable combining perception of need for treatment and a diagnosis of a need for treatment was the major determinant in use of dental services.
Brothwell et al.	2008	Manitoba Study of Health and Aging, Canada, aged 65 and over living independently (n = 1,751)	Visited the dentist within the previous 6 months.	Logistic regression. Andersen & Newman's model of health services utilisation.	Higher education and greater use of health services had a positive effect on visitation rate.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Brown et al.	2009 b	California Health Interview Survey (telephone) 2001 and 2003. Adults aged 18 and older (n = 56,279 and n = 42,044 respectively).	Use of dental care in the last 12 months.	Probit model.	Those with private health insurance are more likely to have visited a dental professional in the last year than those without. Those with higher family incomes, women, those who are married, more educated (high school education vs. those with less than high school education), and higher health status are more likely to have visited.
Brown et al.	2009 a	Data from the California Health Interview Survey (telephone) 2003. Adults aged 65+ years (n = 8,668).	Visit to a dental professional at least once in the previous 12 months.	Logistic model.	Women with more functional limitations are less likely to access dental care than those with fewer limitations. Women in excellent, very good, good, or fair health (vs. poor health) are more likely to visit. Men in excellent or very good health (vs. poor health) are more likely to visit. Those with dental insurance, and higher levels of education or income are more likely to visit. Asians are more likely to visit than white elderly.
Celeste et al.	2011	Surveys of 15-19 and 35-44 year-olds in Brazil in 1986 and 2002, and of 20-25 and 35-44 year-olds in Sweden in 1968, 1974, 1981, 1991 and 2000.	% who visited a dentist in the last 12 months (adjusted prevalence differences and ratios).	Poisson regression.	A socioeconomic gap was found in both countries although decreasing disparities in utilisation of dental care were observed.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Choi	2011	Behavioral Risk Factor Surveillance System (2002 and 2004 telephone surveys of adults, 18 years and older, in the US).	Dental visit within past 12 months.	Linear probability model.	Medicaid dental benefits increase the probability of a dental visit within 12 months.
Christensen et al.	2007	Administrative data: A 10% sample of the total population of 18+ year-olds taken from a population register. Data retrieved from the Danish National Health Insurance register and Statistics Denmark. A cohort of persons aged 18-64 years were drawn from the sample in 1999 and observed until 2003 (n = 319,809).	Having visited a dentist one or more times, and having received one or more oral examinations during the past 5 years.	Logistic regression.	Being female, young, having a high level of education, being married, and having a high income had a positive effect on dental visits. High odds for oral exams was found among younger adults, women, married persons, and people with high income, and high education.
Conrad et al.	1987	Data from a sample of claims data insured through Pennsylvania Blue Shield (n = 4,173 families) and survey data. Adults age 18+.	Probability of any use.	Discriminant analysis.	Among primary subscribers, the probability of any use is lower among younger age groups (vs. those 65+ years), and the opposite is the case for spouses. Education has a positive effect on the probability of any use.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Dixon et al.	1999	Postal questionnaire to 15+ year-olds (n = 324) in the West Coast of the South Island of New Zealand.	Usually attend the dentist only when there is a problem, two or more years since the last dental visit.	Logistic regression.	The odds of attending only when there is a problem increased with age, was greater for those on benefit and for dentally anxious individuals. The odds of having two or more years since the last dental visit was greater among those who were dentally anxious.
Drilea et al.	2005	Data from the Medical Expenditure Panel Survey Household Component 2000. 18+ year-olds (n = 15,250).	Dental visit in 2000.	Logistic regression.	Being a current smoker and non-hispanic black or hispanic (vs. white) reduced the odds of a visit. Being dentate, having private dental insurance, having a higher level of education, being above the poverty level, being female and age 45+ (vs. 18-24) increased the odds of a visit.
Ekanayake & Mendis	2002	Employed adults in Sri-Lanka (n = 210)	Time since last dental visit was less than or equal to 24 months.	Logistic regression. Andersen & Newman's model of health services utilisation.	Being female and having had dental pain within the last 6 months were associated with visiting a dentist within the past 24 months.
Ekanayake et al.	2001 a	Survey of adolescents in Sri Lanka (n = 492 Year 11 students).	Dental utilisation (used vs. never used).	Logistic regression.	Being female, having a perceived need for care, and having received advice about oral health increased the odds of having attended.
Evashwick et al.	1984	Massachusetts Health Care Panel Study 1974 and 1976 (n = 1,317).	Use of dental services during the preceding 15 months.	Percentages. Andersen model of health services utilisation.	31.8% had used dental services during the preceding 15 months. Use decreased with increasing age, if widowed, or if had problems walking, and was greater among females than males, and those with more education, or income.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Evashwick et al.	1982	Household interview survey of 883 persons age 62+ residing in Seattle, Washington (n = 717).	Number of visits to dentist in past 12 months; most recent visit to dentist (0 = within one month or less to 4 = >1 year).	Ordinary Least Squares Regression. Andersen model of health services utilisation.	There was a positive relationship between number of visits and having a regular dentist and dentures. There was a negative relationship between delay in visiting the dentist and education, having a regular dentist and having dental problems.
Finlayson et al.	2010	2006/07 survey of Hispanic farm workers in California aged 18-55 years (n = 326).	Dental visit in the past year.	Logistic regression.	Those with more symptoms (such as untreated decay, gum bleeding on probing) were less likely to have visited in the past year. Those who would ask a dentist for advice and had a regular dental care source were more likely to have a past-year dental visit.
Garrido-Cumbrera et al.	2010	Data from the 2006 Spanish National Health Survey (n = 29,478).	Visit a dentist in the past 3 months.	Poisson regression.	After controlling for self-perceived oral health, those from lower social classes had a lower probability of visiting a dentist.
Geyer and Micheelis	2012	Data for 35-44 year-olds from the 1989 (n = 500), 1997 (n = 655) and 2005 (n = 921) surveys.	Visit dentist because of complaint (vs. prevention/early detection).	Logistic regression.	In 2005, having up to 9 years education (vs. 12/13 years) increased odds of visiting because of a complaint. In each survey, having the lowest level of income increased the odds of visiting because of a complaint. In 1989 and 2005, being female decreased the odds of visiting due to a complaint.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Gift & Newman	1993	Data on 65+ year-olds from 1989 National Health Interview Survey of 116,929 individuals in the US.	Visited a dentist in the past 12 months.	Percentages for those visiting in the last 12 months. No significance tests.	The presence of teeth was highly correlated with reporting a dental visit. Those with better self-perceived health, higher education, higher income and with insurance were more likely to visit a dentist.
Gilbert et al.	1998	Dentate persons aged 45+ years from the Florida dental care study. Telephone interviews every 6 months following an in-person baseline interview and clinical examination (n = 873).	6-monthly use of dental services during a 24-month period.	Generalized estimating equations for binary data assuming an unstructured correlation structure in a population-averaged model. Andersen & Newman's model of health services utilisation.	Females had higher probability of use; ability to pay was an important enabling factor; not perceiving a need was associated with a lower likelihood of seeking care, when the reason was that the subject was aware of a problem, but it could wait. Having broken fillings, abscesses, toothache, cavities, broken or loose teeth was associated with use; people dissatisfied with the appearance of their teeth were less likely to seek care.
Gomes et al.	2008	Data from a health and nutrition survey of Portuguese 18+ year-olds living in Porto, Portugal (n = 2,488).	At least one visit, one visit, or two visits, to the dentist in the previous year (vs. none).	Logistic regression.	The odds of visiting increased with years of education. Being 50+ years (vs. 18-29 years) decreased the odds of visiting at least once in the previous year, as did being a blue-collar worker or having no paid job (vs. white-collar).
Goodman et al.	2005	Data from the 1996 Medical Expenditure Panel Survey for the US community-based population (n = 21,571).	Visit and preventive visit (prophylaxes, fluoride treatments or sealants) in 1996.	Percentages.	Females, whites, those with higher levels of education, higher levels of income, with dental insurance, or residing in an urban area, were more likely to have a dental visit or preventive visit.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Groenewegen & Postma	1984	16-40 year-olds in the Netherlands (n = 2,109)	Visited the dentist at least once a year.	Percentages.	The supply of dentists, education level and income affected use of services
Grytten et al.	2012	Postal questionnaire among Norwegian 20 years and older living at home (n = 1861) in 2008.	Demand: visit the dentist in the last year. Utilisation: expenditure for dental treatment for those who visited the dentist in the last year.	Two-part model (Logistic regression and multiple regression analysis).	80% had visited the dentist during the last year. Small differences in demand by household income, and no differences in utilisation by income. Females visit the dentist more often than males, younger people visit less often than older adults and those who are dentate visit more often than edentulous adults. Older adults and edentulous adults have higher expenditure than younger adults or dentate adults.
Grytten	1991	Interview data of 20+ year-olds in 1975 (n = 7,506) and 1985 (n = 7,318), and sample of 559 25, 40 and 50-year-olds in 1987.	Those who demanded dental services during the last year.	Multiple Classification Analysis, which gives the % of individuals demanding dental services during the last year in subgroups of independent variables.	In 1975, there was an association between demand and presence of teeth, income, gender, travel time and model of transport. In 1985, all these variables except travel time were significant. In 1987, time spent in a waiting room was significantly associated with demand for dental services.
Grytten	1992	1989 personal interviews with 1,200 Norwegians 20 years and older.	Number of visits, conditional on having any visit in the past year.	Tobit analysis.	Number of dentists increased with increasing number of dentists and number of teeth. Travel time and time spent on a waiting list had a negative effect on the number of visits.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Hjern et al	2001	Swedish adults from the 1988/89 and 1996/97 Survey of Living Conditions (25-64 years; n = 7,649 and 7,610 respectively).	No dental care in the last 24 months; goes regularly.	Percentage for those who had dental care in the last 24 months, or who go regularly. For the 1996/97 data, Logistic regression for those with no dental care in the last 24 months.	Those with less education had higher odds of no dental care in the last 24 months; socio-economic differences in use of dental care most marked in those aged 45-64.
Holtzmann et al.	1990	Telephone interviews of 398 60-69 year-olds in Denver, Colorado.	Visit a dentist for any reason within the previous 12 months.	Discriminant analysis.	Those who visited the dentist in the past 12 months had retained some natural teeth, reported lower self-perceived needs, fewer total symptoms, did not use complete dentures, had slightly lower fear and anxiety scores, and had better self-rated oral health than those not using dental services in the previous 12 months.
Jaafar & Razak	1988	Dental records of 500 adults, age 19+ years, attending the Malaysian University Dental Centre were randomly selected.	Reasons for attendance.	Percentages.	More women visited for fillings, dentures and check-ups than men. More men visited for treatment of abscesses, bleeding gums and tooth mobility.
Jack & Bloom	1988	1986 US National Health Survey (relevant here: adults aged 22+ years).	Number of dental visits per person per year; dental visit in the past year.	Percentages.	Both the number of dental visits per person, and the proportion with a visit in the previous year increased with education level.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Jatrana & Crampton	2012	2004/05 data from New Zealand SoFIE-Health. 18,320 15+ year-olds.	Deferring visit to a dentist in the preceding 12 months because of cost.	Logistic regression.	For both men and women, younger age, being in the middle tertile of income, having education, having more individual deprivation characteristics, current smokers and reporting more than two comorbid diseases were all significantly associated with increased odds of deferring dental visits because of cost.
Kaprio et al.	2012	Data from the nationwide Health 2000 Survey in Finland. Dentate 30+ year-olds (n = 4,926).	Regular use of oral health care services (vs. never or only when in pain).	Logistic regression.	Having lower levels of education or poor subjective oral health reduced the odds of regular use. Being female increased the odds of regular use of oral health care services.
Kaylor et al.	2010	Female respondents, aged 18-44 years, of the 2003/04 Ohio Family Health Survey (n = 9,819).	Dental utilisation in the previous year.	Logistic regression. Andersen & Newman's model of health services utilisation.	Women with a perceived unmet dental need and who did not have a medical visit in the past year were less likely to have had a dental visit. Women in better health and with private insurance were more likely to have had a dental visit.
Kaylor et al.	2011	Female respondents, aged 18-44 years, of the 2003/04 National Health and Nutrition Examination Survey (n = 1,071).	Having a dental visit in the previous year.	Logistic regression. Andersen & Newman's model of health services utilisation.	For those with Medicaid Dental Insurance, unmarried respondents were more likely to have a dental visit as those who were married, and those with an evaluated need were less likely to report a dental visit. For those with no dental insurance, those without a high school diploma were less likely to have a dental visit vs. those with a high school diploma. Those with low income or perceived unmet dental need were less likely to report a visit, and those with an evaluated need were less likely to report a dental visit.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Kiyak	1987	Face-to-face interviews among people > 60 years in Seattle/King County area (n = 258).	Use of low-cost dental programs (vs. non-use) within the past 3 years.	Ordinary Least Squares Regression; logistic regression. Andersen model of health services utilisation adapted to dentistry.	Elderly with more natural teeth were more likely to have obtained dental care in the past 3 years. The more importance an individual attributed to oral health, or perceived more need for services, or expressed more pro-dental beliefs, or the more sources of information a respondent reported having access to, the more likely he/she was to seek dental care. Men were more likely to have used dental services. Those with more sources of income were less likely to have used dental services.
Koletsi-Kounari et al.	2011	2006 National Household Survey in Greece, 18+ year-olds (n = 1,005).	Visit a dentist in the past 12 months. Regular dental check-up.	Logistic regression.	Being in the 57-99 (vs. 18-36) age group or having a lower level of education decreased the odds of visiting the dentist in the past 12 months. Having a higher SES increased the odds. Being physically inactive or obese decreased the odds of having a regular dental check-up. Having a higher SES or higher Mediterranean diet score increased the odds of having a regular check-up.
Kosteniuk & D'Arcy	2006	Dentate adults, 18 years and older, from the 1999–2000 Saskatchewan (Canada) Population Health and Dynamics Survey (n = 5,003).	Dental service use within the last 2 years.	Logistic regression.	The odds of dental service use was higher among those who had higher levels of education and income, who had dental insurance and engaged in regular general check-ups.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Kronstrom et al.	2002	Questionnaires for adults aged 55-79 years in Sweden (n = 1,001), and 45-69 years in Denmark (n = 1,175).	Latest visit to a dentist less than one year ago; visit the dentist twice a year or more.	Logistic regression.	Being older, female, having good dental conditions and income level were associated with visiting less than one year ago, and twice a year or more vs. less frequently.
Kuthy et al.	1996	10 years of Medicare claims data from Cincinnati Health Department for users 62+ years who participated in the Municipal Health Services Program.	Categories of dental user types (no dental service use, but used medical or pharmacy services, two complete dentures, compliant, infrequent and unclassified).	Logistic regression.	Higher levels of medical use may "crowd-out" dental use, even when it is without cost.
Lawton et al.	2008	Women's Lifestyle Study: face-to-face interview of 51-74 year-old women (n = 1,817).	Last dental visit > 2 years ago.	Logistic regression.	Age was negatively associated with having the last dental visit > 2 years ago. Having no secondary school education and a BMI > 30.1increased the odds of not visiting in the past 2 years.
Lester et al.	1998	Interview of group of 263 housebound adults >60 years in London, England in 1994.	Time since last visit; barriers to dental attendance.	Chi-square test, multivariate analysis (type not specified).	Presence of natural teeth, residential status and age were all significant in explaining time since last dental visit. Lack of perceived need, cost and lack of suitable transport were barrier to attendance.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Li et al.	2011	Data from four surveys of non-institutionalised Danes aged 15+ years in 9 birth cohorts from 1975-2005 (n = 4,330).	Annual dental care over the preceding 5 years.	Logistic regression.	In 1975, 58.8% of the sample attended regularly, compared to 86.7% in 2005. The odds of visiting regularly were lower for males, those of lower SES, those who wore dentures (vs. none). It was higher for those who received school dental care during childhood in all grades.
Lissau et al.	1989	Self-administered questionnaire to 756 Danes 20-21 years-old in 1984/85. Information on social environment was obtained by questionnaire to their mothers in 1974.	Number of dental visits during the last 3 years.	Multivariate dummy regression model.	The social environment (family type and regularity of mother's dental visits), gender, education status, pain tolerance, perceived economic barriers, and an assessment of dentists as kind/not kind had a significant effect on number of visits.
Locker et al	1991	Data from the Ontario study of the oral health of older adults. Dental examinations and interviews with 907 50+ year-olds.	Not having had a dental visit in the previous year; visiting only when having pain or other trouble.	Logistic regression.	Those with an annual household income of <$20k, being edentulous and without insurance coverage had greater odds of not visiting in the previous year. Those with only elementary education, income of <$20k, and without dental insurance coverage had greater odds of visiting only when having pain or other trouble.
Locker et al	2011	Telephone interview survey in Canada, national sample of adults 18 years and over (n = 2,027).	Dental visit in previous year.	Logistic regression.	Those reporting financial barriers were less likely to have a dental visit in the previous year irrespective of their insurance status and household income.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Luzzi and Spencer	2008	Postal questionnaire to public dental patients (mean age: 54.9 years). Past attendance behaviour obtained from electronic patient clinical records (3.5 years) and actual attendance obtained from records one year after questionnaire (n = 517).	Visited dentist post - questionnaire vs. no visit.	Logistic regression. Theory of Planned Behaviour.	Intention to visit, self-efficacy, past behaviour and age were significant predictors of visiting the dentist post-questionnaire.
MacEntee et al.	1993	Interviews of adults aged >70 years in Vancouver, U.S. (n = 255).	Use of dental services during the preceding year.	Logistic regression.	Use of dental services was associated with female and young subjects, while men and older subjects usually went to the dentist to relieve pain. Number of natural teeth was important in predicting use of dental services. Subjects from higher socioeconomic groups were more likely to have been treated in the previous year.
Maharani	2009	2006 and 2007 Indonesian National Socio Economic Survey (n = 1,107,594 and 1,167,019 respectively).	Dental care utilisation within a 1-month recall interval.	Logistic regression.	The odds of utilisation were greater among those in the 30-44 age group (vs. < 15 years), females, those with a rural residence, and for those with better living standards.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Maharani & Rahardjo	2012	Indonesian Socioeconomic Surveys for 1999, 2001, 2003, 2005, 2007 and 2009.	Use of services in the last month.	Concentration index as a measure of inequality in use of dental care as related to SES.	There was a significant concentration of dental care utilisation among groups of higher SES, and use of dental care was more dependent on ability to pay than on need for care.
Manski et al.	2012	Data from the 2008 Health and Retirement Study. 51+ year-olds (n = 14,970).	Visit the dentist at least once in the previous 2 years.	Logistic regression.	Those aged 51-64 and 65-69 had lower odds of a dental visit than those aged 80+. Females had greater odds of a dental visit than males. Those with lower income levels and lower education levels had lower odds of visiting. Widowed or divorced people had lower odds of visiting than married people.
Manski & Goldfarb	1996	Data from the National Health Interview Survey of 5,327 non-institutionalised 55-75 year-olds not eligible for Medicaid.	Visited the dentist at least once, and number of visits in the previous year.	Two-part logistic regression model.	Adults with a higher level of family income, females, white, older, and who have teeth were more likely to visit. Those without insurance coverage, with a larger family, and lower levels of education were less likely to visit. Those more likely to have more dental visits were those with higher family income levels, females, white, those who visited a dentist for continuing care, those who visited to relieve a problem (vs. preventive care), and those who visited for an office-initiated check-up. Those with a larger family size and those who did not graduate from college were less likely to have more dental visits.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Manski	1995	Non-institutionalised 55-75 year-olds not eligible for Medicaid from the 1986 National Health Interview Survey (n= 5,333).	Dental visit during the previous year.	Logistic regression.	Those with less than college education were less likely to visit a dentist, as were those without insurance. Income, being white (vs. black), age, being female, and having teeth were positively associated with visiting.
Manski & Magder	1998	1989 National Health Interview Survey of 49,687 18-64 year-old dentate adults in the US.	Visited a dentist in the past year.	Logistic regression.	Older adults had greater odds of visiting in the past year, as did married people (vs. single), those with higher levels of income and education, with good or excellent self-rated health status, and those keeping house or students (vs. working). Males, those without dental insurance, or widowed/divorced/separated had lower odds of a visit.
Manski et al.	2010	2006 Health and Retirement Study. Adults aged 50 and over, and their spouses (n = 16,911).	Dental visit during the past two years.	Logistic regression.	The odds of having a dental visit were higher for females and those aged 65 and older, and lower for people with lower income and education levels, family sizes of 3 or more, without teeth and without dental coverage.
Manski et al.	2001	U.S. Population: 1977 National Medical Care Expenditure Survey (n = 38,815), 1987 National Medical Expenditure Survey (n = 34,459), 1996 Medical Expenditure Panel Survey (n = 21,571).	Visit the dentist at least once in a year; annual number of dental visits given use.	Logistic regression; OLS regression.	Females were more likely to see a dentist, and had more frequent visits than males. The likelihood of visiting a dentist increased with education level. In 1977, those in employment visited the dentist more frequently than those not in employment, whereas the gap had disappeared by 1996. Employed people visited the dentist less frequently during the 20 year period.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Marin et al.	2010	Survey of adults 18+ years in Buenos Aires (n = 1,122).	Visited the dentist in the last year.	Logistic regression.	Having income <€200, residing in the suburbs and having unsatisfied basic needs were associated with utilisation.
Marino et al.	2005	2000/01 Structured interview and clinical examination of Greek (n = 374) and Italian (n = 360) immigrants to Australia.	Used dental services in last 12 months.	Logistic regression.	Having oral health knowledge and fillings increased the odds of using dental services in the last 12 months. The odds of visiting increased with number of teeth.
Marshman et al.	2012	2008 postal survey of adults in the Yorkshire and Humber region of the UK (n = 10, 864).	How long since last dental visit? (< 1 year, 1-2 years, 2-5 years, > 5 years, never)	Structural Equation Modelling. Andersen's behavioural model.	More recent dental visits were associated with increased oral health impacts for those aged 16-44 years
Mattin & Smith	1991	Interview and oral examination of 195 Asians aged 55+ years.	Patterns of attendance and barriers to uptake of dental care.	Percentages.	14.9% claimed to visit the dentist regularly, and 71.3% had visited within the last 5 years. The main reason for non-attendance was that they felt no need to attend unless they were in pain or required new dentures.
McGrath et al.	1999	Interview survey of UK older people (aged 60 or older) (n = 1,116).	Visited the dentist within the past year for a non-dental emergency.	Logistic regression.	Being from a high social class background, having higher educational attainment, and having more than 20 teeth was associated with an increase in the likelihood of being a ‘regular’ attendee.

