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# Epidemiological studies of Oral Health, development and influencing factors in the county of Dalarna, Sweden 1983–2013

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### **Abstract**

Edman, K. 2016. Epidemiological studies of Oral Health, development and influencing factors in the county of Dalarna, Sweden 1983–2013. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine* 1191. 55 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-554-9501-5.

The aim of this thesis is to describe the development of oral health and possible associations with socioeconomic and socio-behavioural factors, in an adult population over a period of 30 years. A further aim is to describe attitudes to, and demands of dental care, and the impact of oral conditions on quality of life.

The study sample consisted of 787-1158 individuals, aged between 35-85 years, randomly selected from Dalarna's population register in 1982, 2002, 2007 and 2012. The studies were carried out in 1983, 2003, 2008 and 2013, and the participants responded to a questionnaire and a clinical examination of oral status.

There has been a substantial improvement in oral status in regard to the mean number of teeth, intact teeth, and less removable dentures over this period of 30 years. The proportion of individuals with alveolar bone loss decreased significantly between 1983 and 2008, but increased significantly between 2008 and 2013. Smoking was the overall strongest factor associated with alveolar bone loss, after adjustment for socioeconomic and socio-behaviour factors, age and number of teeth. Calculus, visible on radiographs, increased significantly between 2003 and 2013. The proportion of individuals with manifest caries declined significantly between 1983 and 2008, but seems to level out between 2008 and 2013. Socioeconomic and socio-behaviour factors were significantly associated with manifest caries. Preventive treatment, meeting the same caregiver as on previous visits, and information about treatment cost was reported to a significantly lower degree as important in 2013, compared with 2003 and 2008, and booking time for treatment was reported as more difficult in 2013, compared with earlier years. Regular recalls was reported as less important in 2013, compared with 2008. A third of the respondents reported oral impact on daily performance and irregular dental visits, limited economy for dental care, less than 20 remaining teeth, manifest caries and temporomandibular disorder were significantly associated with oral impact on daily performance.

*Keywords:* Periodontal disease, dental caries, epidemiology, edentulousness, removable dentures, smoking, socio-behavioural, socioeconomic, tobacco, oral health related quality of life

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"Ett folks hälsa är källan till all dess kraft, dess andliga såväl som dess materiella. Att bevara och utveckla släktets hälsa borde väl därför utgöra en af de allra främsta omsorgerna för hvarje nation, om icke den allra främsta"

Riksdagens andra kammare den 17 januari 1904



# List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

- I Edman, K., Öhrn, K., Holmlund, A., Nordström, B., Hedin, M., Hellberg, D (2012). Comparison of oral status in an adult population 35-75 year of age in the county of Dalarna, Sweden in 1983 and 2008. *Swed Dent J.* 36:61-70.
- II Edman, K., Öhrn, K., Nordström, B., Holmlund, A., Hellberg, D (2015). Trends over 30 years in the prevalence and severity of alveolar bone loss and the influence of smoking and socio-economic factors – based on epidemiological surveys in Sweden 1983-2013. *Int J Dent Hygiene* 13(4):283-91.
- III Edman, K., Öhrn, K., Nordström, B., Holmlund, A. Prevalence of dental caries and influencing factors, time trends over a 30-year period in an adult population. Epidemiological studies between 1983 and 2013 in the county of Dalarna, Sweden. *Acta Odontol Scand.* Accepted.
- IV Edman, K., Holmlund, A., Nordström, B., Öhrn, K. Attitudes and demands of dental care, Sweden 2003-2013, and clinical correlates of oral health-related quality of life in 2013. Submitted.

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# Abbreviations

ABL	Alveolar bone loss
CI (95%)	Confidence interval, estimates the precision of the odds ratio (OR)
DFS	Decayed filled surfaces
DS	Decayed surfaces
DT	Decayed teeth
€	Euro, European currency (€1 ≈ 10 SEK)
MC	Manifest caries
NDI	The national dental insurance
OHR	Oral health related
OHRQoL	Oral health related quality of life
OIDP	Oral impact on daily performance
OR	Odds ratio, measure the association between an exposure and an outcome
PASW	Predictive analytics software
PMTC	Professional mechanical tooth cleaning
SEK	Swedish crown
Snuff	Dry or moist form of tobacco, which can be used orally or nasally
Snus	Swedish moist snuff, which is used orally and placed under the lip
SPSS	Statistical package for the social sciences
SPT	Supportive periodontal treatment
TMD	Temporomandibular disorder
WHO	World health organization