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Author(s)	Date	Data source and population	measure of utilisation	Type of analysis/theoretical framework	Findings
Meng et al.	2007	2004 telephone survey (n = 504) of adult Floridians, aged 18+.	Regular attendees vs. attend when there is a problem.	Logistic regression.	Those with a high fear of dentistry were less likely to be regular dental attendees; those with an annual personal income over $50k or able to comfortably pay an unexpected $500 bill were more likely to be regular dental attendees.
Millar & Locker	1999	1996/97 Canadian National Population Health Survey for adults aged 15 years or over (n = 70,884).	Dental visit in the past year.	Logistic regression.	Women, younger adults, those residing in an urban location, with higher levels of household income, greater than secondary education, and with dental insurance had higher odds of visiting the dentist within the past 12 year.
Mucci & Brooks	2001	1998 Massachusetts Behavioral Risk Factor Surveillance System telephone survey of adults aged 35 years and older (n = 2,119).	Visited the dentist in the previous year.	Logistic regression.	Long term smokers were less likely to visit the dentist than those who never smoked, and the odds of visiting decreased with every additional five years that they smoked. The odds of visiting were less for those who smoked 1 or more cigarettes a day vs. those who smoked less.
Muirhead et al.	2009	Telephone survey of working poor Canadians aged 18-64 years (n = 1,049).	Last visit to the dentist greater than or equal to one year ago.	Logistic regression. Gelberg–Andersen Behavioral Model for Vulnerable Populations.	Males were more likely to visit the dentist more than one year ago, as were 25-34 year-olds (vs. 18-24), and those making 'out-of-pocket' dental payment, having a history of welfare receipt, being without a functional dentition, and having a perceived need for treatment.
Mumcu et al.	2004	Interviews of adults in Turkey (n = 866).	Dental visit in the last year.	Logistic regression.	Being female increased the odds of utilisation, as did education level.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Neff et al.	2010	2002 U.S. National Health and Examination Survey of adults 18+ years (n = 1,490).	Preventive dental visit or emergency dental visit in the past 12 months.	Logistic regression. Aday-Andersen conceptual framework (behavioural model of health services use).	Factors increasing the odds of a preventive dental visit (vs. none) were being married, having more education, a regular dentist. Having caries decreased the odds, as did being older and consuming alcohol. Factors increasing the odds of an emergency dental visit were having tooth pain in the past month and having a regular dentist.
Nguyen & Hakkinen	2004	1996 Finnish Health Care Survey. All adults (n = 5,375) and adults aged 20-40 years (n = 2,076).	Total number of visits and probability of a visit in the study year.	Ordinary Least Squares Regression and concentration index.	Pro-rich inequalities in private care and pro-poor inequalities in public care. Income and recall are related to the pro-rich distribution of use.
Nguyen & Hakkinen	2006	1996 Finnish Health Care Survey. Adults aged 20-40 years (n = 2,010).	Visit a dentist in the study year; number of visits in the study year.	Logit model, zero-truncated negative binomial model (three-part model)	Age, being female, a student, being in pain and being recalled were positively associated with visiting a dentist. Visit time, dentist density, fear, insufficient public services and expensive private care were negatively associated with visiting. Age, recall and insufficient public services were positively associated with choice of private vs. public dentists. Being a student and sufficient public services were negatively associated with the choice. Income and dentist density increased the number of private visits.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Nguyen et al.	2005	1996 Finnish Health Care Survey. Adults aged 20-92 years (n = 4,512).	Visited the dentist, visited the dentist due to recall, and number of visits to dentists from the beginning of the study year until the interview day.	Recursive probit model (probability of a visit, and a dentist-recalled visit), TPM (single probit equation model for the probability of visiting a dentist and ZTNB model for number of visits).	Women who were recalled sought care more than those who were not recalled. Pain, being recalled, and a low number of missing teeth are the main factors predicting females' dental care-seeking. Among males, their care-seeking is positively affected by pain, dentist recall, and income. Visit time, higher education level and DP ratio were positively associated with number of dental visits among females. Among males, number of visits is positively associated with age. For both genders, total use is increased by pain, dentist's initiative and the low number of missing teeth. Fear decreases total use for females, and unemployment decreases total use for males.
Nihtila et al.	2010	Administrative data: adults who attended the PDS in Espoo, Finland, who had made 6 or more visits in 2004 (n = 3,173) and a group who had made 3 or fewer visits (n = 22,820); a random sample of 320 was selected from each group.	Heavy users (6 or more visits) and low users (3 or fewer visits).	Differences between heavy and low consumers of dental services were evaluated by the chi-square test and the t-test.	A higher proportion of low users were women, younger, and white-collar workers.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Nyyssonen et al.	1983	Telephone interview of Finnish adults over 17 years (max 64 years) who had used dental services within the last 5 years (n = 1,368).	Choice of public and private practice.	Logistic function.	Use of public services was greater in rural than urban areas. Directors and office employees used more private services than public ones. People who had used public services generally had lower income than those who used private services. Highly educated people used more private services than public services. The larger the family, the more people used public dental services.
Ohi et al.	2009	2000/03 study of elderly Japanese living (70 yrs and over) in Sendai City, Northern Japan (n = 1,170)	Used dental services within the previous year.	Logistic regression.	Having a greater number of remaining teeth and use of removable dentures (vs. no teeth) increased the odds of using dental services within the previous year.
Okoro et al.	2012	Non-institutionalised adults, 18+ years, in 16 states who participated in the 2008 Behavioral Risk Factor Surveillance System (n = 80,486). Data collected via interview.	Not having had a dental visit or cleaning in the past year.	Logistic regression; adjusted prevalence ratios.	Adults with current depression had higher prevalence of non-use than those without depression, after adjusting for age, gender, race/ethnicity, education, marital status, employment status, adverse health behaviours, chronic conditions, BMI, assistive technology use and perceived social support.
Okunseri et al.	2004	Study of 358 adults aged 18-64 years via interview in Benin City, Nigeria.	Visit to the dentist in the previous 12 months.	Logistic regression.	Being younger and female were associated with visiting a dentist in the previous 12 months. Being in employment reduced the odds of visiting the dentist.

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Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Okunseri et al.	2011	Claims data (Medicaid dental claims for non-traumatic dental conditions in emergency departments and physician's offices) 2001-2003 (n = 23,999).	Typical and frequent users.	Finite mixture model.	Males and 19-42 year-olds were most likely to be frequent users.
Osterberg et al.	1998	1988/89 interviews of a sample of the Swedish population aged 45-64 (n = 3,040) and 65 years and over (n = 1,778).	No visit to a dentist last year or within the last 5 years.	Logistic regression.	Males had greater odds of not visiting, as did those who were not married. Those with only elementary school education, blue collar workers, and with an income less than the median also had greater odds of no visit in the last 5 years.
Osterberg et al.	1995	For 1976 and 1984 information from the National Dental Health Insurance Register was coupled to another register from the National Social Insurance in Goteborg, Sweden for adults > 20 years born on the 20th of every month (n varied between 11,028 and 11,233).	Utilisation of dental care during the calendar year.	Stepwise logistic regression.	Among those aged 20-64, age, low income, not married, and early retirement pension were negatively associated with utilisation in both years. Among men 65+ years, housing allowance and not married were significant factors for utilisation in both years.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Pavi et al.	2010	2006 interviews of Greek citizens aged >18 years (n = 4,003).	Visited a dentist within the last year; number of dental visits within the last year (given at least one visit).	Logistic regression, and poisson regression.	The odds of visiting a dentist were higher for women than men, for those with a monthly family income of €1,000-1,499 and over €2,000 compared to those with an income of €0-499, for those with secondary or higher levels of education, and those with private insurance. Monthly income of €500-1,499 and higher number of dentists per 1,000 population correlate to lower number of dental visits, while visiting for treatment (instead of preventive) correlated to higher number of dental visits.
Pavi et al.	1995	Interviews of 16-65 year-olds living in affluent (n = 372) and deprived (n = 863) areas of Glasgow, Scotland.	Regular attendees: visited a dentist within the last two years and the reason for their last dental attendance was for scaling/polishing or for a check-up.	Multiple stepwise regression analysis.	Social environment (deprived or affluent) was the strongest predictor of dental attendance. Dental anxiety was negatively associated with attendance.
Petersen	1983 a	Interviews and dental exams of male employees (15-64 years) at a Danish shipyard (n = 841).	Regular dental visits (a dental visit at least once a year).	Chi-square tests.	The percentages of regular visitors was lower in the older age groups. Most clerical staff visited the dentist regularly, but regular visits were less frequent among workers.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Petersen	1983 b 1984	Interviews of 5,151 20-69 year-olds in Denmark in 1976.	Dental visits (3= regular, 2 = irregular, 1 = never).	Multivariate dummy regression model.	Those residing in an urban area, in the 20-44 age groups, having a high or medium income level, having high school or secondary school education had more regular dental visits. Male, those having lost teeth, working in a physical exhausting job, father's occupation unskilled/semi-skilled worker (vs. non-agricultural) had more irregular dental visits.
Pizarro et al.	2009	Catalan Health Interview Survey 1994 (n = 15,000) and 2001/02 (n = 8,400).	Dental care visit in previous year.	Logistic regression. Andersen & Newman's model of health services utilisation.	Males had lower odds of a visit, as did skilled non-manual, skilled and non-skilled manual workers (vs. managerial or freelance professionals) and those with public health insurance only. In '94, 18-64 year-olds had greater odds of a visit (vs. 17 or less); in 01/02, they had lower odds. 65+ year-olds had lower odds of a visit.
Rajala et al.	1978	Employees of a paper mill in Finland in 1975 (n = 300).	Regular use of dental services (annually, or once in 2 years).	Cochran's Q test.	The main reason for dental visits was subjective assessment of treatment need. People in the highest income group used more dental services than those with lower income.
Reisine	1987	Survey of 287 university employees in the US.	Log of number of dental visits over the past 2 years.	Ordinary Least Squares. Andersen & Newman's model of health services utilisation.	Those who were older tended to have more dental visits and women had more dental visits than men. Number of decayed teeth was negatively associated with use and number of decayed, missing and filled teeth (DMFT) was positively associated with use.
Rise & Holst	1982	1975 Norwegian Health Survey of 1,493 non-institutionalised 65+ year-olds.	Dental visit within the last year.	Difference of proportions.	The most important determinant of elderly people's use of dental services is whether they are dentate or edentulous, followed by education and age.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Roberts-Thomson et al.	2011	Adults aged 20-24 years (n = 1,261) resident in Adelaide, South Australia. Subjects interviewed via telephone in 1998/99 and again 2.5 years later.	No dental visit since baseline.	Logistic regression.	Having a perceived need for a dental visit, difficulty in paying a $100 bill, being male, or a smoker increased the odds of making no dental visit since baseline.
Roberts-Thomson et al.	2008	2004/06 Australian National Survey of Adult Oral Heath dentate respondents aged 15+ years who had made a dental visit in the previous two years (n = 10,099).	Dental visit for relief of pain within the past two years, and dental extraction in the past year.	Logistic regression.	Compared to those age 15-34 years, being 55-74 or 75+ years decreased the odds of visiting for relief of pain. Having income less than $60,000 (vs. $80,000+) increased the odds of visiting for relief of pain, as did having no education beyond schooling. Being aged 75+ years decreased the odds of visiting for an extraction. Being male, having no education beyond schooling, and lower income levels increased the odds of having an extraction.
Sabbah & Leake	2000	National Population Health Survey of Canadians aged 12 years and over (n = 17,626).	Visit to a dentist in the past year.	Logistic regression.	For those aged 12-19 years, having a household income greater than $20,000, and a population/dentist ratio of <2,000/dentist were associated with higher odds of visiting. For those 20-64, and 65+ years, having a high school education or greater, an income >$20,000, a dentist/population ratio of <2000/dentist, being a non-smoker, being in good-excellent health increased the odds of visiting. Being in employment also had a positive effect for those aged 20-64 years.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Sakalausliene et al.	2009	2005 questionnaire survey of 35-44 year-old university employees (n = 553) in Lithuania.	Preventive check-up once every one to two years or once every three to five years (vs. emergency visit).	Logistic regression.	Being female increased the odds of a preventive dental visit, as did having a high income, a short time interval since the most recent dental visit, and no teeth lost.
Sanchez-Garcia et al.	2007	Home interviews for individuals aged 60+ years (n = 682) in the southwest of Mexico City.	Made use of oral health services within the past 12 months.	Logistic regression.	Being female, having more than 6 years of schooling increased the odds of visiting the dentist. Having more than 3 illnesses and coronal DMFT of > 22 decreased the odds of visiting.
Scheutz & Heidmann	2001	Interviews of 20-34 year-old Danes (n = 464) in 1997.	Did not visit a dentist within the last 1.5 years.	Logistic regression. Andersen & Newman's model of health services utilisation.	Those aged 20-24 (vs. 30-35) had a higher odds of not visiting within the last 1.5 years, as did males, those having no or little exercise, smokers, those who find the cost important, those who are anxious, with bleeding gums greater than once a month, and perceived condition of teeth less good or poor.
Schwarz	1996 a	Surveys of Danes aged 15+ years in 1975 (n = 1,204), 1980 (n = 1,108), 1985 (n = 1,123) and 1990 (n = 1,003).	Dental behaviour during the past 5 years (regular: at least once a year vs. all others).	Logistic regression. Andersen & Newman's model of health services utilisation.	From 1989 to 1990, the significant predictors for regular dental care shifted from being predominantly predisposing (age, gender, occupation) and need variables to predominantly enabling (income) and need variables (perceived condition, perceived bleeding, number of teeth).

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Schwarz & Hansen	1976	Interviews of 1,600 15+ year-old Danes.	Dental visits within the last 5 years.	Chi-square tests.	58% reported at least yearly visits during the last 5 years. Females and those living in urban areas more frequently reported regular visits than males. A strong relationship was found between dental visit habits and number of teeth and age. Number of teeth was the strongest predictor of use.
Schwarz & Lo	1994	Interview and clinical exam of 35-44 year-olds (n = 398) and 65-74 year-olds (n = 559) in Hong Kong, China.	The 35-44 group were categorised into regular, irregular and non-users, and the 65-74 group were categorised according to their last dental visit (within 2 years, 2-5 years and 5 years or more).	Logistic regression. Andersen & Newman's model of health services utilisation.	For 35-44 year-olds, the probability of regular use increased for those who were prevention oriented, had access to a dental benefit programme, had not experienced pain, had a higher income, perceived their teeth as fair or poor, and perceived a need for treatment. For 65-74 year-olds, those who had not seen a dentist in the last 2 years were more likely to have had pain and to know less about dental caries, and to have a need for treatment.
Seirawan	2008	Behavioral Risk Factor Surveillance System (2003 telephone survey 18+ year-olds, in the US) (n = 264,684).	Dental visit within the last year.	Logistic regression.	Having a household income >= $35,000, having greater than a high school diploma, and being married were associated with having a dental visit within the last year.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Sheiham et al.	1985	Dental exam and questionnaire among a sample of 336 dentate men and 110 dentate women (16-64 years) randomly selected from employees of two industrial plants in England in 1980.	Visit for a check-up or when in trouble. Frequency of attendance.	t-tests.	More women visited for a check-up or on a 6-monthly basis than men. Non-manual workers visited the dentist more regularly than manual workers. People who took sugar in their tea/coffee visited less regularly than those who did not take sugar. For those aged 16-35 years, those attending only when in trouble had more decayed teeth, and more missing teeth, than regular attendees.
Sibbritt et al.	2010	Data from the Australian longitudinal study on women's health. 70-75 year-olds (n=9,387) surveyed in 1999, 2002 and 2005.	Consulted with a dentist in the previous year.	Multivariate Generalized Estimating Equation.	Those residing in an urban area, who never married (vs. married), non-smokers, with no diabetes, and with increased physical functioning were more likely to consult with a dentist. Those who were separated, divorced or widowed (vs. married), had difficulty managing income (vs. easy), less than University education, or did not require home maintenance services were less likely to visit.
Sintonen & Maljanen	1995	Self-administered questionnaire survey of employees who are members of a fund reimbursing health expenditure in Finland (n = 1,779) in 1981.	Number of visits and expenditure between January 1980 and April 1981.	Logit for regular use (at least once in two years), log-linear two-part model (logit + OLS) and two-part tobit (probit + tobit).	Price had a negative effect on probability of visiting and amount of care (AC). High valuation of oral health associated with high education lead to a higher propensity to seek care. Dental problems and risk of dental depreciation had an increasing effect on seeking care and AC. Recall has a positive effect on AC. Fear and income loss are greater barriers to a regular visiting pattern than to visiting.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Skaar & Hardie	2006	1997 Medicare Current Beneficiary Survey among those aged 65+ years.	Number of dental visits in 1997, and type of service received (preventive, restorative, oral surgery, other).	Chi-square test.	41% had a dental visit. Younger adults, those with high education or income, married, or white had more dental visits. Younger adults were more inclined to have preventive services. Females had more preventive services, and less restorative services or oral surgery. Those with higher income (>$50,000) or high school or college-level education were most likely to have preventive services, but least likely to have oral surgery.
Skaret et al.	2003	Norwegian 18-year-olds surveyed again at age 23 (n = 968).	Had not been to the dentist for the last 5 years or more.	Logistic regression.	Having multiple fears and incomplete treatment at age 18 were associated with non-utilisation of dental care at age 23.
Slack-Smith et al.	2007	2001 Australian National Health Survey of 18-24 years (n = 1,624).	Dental service attendance in the previous 12 months.	Logistic regression.	Having private health insurance, being female, and having low alcohol consumption were associated with greater odds of dental service attendance.
Sogaard et al.	1987	1979/80 survey of 1,511 Norwegians, aged 16-79 years.	Regular users: those visiting a dentist at least once a year.	Multiple Classification Analysis (for analysis of categorical independent variables).	17.4% of females and 21.7% of males reported visiting the dentist less than once a year (irregular). Age, family income and education were associated with regular use of dental services for both males and females.
Sohn and Ismail	2005	Self-administered questionnaire survey of dentate adults (18-69 years) in the Detroit tricountry area (n = 630) in 2000/01.	Visited a dentist in the past 12 months.	Logistic regression.	Being female, older, having higher levels of income, having dental insurance, and good-to-excellent self-perceived oral health increased the odds of attending. Having dental anxiety reduced the odds.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Spencer and Harford	2007	2004/06 Australian National Survey of Adult Oral Health. Dentate adults, aged 15+ (n = 12,861)	Visit dentist within the last 12 months; dental visit more than five years ago.	Percentages and confidence intervals for those visiting in the last 12 months and those who had their last dental visit more than five years ago.	A greater proportion of females, those living in the capital city, with more education, eligible for public dental care, and those with dental insurance visited within the last 12 months. A greater proportion of males, those residing outside the capital city, with 9 years or less of education, ineligible for public dental care, and without dental insurance had their last dental visit more than five years ago.
Stadelmann et al.	2012	Swiss Health Surveys of adults 15+ years, conducted in 1992/93, 1997, 2002 (n = 18,756) and 2007 (17,931).	Dental care utilisation within the last 12 months, and reason for dental visit.	Percentages.	Dental visits declined from 70% in 1992/93, 66% in 1997 to 63% in 2002, but increased in 2007 (66%). Fewer visits were observed among older adults, males, weak social strata, smokers, persons with >8 missing teeth, and among those with removable dentures. Those with fewer missing teeth were more inclined to visit for a check-up, or caries/filling/endodontic treatment, and less inclined to visit for an extraction. Non-smokers were more inclined to visit for a check-up and less inclined to visit for caries/filling/endodontic treatment than smokers.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Stahlnacke et al.	2005	In 1992, a mail questionnaire was sent to 50-year-olds in two counties in Sweden, in 1997 they were sent a new questionnaire (n = 5,363).	High users: visited a dentist less than 1 year ago and went to dental care 2+ times per year. Low users: latest visit more than 1 year ago and regular visits every 2nd year or more seldom. All others were characterised as 'normal'.	Logistic regression (high vs. low/normal and low vs. high/normal. Petersen's conflict model for dental care utilisation.	Poor perceived oral health increased the probability of having both low and high utilisation. Entrepreneurs have higher probability of being high users than blue-collar workers. Feelings of anxiety at most recent visit strongly affected the probability of low utilisation. Having low utilisation in 1992 affected the probability of low and high utilisation in 1997. Those who were unmarried had higher odds of being low users.
Stewart et al.	2002	1982/84 Hispanic Health and Nutrition Examination Survey in 5 South-western states of the U.S. Adults aged >17 years (n = 6,324).	Dental visit less than 2 years ago, or less than 5 years ago.	Logistic regression.	Higher levels of education (high school or greater) increased the odds of using dental care.
Sugihara et al.	2010	2008 questionnaire survey of Japanese adults aged 60-98 years (n = 211).	Regular dental check-ups.	Logistic regression.	Women had higher odds of visiting regularly for a check-up, as did those who cleaned their teeth/dentures 3 or more times a day.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Suominen-Taipale & Widstrom	1998	1991 Telephone survey of adults aged 25-79 years in Finland (n = 3,175)	Visited a dentist or denturist during the last 6 months.	Logistic regression.	Being female increased the odds of a dental visit, as did having a high income, more than 12 years of education, and having teeth, even with > 10 missing teeth (vs. edentulous).
Suominen-Taipale et al.	2000	Survey data 1978 (n = 5,942), 1988 (n = 5,000) and 1997 (n = 5,000) of Finnish adult population (15-64 years).	Dental visit during the past year.	Logistic regression.	Significant predictors for the utilisation of services were the number of missing teeth, age, gender, occupation and tooth brushing frequency.
Suominen-Taipale et al.	2001	Postal questionnaire, health examination, and an interview among 65-74 year-olds in two areas of Finland in 1997 (n = 1,500).	Visit a dentist during the past year.	Logistic regression.	44% had visited a dentist during the past year. Number of teeth and household income were predictors of dental attendance, as were having a recent toothache and visits to a physician during the previous year.
Syrjala et al.	1992	Young and middle-aged patients visiting two occupational health centres in Oulu (n = 390).	Factors preventing regular dental care (annual check-up).	2-sample t-test.	Those who had last visited a dentist more than 2 years ago had more barriers of daily brushing, unpleasant experiences and laziness.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Tennstedt et al.	1994	Home interviews and dental examinations for 70+ year-olds in New England (n = 2,057).	Recency of last visit (3+ years, 2-3 years, 1-2 years, <1 year); number of visits in previous 12 months (0, 1, 2, 3+).	Ordinal logistic regression.	Those with more filled teeth, fewer caries and who did not feel a need for dental care, with more positive attitudes towards dental care, those who practiced regular dental hygiene were more likely to have visited the dentist relatively recently. Dentate adults with more education and a usual source of dental care reported more dental visits in the last year, as did those who practiced regular dental hygiene and who were younger.
Tomar et al.	1998	1995 California Behavioural Risk Factor Surveillance System. Persons aged 25 years and older (n = 3,266).	Visited the dentist within the past year.	Logistic regression.	Being male decreased the odds of visiting, as did having high school education or less, being below the poverty line or 101%-200% of poverty line, having no dental insurance coverage, and having had teeth extracted for decay/disease. The odds of visiting increased with age (vs. 25-34 year-olds).

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Tuominen et al.	1988	Survey of Finnish adults 30+ years (n = 5,028 dentate and n = 2,162 edentulous).	Dentate: receiving a full dental examination, oral hygiene education, new removable dentures, extraction(s), fillings or periodontal treatment, crown(s) or bridge(s) during their latest series of dental visits. Edentulous: receiving a check-up, oral hygiene education, new removable denture(s), or extractions during their latest series of visits.	Logistic regression.	Among the dentate population, the odds of attending for a full dental examination was greater for females, those with higher education, and those who visited the dentist because they were recalled, whereas being 60+ years, having a low income, and wearing removable dentures reduced the odds. Being female increased the odds of having fillings or periodontal treatment, crown(s) or bridge(s), and reduced the odds of having an extraction. Having high education increased the odds of having oral hygiene (OH) education, fillings or periodontal treatment, crown(s) or bridges. Being 60+ years reduced the odds of having fillings or periodontal treatment. Having low income reduced the odds of having fillings, crowns, or bridges. Having high income increased the odds of having OH education, new removable dentures, fillings or periodontal treatment. Visiting for a recall increased the odds of OH instruction, extractions, and fillings or periodontal treatment. Among edentulous adults, being 30-44 years increased the odds of attending for a check-up or extraction(s). Visiting for a recall increased the odds of a check-up, OH education, new removable denture(s), and extraction(s).

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Tuominen & Paunio	1987	Data from the Mini-Finland Oral Health Survey. 65+ year-olds (n = 1,575).	Use of oral health services, and expenditure, in the preceding 12 months.	Two-Part Model (Logit and OLS).	Experiencing toothache or oral discomfort, recall/recommendation and income were positively associated with utilisation, and income was positively associated with the amount spent on dental care among dentate adults. Among edentulous adults, experiencing oral discomfort was positively associated with use.
Tuominen et al.	1985	Data from the Mini-Finland Oral Health Survey. Edentulous 30+ year-olds (n = 2,162).	Oral health expenditure during the preceding 12 months.	Logit models.	Use was negatively associated with lower income and education, and higher age. Professional initiative (recommendation to visit by a health professional: dentist, physician or health nurse) and decreasing availability of services were positively associated with use.
Ugur & Gaengler	2002	Questionnaire and oral examination of 532 Turkish people older than 12 years (n = 532) in Witten, Germany.	Regular users: people who visited every year to have their teeth examined vs. going to the dentist if tooth problem.	Logistic regression.	Older adults had greater odds of visiting, as did females, those with greater than primary education, and a poor perceived condition of oral health.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Unell et al.	1996	Postal questionnaire to 50-year-olds (n = 8,890) in Sweden in 1992.	High users: visited a dentist less than 1 year ago and went to dental care 2+ times per year, and more than SEK1000 expenses for dental care. Low users: latest dental visit more than 1 year ago and regular visits every second year or more seldom, and expenses less than SEK 300. All others were characterised as 'average'.	Chi-square tests.	There is a social gradient (SES measured by occupation) for men's utilisation of dental care, but not for women.
Varenne et al.	2006	Face-to-face interviews among adult city-dwellers aged 15+ living in Ouagadougou, Burkina Faso in Sub-Saharan Africa (n = 3,030).	Use of oral health care services by adults who had experienced oral health problems during the previous 12 months.	Logistic regression. Andersen & Newman's model of health services utilisation, and the conceptual framework of the WHO International Collaborative Study of Oral Health Outcomes.	Those aged 25-34 had greater odds of using services (vs. over 54 yrs), as did Christian/Animist (vs. Muslim), those with high or moderate household material living conditions, considered oral disease as important as other health problems, active participants in social networks, have a moped or vehicle as a means of transport (vs. on foot or bicycle), or if the oral problem caused limitation or stopped any of usual activities. The odds of visiting were lower for those who considered that going to the dentist is synonymous with pain.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Vikum et al.	2012	Data from the third Nord-Trøndelag Health Survey (2006/08). 17,136 males and 21,414 females age 20+.	Have you seen a dentist in the last 12 months?	Poisson regression with robust error variances.	Pro-rich income inequality among men and women, and was highest among those aged 60+ years. Pro-educated inequality was found among those aged 60+ years.
Watson & Brown	1995	Data from the 1986/86 U.S. National Survey of Oral Health. 18+ year-olds (n = 1,957).	Visited the dentist during the prior year.	Percentages.	64% of white adults had visited during the prior year, compared to 44% of Hispanics and blacks. 7% of Hispanic 16-64 year-olds and 24% of 65+ year-olds had never received dental care.
Widstrom et al.	1984	Postal questionnaire in 1981 among Finnish citizens, aged 20-59 years, who emigrated from Finland at 16+ years, residing in a Stockholm suburb (n = 1,002).	Visited a dentist in Sweden regularly (at least every second year); had not attended a dentist in Sweden.	t-tests, chi-square tests and multivariate analysis using the Automatic Interaction Detector (AID).	More women than men visited a dentist regularly. The youngest and oldest men visited a dentist least regularly. The number of regular attendees was higher in higher social classes. Duration of residence and having a perceived need for treatment were associated with attending a dentist in Sweden. Persons of lower social class were less likely to visit a dentist in Sweden, as were men.
Wilson & Branch	1986	Data from the Massachusetts Health Care Panel Study. 75+ year-olds (n = 496).	Dental visit within a two year period.	Logistic regression.	Dentate status, history of alcohol consumption and perceived need for dental care were associated with use of dental services. Dentate status is a better predictor of use of dental care than perceived need for care.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Wu et al.	2005	2000 survey of Chinese (n = 177) and 1997 survey of Russian (n = 300) immigrants to the US, aged 60+ years.	Dentist visit in the previous 12 months.	Logistic regression.	Among the Chinese, having a higher level of education, having spent a longer time in the U.S., and seeing friends regularly increased the odds of visiting; being a smoker reduced the odds. Among Russians, using dentures decreased the odds of visiting, as did an income level of $10,000 or above (vs. below) and being older.
Wu et al.	2007	1999-2002 U.S. National Health and Nutrition Examination Survey. Dentate individuals 60 years and older (n = 1,984).	Time since last dental visit and regular visits for a check-up.	Logit models.	Poorer oral health was associated with more time since last dental visit. Individuals who reported having tooth pain, and a greater hypo salivation score were likely to have had a more recent dental visit. Greater age, higher levels of education and income, healthy diet, and moderate factors; diabetes and heart disease were negative factors. Higher numbers of decayed and missing teeth were negatively associated with frequency of visiting. Being female, a higher level of education and income, dental insurance coverage, and healthy lifestyle were positively associated with frequency of visits. Having diabetes was negatively related to regular visits.

Appendix 2 continued

Author(s)	Date	Data source and population	Measure of utilisation	Type of analysis/theoretical framework	Findings
Yu et al.	2001	U.S. adolescents (11-21 years) from the National Longitudinal Study of Adolescent health (n = 5,644) 1994/95 (parents questionnaire) -1996 (adolescent questionnaire).	No dental examination in the last year; never had a dental examination.	Logistic regression. Andersen & Newman's model of health services utilisation.	Being male, older, having no medical insurance, less than high school education, household income less than $60,000, parent doesn't work outside the home increased the odds of not having a dental exam in the last year. Having an excellent/very good perception of health decreased the odds. Having a household income less than $60,000, or parent not working outside the home increased the odds of never having a dental exam.
Zavras et al.	2004	2001 WHO Survey on Health and Responsiveness in Greece of 17+ year-olds (n = 1,819).	Utilisation during the last month.	Logistic regression (any utilisation) and poisson regression (number of visits).	Income influences utilisation and number of visits. Income has a positive effect on number of dental visits, and age has a negative effect on number of visits.

Appendix 3 Changes in treatment provided over time

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Ahlberg et al.	1997	Clinical treatment records	1989-1993	Attendees at a company dental clinic (n = 268).	Percentage treatment mix.	Restorations compose approximately one third of treatments each year. Diagnostic treatments (examinations and X-Rays) increased.
Beazoglou et al.	1993	US aggregate time series data	1950-1989	US population	Expenditure, factors associated with changes in utilisation.	Economic and dietary factors are significantly related to changes in utilisation
Bentley	1991	Reports (Health Care Financing Administration)	1980-1989	Americans	Overall national dental expenditures.	National spending for dental services and per capita spending increased significantly, but decreased as a percent of personal health care spending.
Brennan & Spencer	2003	Survey data (mailed questionnaires to dentists. Dentist recorded the types of services provided over one or two self-selected days)	1983/84, 1988/89, 1993/94, 1998/99	Dentists in private general practice.	Number of restorations per dentist.	Number of restorations decreased, mostly due to a decrease in amalgams.
Brennan & Spencer	2006	Survey data (mailed questionnaires to dentists. Dentist recorded the types of services provided over one or two self-selected days)	1983, 1988, 1993, 1998, 2003	Dentists in private general practice	Mean services per visit, annual services per dentist, and annual services per patient (restorative, diagnostic, preventive, endodontic, crown & bridge, prosthodontic, extraction, misc, perio, orthodontic).	Annual number of restorative, prosthodontic and extraction services per dentist decreased over time. Diagnostic, preventive, endodontic and crown and bridge services increased. Findings consistent with improved oral health and retention of teeth.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Christensen et al.	2007	Administrative data from 'Statistics Denmark' and the NHI (Danish National Health Insurance).	Annual data 1994-2003	Danish adults aged 18+	Number and % of oral exams, % who visited a dentist, factors associated with having one or more dental visit or oral exam in the last 5 years.	Fewer dental visits and oral exams in the older age groups.
del Aguila et al.	2002	Administrative data from a dental insurance data warehouse (Washington delta dental).	1993, 1999	All ages.	Number of patients and dentists, number of treatments, and percentage of procedures (examinations, diagnosis, prevention, treatment related to caries and periodontal disease, prosthodontics, orthodontics, oral surgery, emergencies, and other care).	Dentists saw more patients and performed fewer treatments per patient. Provision of composites, crowns and orthodontics increased while amalgams and extractions decreased.
del Aguila & Felber	2004	Administrative data from a dental insurance data warehouse.	Annual data 1993-2001	Adults in a Washington Dental Service.	Trends of scaling and root planing, periodontal maintenance procedures and osseous surgery per 1000 patients receiving any care.	Use of scaling and root planing increased for general practitioner dentists, with a marked increase in periodontal maintenance for general practitioners and a dramatic decrease in osseous surgery by specialists.
Eklund et al.	1997	Claims data from Delta Dental Plan of Michigan.	1980, 1985, 1990, 1995	People in Michigan in a prepaid insurance program.	Mean number of oral exams, prophylaxes, restorations, extractions, endodontics, dentures & periodontal services by age group over time	Changes consistent with improvements in oral health. Periodontal services, prophylaxis and oral exams increased, dentures, restorations and extractions decreased.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Eklund	2010	Insurance claims data.	1992, 1997, 2002, 2007	Adults and children covered by Delta Dental who were treated by dentists in Michigan, US, except those eligible for Medicaid < 21 years.	Mean number of restorations, amalgams, resin-based composite restorations, crowns, extractions, endodontic procedures, pontics, and removable partial dentures per user of dental care	Need for restorative and prosthodontic procedures in the US declined, consistent with a decline in caries.
Eklund et al.	1998	Claims data from Delta Dental Plan of Michigan.	1980, 1985, 1990, 1995	People in Michigan in a prepaid insurance program.	Changes in per-patient income from different treatment groups.	There was an increase in per-patient income in Class I services (examinations, prophylaxis, topical fluoride, preventive services), and a decrease in Class II (radiographs, simple restorations, crowns, endodontics, extractions, periodontal services and other minor restorations) and Class III (prosthodontics).
Elderton & Eddie	1983 a	Annual reports.	Selected years (5) 1965-1981	Adults using the General Dental Service (GDS) in Scotland, England & Wales.	Cost of fillings, endodontics, crowns & bridges as a % of total expenditure; number of treatments (fillings, endodontics, crowns, bridges).	Cost of fillings decreased, cost of other treatments increased. Number of all treatments increased.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Elderton & Eddie	1983 b	Annual reports.	Selected years (5) 1965-1981	Adults using the General Dental Service (GDS) in Scotland, England & Wales.	Cost of restorations, prosthetics, diagnosis, periodontal, extractions, orthodontics, general anaesthetics, examinations, and scaling, periodontal treatment as a % of total expenditure; number of examinations, extractions, scalings and periodontal treatments and number per exam.	Cost of restorations, diagnosis, periodontal, exams, orthodontics and scaling increased. Cost of all other treatment decreased. Number of exams and scalings increased, and number of extractions decreased.
Emphasis JADA	1988	Claims data from Delta Dental Plan of California.	1977 and 1986	Californians in a prepaid insurance program.	Percent change in dental care services delivered between 1977 and 1986	Decreases in extractions, restorations and removable prosthodontics.
Heloe	1978	Survey data (interviews).	1973, 1975, 1977	Norwegian population aged 15+.	Percent of prophylaxis, fillings, other and "blood and vulcanite" received.	Fillings was the predominant course of treatment over the 3 years (55%). Extractions and denture services were decreasing and preventive services were increasing.
Heloe et al.	1988	Survey data (interviews).	1973, 1977, 1979, 1981, 1983, 1985	Norwegian population aged 15+.	Percent of extractions, fillings, denture services, removal of "tartar" plaque, and other services including preventive received at last visit to dentist.	Extractions, denture services and fillings decreased, while preventive and other services increased.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Lacey*	2006	Scottish Dental Practice Board.	1982-1998	Scottish adults aged 18 years and over.	Total number of examinations, mean number of examinations per dentist, number of dentists, fees for dental examinations.	Mean number of examinations per month per dentist decreased from 96 in 1982 to 87 in 1998, while cost of an examination increased. Total number of examinations and dentists also increased.
Leake et al.	2005	Administrative data - from Health Canada.	Annual data 1994-2001	Canadian First Nations and Inuit people in Canada	Mean number of adjunctive, surgical, periodontal, restorative, preventive and diagnostic services; cost per time/service for orthodontic, surgical, fixed prosthetic, removable prosthetic, endodontic and restorative services; indices of factors contributing to the change in total expenditure, percentage of clients receiving services.	A continuing trend towards a less expensive mix of services. Number of clients increased and number of services per client decreased. Mean number of diagnostic, preventive and restorative services decreased in 1996. Periodontal services decreased steadily.
Lee et al.	2012	Data from the National Hospital Ambulatory Medical Care Survey (visits to emergency departments).	Annual data 2001-2008	All ages.	Number of ED toothache visits/year.	ED dental visit rates increased.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Lewis & Thompson*	1992	Administrative data Alberta's Extended Health Benefits dental plan.	1974-1991	Adults aged 64+ years (& their dependents) from Alberta, Canada.	Numbers eligible, number of users, % eligible who used program, number of services per user, expenditure.	Numbers eligible and the utilisation rate increased.
Murray & Nunn	1993	Annual reports.	Annual data 1980-1990	Children using the Community Dental Service, and handicapped adults in England & Wales.	Multiple outcomes; number of teeth filled & extracted, & number of Gas.	Number of fillings, extractions, and GAs increased for handicapped adults.
Osterberg et al.	1995	Administrative data (National Dental Health Insurance Register).	Annual data 1974-1984.	Samples from Goteborg, Sweden >20 years born on the 20th of every month (n ranges between 11,028 and 11,233 each year).	Dental utilisation rate. Regular attendees were defined as those receiving dental care at least once each calendar year during a minimum of 7 years (7-9 years). Exponential linear regression analyses.	Utilisation rate increased among men and women, and higher age groups showed the most marked increase, which can be partly explained by the decrease in edentulous individuals.
Schwarz	1996 b	Administrative data (National Health Insurance dental services register).	1975, 1980, 1985, 1990	Adult Danish population.	Multiple outcomes; % of dental services endo+surgery, extractions, fillings, periodontal, preventive, scaling, X-ray, examination. Number of services in 1975 & 1990.	Fillings and extractions decreased and endodontic treatment increased.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Sjostrom et al.	1998	Sample of insurance claims data.	Annual data 1990-1992	1/60 of the population (20-80+ years) living in the County of Goteborg and Bohus Ian on 31December 1992 (n = 9283)	Pattern of attendance, complete and/or acute treatment, % of patients treated by a hygienist.	Women visited the dentist more regularly than men, the number having had only an emergency exam was highest among those who had visited a dentist in only one of the 3 years.
Smith	1983	Dental estimates board personal communication.	Annual data 1969-1981	Adults using the General Dental Service (GDS) in England & Wales	Number of crowns and bridges	Total crowns and bridges increased.
Spencer et al.	1994 b	Survey data.	1983 and 1988	Australian dentists.	Estimates of annual service provision.	Significant differences were found in the increased work effort in advanced restorative and endodontic services, and the decrease in prosthodontic service.
Spencer et al.	1994 a	Survey data.	1983 and 1988	Australian dentists.	Estimates of numbers and types of restorative services.	Number of fissure sealants, crowns and one-surface glass ionomers increased, and numbers of one- and two-surface amalgams, and one-surface resin composites decreased.
Suominen-Taipale et al.	2000	Administrative data - reimbursements from the Social Insurance Institution (Private Sector).	Followed cohorts from 1986, 1990, 1994 until 1997	Young Finnish adults (19-38 years).	Mean cost of treatment and number of courses of treatments for each cohort, and proportion of treatment received in 1997.	Young adults attending more frequently received less restorations and surgery.

Appendix 3 continued

Author(s)	Date	Data source	Time-period	Population	Outcome	Findings
Suominen-Taipale et al.	2000	Survey data.	Annual data 1978-1997	Finnish adult population (15-64 years).	Self-reported dental visits, and mean number of visits per person.	An increase in utilisation was found during the first decade in the younger age groups, and in the second decade in the older age groups.
Wall	2012	Data from the National Hospital Ambulatory Medical Care Survey (visits to emergency departments) in the US.	1997/98 and 2007/08	All ages.	Number of ED dental visits, dental visits as a % of total ED visits.	ED dental visit rates increased.
Wall et al.	2012	Data from the National Health Interview Survey.	Annual data 1997 to 2010.	2+ years.	Dental visit within the past year.	Percentage with a dental visit ranged from 63.9% in 2008 to 66.4% in 2000 and 2003. The utilisation rate for 21-64 year-olds decreased from 66.8% in 1997 to 61.8% in 2010. Between 1997 and 2010, levels of utilisation fell for all except for those in the highest income category, where it remained relatively stable.
Woods et al.	2009	Administrative data (Irish Dental Treatment Services Scheme).	June 1996-April 2005	16-34 year-olds in Ireland.	Ratio of amalgams to extractions.	A substitution from extractions to amalgams following an increase in fees for amalgam restorations.

* Google Scholar

Appendix 4 A comparison of professionally-defined need and treatment provided

Author(s)	Date	Data source & population	Assessment of need	Findings
Broderick & Niendorff	2000	Need for treatments measured in the 1991 Oral Health Status and Treatment Needs Survey of American Indians and Alaska Natives among those who sought care in the Indian Health Service, and mean minutes of treatment needed is compared with mean minutes of treatment provided (to those who sought care) in 1991. Adults and children (over 5 years old) (n = 21,937).	Simplified quantitative index (professionally assessed dental treatment need) and mean minutes of treatment needed was calculated.	The basic needs (diagnostic and preventive services) of those who sought care were largely met, whereas one-third to one-half of the need for complex restorations, endodontics, periodontal therapy, prosthodontics, and orthodontics were met in 1991.
Eddie & Elderton	1983	Need for prosthetic treatment was measured among 720 dentate Scottish adults in the 1978 UK Adult Dental Health Survey. This was compared with treatment that was received under the National Health Service within 1 and 3 years.	Simplified quantitative index (professionally assessed dental treatment need).	12.7% of the people who attended a dentist with a prosthetic need received the predicted treatment within 1 yr and 21.3% within 3 yr. 5.1% of the whole sample received more than the predicted treatment. This included 25 of the 500 people for whom the criteria predicted no need for dentures. 25.3% of the sample received less treatment than predicted.

Appendix 4 continued

Author(s)	Date	Data source & population	Assessment of need	Findings
Grembowski et al.	1997	Oral examinations were conducted (no radiographs) to measure oral disease and restoration quality among Washington State employees and their spouses. These 20-34 year-olds (n = 681) were followed for two years to measure use of restorative services from dental insurance claims.	Examiners (dental hygienists) rated quality of each filling.	39.0% of adults had one or more restoration replaced in non-decayed teeth with satisfactory fillings at baseline, 18.1% had one or more restorations placed in teeth with no decay or fillings at baseline.16% of adults either received no replacement restoration in teeth with unsatisfactory fillings at baseline, or had decayed teeth at baseline that were not filled or crowned.
McLoughlin (Masters thesis)	1990	Compared treatment estimated as needed in a survey with treatment provided to a sample of long-stay institutionalised psychiatric patients in the Mid-Western region of Ireland (n = 251).	WHO epidemiological criteria.	The treatment need as predicted by epidemiological survey closely matched that provided for extractions, fillings and periodontal treatment. The predicted need for dentures was far in excess of that provided.
Naegele et al	2010	Data on the number of teeth with treatment needs of dental-health-insured administrative employees of a large company in the city of Rio de Janeiroa was estimated when they presented for a routine dental check-up performed by salaried dentists (n = 3,818). Number of teeth treated was obtained from the dental insurance electronic records, having visited a fee-for-service dentist within 6 months for dental treatment (n = 1,239).	Simplified quantitative index (professionally assessed dental treatment need).	The sum of teeth treated by fee-for-service dentists was much higher than that predicted by salaried dentists.

Appendix 4 continued

Author(s)	Date	Data source & population	Assessment of need	Findings
Nuttall	1983	The dental status of tooth surfaces, as recorded during the 1978 UK Adult Dental Health Survey, was compared with the treatment dental attendees subsequently received in the GDS during the year following the survey (n = 281), and among those who sought care by the end of the third year (n = 426).	Simplified quantitative index (professionally assessed dental treatment need).	A year after the survey, almost twice as many surfaces had been filled than were predicted on the basis of the survey. After 3 years, this had risen to a 3.5-fold difference. Despite this, 59% of the restorative need identified by the survey criteria remained unmet by the end of the 1st yr; 46% was unmet by the end of the 3rd yr. A surface that received a filling for the first time was three times more likely to have been identified as in need of filling during the survey than a surface which was refilled.
Wanman & Wigren	1995	Epidemiologic study of 35-, 50-, and 65-year-olds and performed dental treatment of matched age groups in 1992 and 1995 in Sweden (n = 900).	Simplified quantitative index (professionally assessed dental treatment need).	Higher frequency of restorations performed than professionally assessed need in the epidemiologic sample.

Appendix 5 Form D1

DEPARTMENT OF SOCIAL & FAMILY AFFAIRS

CLAIM FORM FOR DENTAL BENEFIT **D1**

Please answer all Questions fully and place a tick ☑ in the appropriate boxes

PART 1 Details about Yourself

PLEASE USE BLOCK LETTERS

Please state your:

PERSONAL PUBLIC SERVICE NUMBER
(PPS No.) same as RSI/TAX NUMBER

Figures							Letters	

Old Insurance Number
(if you were employed before 1979) _____

Full Name _____

Address _____

_____

Date of Birth	DAY	MONTH	YEAR

Birth Surname _____

Mother's Birth Surname _____

Telephone Number _____

Are you? Single ☐ Married ☐ Other ☐

Are you in paid employment? YES ☐ NO ☐

If 'YES' state present
Employer's Name _____

If 'NO' state date you last worked _____

Are you getting any payments from this Department, a Health Board or from any other source?

YES ☐ NO ☐

Type of Payment _____

Claim Number _____

If you are participating in a Scheme, i.e. FÁS, CES, etc.
Please state:

Type of Scheme _____

If you attended college in the last two years state dates:

	MONTH	YEAR		MONTH	YEAR
FROM			TO		

Do you hold a medical card? YES ☐ NO ☐

PART 2 Working in another EEA Country

Did you ever work in the United Kingdom or in any other EEA Country? YES ☐ NO ☐

If 'YES' state the Country _____

Period of employment in that Country

	MONTH	YEAR		MONTH	YEAR
FROM			TO		
FROM			TO		

PART 3 Name your Dentist

If my application is approved, I wish to get my treatment from

Dentist's Name _____

Address _____

_____

PANEL NO. ☐

I understand that s/he must be on the Dental Panel.

I declare that all the details given are true and complete. I understand that I must not change my Dentist during this course of treatment without the consent of the Department.

SIGNED _____ **DATE** _____

DECLARATION

To be signed by you when treatment is finished

I declare that the treatment outlined overleaf has been carried out to my satisfaction.

SIGNED _____ **DATE** _____

To be signed by your Dentist

Complete and return within one month of finishing treatment.

I have completed the treatment in this case.

I claim payment of € _____

SIGNED _____ **DATE** _____

PANEL NO. ☐

DATA PROTECTION AND FREEDOM OF INFORMATION. The Department of Social and Family Affairs will treat all the information and personal data which you give as confidential. It will only be disclosed to other bodies in accordance with Social Welfare law and it will be subject to the Department's responsibilities under the Data Protection Act and Freedom of Information Act.

Appendix 5 Form D1 continued

PART 4 TO BE COMPLETED BY YOUR DENTIST

Insert in the chart the number corresponding to any natural teeth missing from the mouth on examination.

A	B
D	C

REPORT
Clinical necessity, where required for specific treatments should be entered here.

0	2	0	History, Examination, Diagnosis, Report & X-Rays				€
0	3	0	Scale & Polish (including mild gum treatment)				€
0	5	1	Protracted Gum Treatment				€
0	7	1	A / B / D / C			Single Compound/ Amalgam Fillings	€
0	7	4	A / B / D / C			Composite Anterior Fillings	€
0	7	5	A / B / D / C			Pin Retained Fillings	€
0	7	8	A / B / D / C			Angle/ Incisal Tip Fillings	€
0	9	1	A / B / D / C			Extractions	€
0	8	0	A / B / D / C			Endodontic Treatment	€
2	1	0	A / B / D / C			Apicectomy	€
1	2	2	A / B / D / C			Partial Denture	€
1	2	3	Full Upper Denture	€	1 3	Denture Relines Upper or Lower	€
1	2	4	Full Lower Denture	€	1 3 3	Denture Relines Upper and Lower	€
1	2	5	Full Upper & Lower Denture	€	1 4 0	Denture Repairs	€
9	9	0	Miscellaneous Items: Please state treatment code(s) and tooth reference(s)				€

Alternative Treatment

TOTAL FEE CLAIMED
(This fee does not include the claimant's portion of the cost, if any.)

€ _____

Claimant's portion of set fee items

€ _____

I accept this Dental Letter in accordance with the provisions of the Dental Agreement. I have examined the person named overleaf and have entered details above of all necessary treatment and its cost.

Signed: _____ Panel No.: _____ Date: _____

Appendix 6 Form D2

DEPARTMENT OF SOCIAL, COMMUNITY & FAMILY AFFAIRS

CLAIM FORM FOR DENTAL BENEFIT UNDER THE DEPENDENT SPOUSES SCHEME

D2

Please answer all Questions fully and place a tick ✓ in the appropriate boxes

Part 1 Details about Yourself

(PLEASE USE BLOCK LETTERS)

Please state your Full Name _____

Address _____

_____

Birth Surname _____

Date of Birth

DAY	MONTH	YEAR

Telephone Number _____

Are you in paid employment? YES ☐ NO ☐

If 'YES' please state your PERSONAL PUBLIC SERVICE NUMBER (PPS No.) (same as your RSI/Tax Number)

Figures							Letters	

Employer's Name _____

If you recently re-entered insurable employment, state date re-entered:

DAY	MONTH	YEAR

Are you getting any payments from this Department, a Health Board or from any other source?

YES ☐ NO ☐

Type of payment _____

Claim Number _____

Do you hold a Medical Card? YES ☐ NO ☐

PART 2 Name Your Dentist

If my application is approved, I wish to get my treatment from:

Dentist's Name: _____

Address: _____

_____ Panel No. _____

I understand that s/he must be on the Dental Panel. I declare that all the details given are true and complete. I understand that I must not change my Dentist during this course of treatment without the consent of the Department.

SIGNED _____ **DATE** _____

PART 3 Details about Your Spouse

Please state your spouses PERSONAL PUBLIC SERVICE NUMBER (PPS No.) (same as your RSI/Tax Number)

Figures							Letters	

Old Insurance Number (If you were employed before 1979) _____

Spouse's Full Name _____

Spouse's Date of Birth

DAY	MONTH	YEAR

Spouse's Mother's Birth Surname _____

Is your spouse working at present? YES ☐ NO ☐

If "Yes", please state Employer's Name and Address _____

_____

Is s/he claiming any payment from this Department?

YES ☐ NO ☐

Type of payment _____

Claim Number _____

If a widow or widower, please state spouse's date of death:

DAY	MONTH	YEAR

Did s/he ever work in the United Kingdom or any other EU country?

YES ☐ NO ☐

If "YES", state country: _____

Period of last employment in that country:

	MONTH	YEAR		MONTH	YEAR
FROM			TO		

DECLARATION

To be signed by you when treatment is finished.

I declare that the treatment outlined overleaf has been carried out to my satisfaction.

SIGNED _____ **DATE** _____

To be signed by your Dentist.

Complete and return within one month of finishing treatment.

I have completed the treatment in this case, and claim payment of:

€ _____ **DATE** _____ **PANEL No.** _____

SIGNED: _____

DATA PROTECTION AND FREEDOM OF INFORMATION. The Department of Social, Community and Family Affairs will treat all the information and personal data which you give as confidential. It will only be disclosed to other bodies in accordance with Social Welfare law and it will be subject to the Department's responsibilities under the Data Protection Act and Freedom of Information Act.

Appendix 6 Form D2 continued

PART 4 TO BE COMPLETED BY YOUR DENTIST

Insert in the chart the number corresponding to any natural teeth missing from the mouth on examination.

A	B
D	C

REPORT
Clinical necessity, where required for specific treatments, should be entered here

	DAY	MONTH	YEAR
History, Examination, Diagnosis, Report & X-Rays			

0	2	0	History, Examination, Diagnosis, Report & X-Rays						€
0	3	0	Scale & Polish (including mild gum treatment)						€
0	5	1	Protracted Gum Treatment						€
0	7	1	A	B				Single Compound/ Amalgam Fillings	€
			D	C					
0	7	4	A	B				Composite Anterior Fillings	€
			D	C					
0	7	5	A	B				Pin Retained Fillings	€
			D	C					
0	7	8	A	B				Angle/ Incisal Tip Fillings	€
			D	C					
0	9	1	A	B				Extractions	€
			D	C					
0	8	0	A	B				Endodontic Treatment	€
			D	C					
2	1	0	A	B				Apicectomy	€
			D	C					
1	2	2	A	B				Partial Denture	€
			D	C					
1	2	3	Full Upper Denture	€	1	3		Denture Relines Upper or Lower	€
1	2	4	Full Lower Denture	€	1	3	3	Denture Relines Upper & Lower	€
1	2	5	Full Upper & Lower Denture	€	1	4	0	Denture Repairs	€
9	9	0	Miscellaneous Items						€

Alternative Treatment

TOTAL FEE CLAIMED
(This fee does not include the claimant's portion of the cost, if any).

€

Claimant's portion of set fee items

€

I accept this Dental Letter in accordance with the provisions of the Dental Agreement. I have examined the person named overleaf and have entered details above of all necessary treatment and its cost.

Signed: _____ Panel No. _____ Date _____

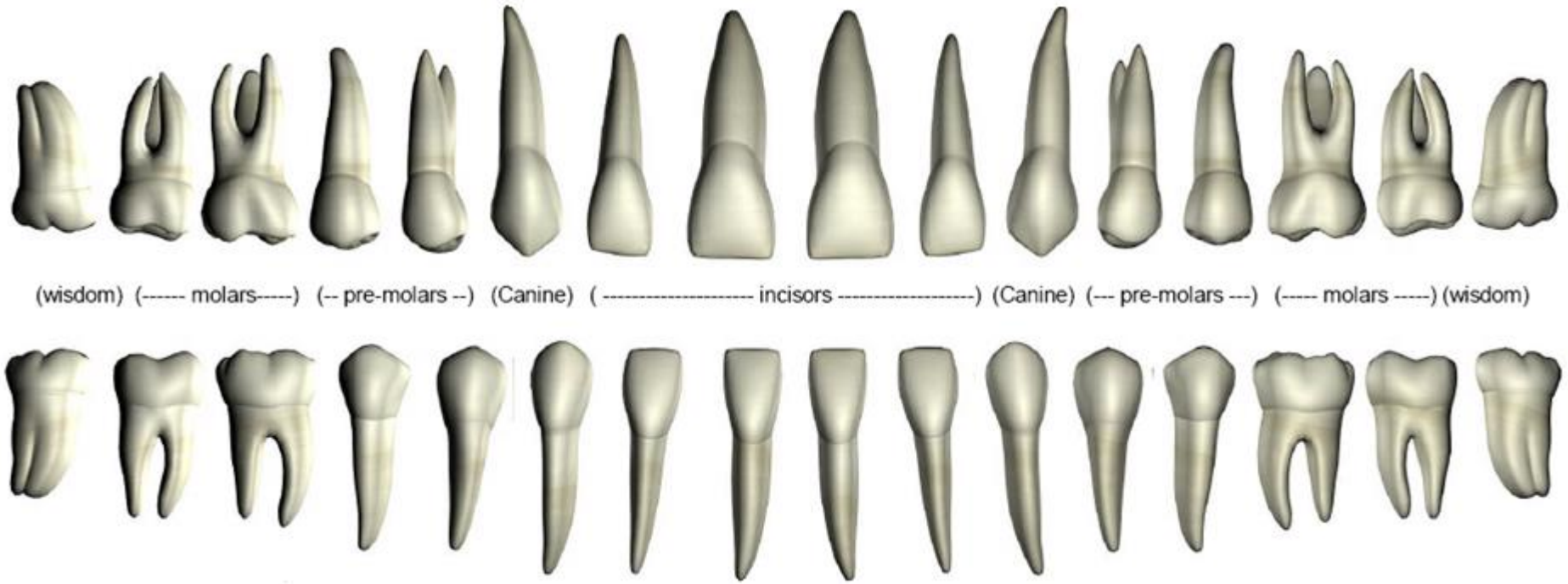
Appendix 7 Obsolete codes in DTBS database

Treatment Code and treatment description	
010 – Patient Did Not Return	
011 – No Treatment Required	
040 – Severe Gingivitis	
050 – Acute Necrotising Ulcerative Gingivitis	
060 – X-Ray Intra Oral	
072 – Double Fillings	
073 – Treble Fillings	
076 – Single Etch Fillings	
077 – Pin Etch Fillings	
081 – Endodontics Post (follow-on treatment after a root canal)	
092 – Extractions	
093, 094, 095 – Extractions (General Anaesthetic)	
101 – Crown: PJC	
102 – Crown: Other	
110 – Pontic (Bridge)	
121 – Chrome Cobalt Denture	
128 – Spillover Code for Partial Dentures	
129 – Uncollected Dentures	
150 – Easing Of Dentures	
160 – Backed Tooth	
170 – Oval Bar	
171 – Obturator	
180 – Stainless Steel Clasp	
190 – Gold Plate Clasp	
201 – Acrylic Inlay(s)	
202 – Gold Inlay(s)	
210 – Apicectomy	211 – Apicectomy (Post Teeth)
220 – Obtudent Treatment	
260 – Penicillin Injection	
270 – Grinding	
271 – S/O 071	
280 – Re-cement Crown	
320 – Re-cast Gold Inlay	
322 – Partial Chrome Cobalt Denture	
323 – Full Upper Chrome Cobalt Denture	
324 – Full Lower Chrome Cobalt Denture	
325 – Full Upper & Lower Chrome Cobalt Denture	
328 – Partial Chrome Cobalt Denture	
340 – Temporisation	
501 – Anesthetists Fee	
502 – Post Operative Visit	
975 – Pin Retained Filling (Alternative)	
978 – Angle/Incisal Tip Filling (Alternative)	

Appendix 8 Tooth identifiers in the DTBS databases

Upper Right | Upper Left

A8 A7 A6 A5 A4 A3 A2 A1 B1 B2 B3 B4 B5 B6 B7 B8



D8 D7 D6 D5 D4 D3 D2 D1 C1 C2 C3 C4 C5 C6 C7 C8

Lower Right | Lower Left

Adapted from http://www.medivision.co.uk/documents/JNY.pdf

Appendix 9 Model selections for analysis of factors associated with NT and SUNT

The Poisson model imposes the restriction that the mean and variance are equal, but in most economic applications, the variance exceeds the mean. In addition, the model is not suitable for data with excess zeros. Frequency distributions, descriptive statistics and formal tests informed which model provided the best fit for the data.

Information measures can be used to compare both nested and non-nested models. All else being equal, the model with the smaller values for Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) is considered the better fitting model (Long and Freese, 2006).

The Vuong statistic is used to compare non-nested models, that is, to compare the NBRM and ZINB in this study. V has as asymptotic normal distribution. If V > 1.96, ZINB is favoured, if V < -1.96, NBRM is favoured (Long and Freese, 2006).

Frequency distributions (Table 1) showed there were no excess zeros for 16-24 year-olds and 35-44 year-olds. Frequency distributions of SUNT and NT for 65+ year-olds showed excess zeros.

Table 1 Frequency distributions of NT and SUNT by age group

	Age Group				Age Group		
NT	**16-24**	**35-44**	**65+**	**SUNT**	**16-24**	**35-44**	**65+**
0	0	9	292	**0**	4	21	315
1	0	2	11	**1**	0	4	19
2	0	0	7	**2**	4	3	15
3	0	1	7	**3**	2	5	16
4	0	1	11	**4**	1	11	17
5	0	1	14	**5**	0	15	39
6	0	3	22	**6**	2	24	32
7	0	3	21	**7**	1	26	28
8	0	1	16	**8**	2	34	29
9	0	3	22	**9**	2	35	28
10	0	5	18	**10**	4	40	21
11	0	3	13	**11**	6	42	23
12	0	2	14	**12**	9	46	35
13	0	3	12	**13**	6	69	23
14	0	13	17	**14**	15	62	15
15	0	7	18	**15**	28	80	10
16	0	6	15	**16**	26	63	10
17	0	18	23	**17**	39	54	11

18	2	16	16	**18**	46	58	6
19	0	16	13	**19**	40	56	6
20	0	21	26	**20**	68	46	3
21	2	27	16	**21**	76	44	2
22	6	40	13	**22**	81	26	1
23	10	39	17	**23**	118	34	3
24	60	82	21	**24**	122	20	3
25	37	70	9	**25**	93	17	1
26	89	111	4	**26**	97	15	2
27	111	112	6	**27**	104	8	0
28	486	152	11	**28**	121	13	0
29	125	90	0	**29**	31	3	1
30	104	55	6	**30**	21	1	0
31	63	34	0	**31**	16	1	0
32	99	30	1	**32**	11	2	0
Total	1,194	976	712	**Total**	1,196	978	714

Table 2 presents descriptive statistics for NT and SUNT. Comparing the mean and the variance for each age group, the Poisson assumption of equal mean and variance of the dependent variable is violated for our data. There is evidence of over-dispersion in the raw data for all three age groups for SUNT and for 35-44 and 65+ year-olds for NT: the mean conditional variance is larger than the mean, indicating that Poisson regression may not be a suitable model. There is evidence of under-dispersion for 16-24 year-olds for NT.

Table 2 Descriptive statistics for number of natural teeth present (NT) and number of sound untreated natural teeth (SUNT)

NT	**n**	**Mean**	**SD**	**Variance**	**Min**	**Max**
16-24	1194	28.13	2.09	4.35	18	32
35-44	976	25.04	5.35	28.67	0	32
65+	712	8.62	9.20	84.61	0	32
SUNT						
16-24	1196	22.96	4.89	23.88	0	32
35-44	978	15.09	6.11	37.39	0	32
65+	714	5.20	6.08	36.95	0	29

SD = Standard Deviation

The likelihood ratio (LR) test was used as a further test for over-dispersion (Table 3). When the dispersion parameter (α) is zero, the negative binomial distribution is equivalent to a Poisson distribution. For NT for 16-24 year-olds, although the LR test indicated that the Poisson was a better fit than the negative binomial model, the mean was almost seven times greater than the variance (Table 2). Therefore, the generalised 2-parameter log-gamma model was fitted to the data. The generalised 2-

parameter log-gamma regression model fitted the data better than the Poisson model or generalised Poisson model, based on a comparison of their AIC and BIC values. A Poisson model was used for NT for 35-44 year-olds.

Zero-inflated count models respond to the failure of the Poisson model to account for dispersion and excess zeros by changing the mean structure to allow zeros to be generated by two distinct processes. In comparing the NBRM with the ZINB for NT for 65+ year-olds, the Vuong test was indecisive and the AIC and BIC measures favoured NBRM (Table 3).

Table 3 Model selection for NT and SUNT

Variable	Tests	Poisson	NBRM	ZIP	ZINB	glgamma2	Model
NT (16-24)							
	AIC	6371.1	6371.1	No excess zeros		5165.3*	
	BIC	6381.2	6381.2			5180.5*	
	LR		0.0				glgamma2
NT (35-44)	AIC	5932.8	5932.8	No excess zeros			
	BIC	5942.6	5942.6				
	LR		0.0				Poisson
NT (65+)	AIC	3595.6	2898.1		2902.1		
	BIC	3603.7	2910.3		2922.3		
	LR		699.5				
	Vuong				0.0 (p=0.5001)		NBRM
SUNT (16-24)	AIC	7286.8	7288.8	No excess zeros			
	BIC	7296.9	7304.0				
	LR		-				Poisson
SUNT (35-44)	AIC	6827.3	6312.2	No excess zeros			
	BIC	6837.0	6326.9				
	LR		517.1				NBRM
SUNT (65+)	AIC	3149.8	2612.2		2583.1		
	BIC	3157.9	2624.4		2603.3		
	LR		539.6				
	Vuong				2.56 (p=0.0053)		ZINB

AIC = Akaike's Information Criterion, BIC = Bayesian information criterion, LR = Likelihood Ratio test, glgamma2 = Generalised 2-parameter log-gamma, NBRM = Negative Binomial, ZINB = Zero-Inflated Negative Binomial. *Generalised Poisson (gnpoisson) AIC and BIC: 6373.1 and 6388.3 respectively.

The Poisson model was used for SUNT for 16-24 year-olds (Table 3): although the LR test could not be computed by Stata, the values for the mean and variance are similar, and tests indicated that the Poisson distribution was a better fit than a negative binomial distribution. The dispersion parameter (LR) was significantly greater than zero for 35-44 year-olds and 65+ year-olds for SUNT, indicating that the data are over dispersed and are better estimated using a NBRM than a Poisson model. For 65+ year-olds, the Vuong test favoured the ZINB over the NBRM; therefore, SUNT was modelled using the ZINB model. However, the results for the second part of the ZINB model were similar to the NBRM model so the results are those from the NBRM output.

Appendix 10 Moderated multiple regression (MMR) analysis

In Article I, moderated multiple regression (MMR) was used to test whether exposure to water fluoridation and behavioural variables moderated the relationship between SES and dental health. An interaction effect hypothesis states that "the relationship between two variables, or the effect of one variable on a second one, depends on the value of a third (moderator) variable". Interaction effects describe the condition under which relationships change in strength and/or direction (Aguinis and Gottfredson, 2010).

The MMR model, is formed by creating a new set of scores, the product of the observed scores for the two predictors (i.e., x*z), and including it as a third term in the equation. The addition of the product term yields the following model:

$$y = a + b_1x + b_2z + b_3x^*z + e$$

where b_3 is the least squares estimate of the population regression coefficient for the product term scores.

In terms of implementing the MMR analysis, the first step involved creating a new variable, which is the product term between x and z, and then performing the analysis in Stata, using the same count models as used in the bivariate and multivariate regression analyses.

The analysis was performed for the six dependent variables (28+NT, 21+NT, NT, SUNT, 18+SUNT, dentate) as appropriate for number of teeth in the age groups.

The independent variables were being disadvantaged (having a Medical Card), being in employment, and having primary education only, all dichotomous variables. The moderator variables were visiting the dentist regularly, attending for a check-up, frequent brushing, and percentage lifetime exposure to fluoridated water.

Creating the interaction variable for dichotomous variables (0,1) entailed multiplying the variables, e.g. regular visits × disadvantaged.

Aguinis and Gottfredson (2010) recommend mean-centring continuous variables. They suggest that it achieves the goal of making the interpretation of the first-order

coefficients meaningful by the process of re-scaling. Centring predictors does not affect the statistical significance of the test of the null hypothesis but it can have an important effect on the values for the intercept as well as coefficients for the first-order effects (i.e., b_1 and b_2) (Aguinis and Gottfredson, 2010). Where the variable was continuous, i.e., with % lifetime exposure to fluoridated water, the mean % lifetime exposure to fluoridated water was first subtracted from each value to create a new variable. This new variable was then multiplied by the independent variables e.g. percent lifetime exposure to fluoridated water_2 × disadvantaged.

A total of 144 (3 × 4 × 12) MMR analyses were run. Only the significant result is presented in Article I for brevity. Disadvantaged × check-up is significant for NT. This means that attending for a check-up (instead of when in need or pain) moderated the relationship between being disadvantaged and tooth retention.

Appendix 11 Model selection for analysis of factors associated with number of treatments provided to the 2003 cohort over the next five years in the DTBS

Figure 1 presents the frequency distribution of number of treatments provided to the 2003 cohort between 2004 and 2008. A total of 256,222 adults aged 16-64 years were treated in 2003, of these, just over 40,000 did not have any treatments in the DTBS over the next five years.

Figure 1 Frequency distribution for number of treatments between 2004 and 2008

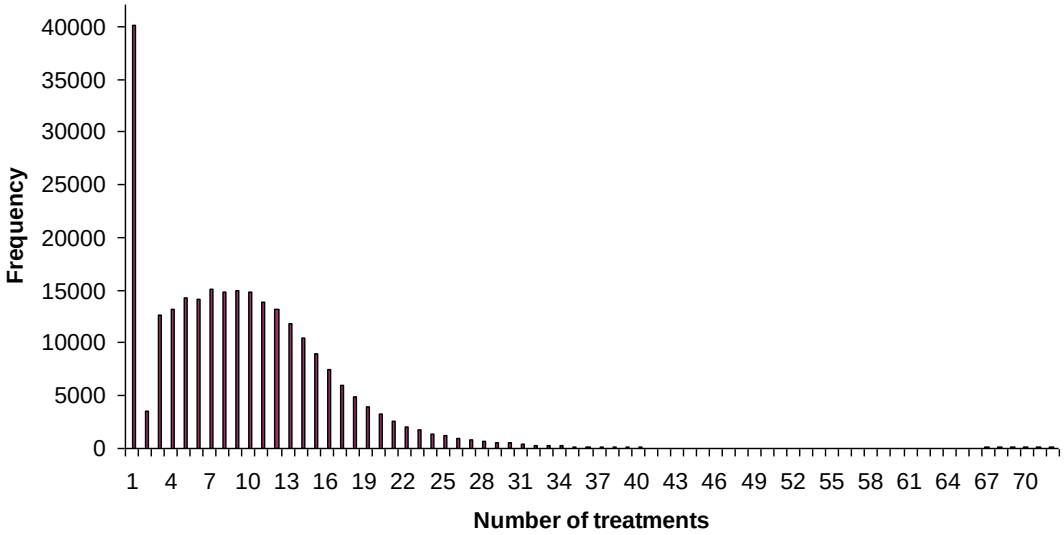


Table 1 presents descriptive statistics for number of treatments. The total number of treatments received by this cohort from 2004 to 2008 (inclusive) was 2,127,704.

Table 1 descriptive statistics for number of treatments

N	Mean	Std. Dev.	Min	Max	Total number of treatments
256,222	8.3	6.7	0	80	2,127,704

Table 2 presents model selection criteria for number of treatments. The NBRM fitted the data better than the Poisson model; therefore the negative binomial model was used in the TPM and FMM. The TPM and FMNB2 fitted the data better than the Poisson or NBRM in preliminary data analysis, so the results from the TPM and FMNB2 are discussed in Article V.

Table 2 Model selection criteria for number of treatments

			TPM		
Test	**Poisson**	**NBRM**	**Logit**	**ZTNB**	**Total**
AIC	1,872,344	1,307,751	175,298	1,081,331	1,256,629
BIC	1,872,395	1,307,813	175,349	1,081,392	1,256,741
LR		560,000 ($p < 0.01$)			

	FMNB	
Test	**NB1**	**NB2**
AIC	1,259,218	1,258,720
BIC	1,259,351	1,258,853