# Introduction

## Epidemiology

Epidemiological studies serve to generate knowledge of the distribution and determinants of disease frequency. A great deal of our knowledge about risks and causes to health and sickness has been discovered by epidemiological studies. The knowledge we acquire by epidemiology can be transformed into practice and used as a tool for prevention and health promotion. Many large-scale epidemiological studies have led to widespread primary preventions of different diseases. For example, the community-intervention trials of fluoride supplementation in water that started in 1945 and led to a marked reduction in dental caries and costs for dental care in children [1]. Another epidemiological study that has contributed to understanding the causes of cardiovascular diseases is the “Framingham Heart Study”, initiated in 1949 [2]. Cross-sectional epidemiological studies, also referred to as “prevalence studies”, are study designs frequently used in epidemiology. These studies include all persons in a population, or a representative sample, without regard to exposure or disease status and the measures are made at a certain time point. The benefits with cross-sectional studies are considered to be relatively low costs, uncomplicated study design and that they are relatively easy and fast to perform. Cross-sectional studies are often used when planning for health and medical care and preventive strategies. To be able to find effective tools for prevention and health promotion we have to know the causation that preceded the disease onset. One definition of the *cause* of a specific disease occurrence is “a previous event, condition, or characteristic that was necessary for the occurrence of the disease at the moment it occurred, given that other conditions were fixed” [3]. As exposures and effects are measured at the same time in a cross-sectional study, conclusions concerning causation cannot be drawn, and results from cross-sectional studies are mainly regarded to generate hypothesis, and other study designs have to ensure possible causal links.

## Oral epidemiology in the county of Dalarna

Epidemiological cross-sectional studies were initiated in 1983 in the county of Dalarna, Sweden, and have been performed every fifth year since then [4-10]. The first survey in 1983 was initiated by the county council, and the aim

was to provide a base for formulating goals for a public oral health plan and to provide possibilities to follow the development of oral health in the future. The project group included delegates from the county council, private dental practice and union representatives in the county of Dalarna. The studies were based on single age cohorts of 35, 50, 65 and 75- year olds, as recommended by the Swedish National Board of Health and Welfare [11]. In the study years 2008 and 2013, the age group of 85 years was added. Data was also collected regarding personnel resources in public and private dental care. The data was used for prospective planning of dental care, personnel and economic resources and for control of dental health goals.

## Oral health and general health

Oral health has improved considerably in recent decades in Sweden, as well as in other countries [12-14]. However, despite great improvements with regard to periodontal disease and dental caries in recent decades, global problems still persist [15], and as a consequence of retaining natural teeth high up in age, the risk for oral disease increases. Traditionally, the number of teeth has been a measure of good oral health, and the World Health Organization (WHO) stipulated goals of a minimum of 20 functional teeth at the age of 80 years [16] have been reached in some industrialized countries. Oral health means more than good teeth and is integral to general health. The relationship between oral and general health has been recognized. For example, periodontal disease is associated with diabetes [17, 18] and rheumatoid arthritis [19, 20]. The severity of periodontal disease and number of teeth have been associated with an increased burden of cardiovascular disease [21, 22]. Daily intake of four or more medications increases the risk for hypo-salivation [23]. Hypo-salivation is common among patients with different systemic autoimmune, hormonal and psychogenic diseases, but also after exposure to radiation therapy directed against the head and neck region [24], and the acquired hypo-salivation may lead to an increased risk for dental caries [25].

## Removable dentures

There is a reduction in the number of edentulous individuals [26-28] and the prevalence of complete and partial removable dentures has decreased [27, 29]. In a recent Swedish study, investigating the age groups 40, 50, 60, 70 and 80 years, no complete denture wearers were found below the age group of 80 years, and removable dentures of any kind decreased from 38% in 1973, to 4% in 2013 [12].

## Periodontal disease

Periodontal disease is an chronic inflammatory disease, affecting tooth-supporting structures, such as the periodontal ligament, tooth root cementum, gingiva and alveolar bone that constitute the four main tissues in the periodontium [30]. Periodontitis has a multifactorial aetiology, and bacteria play an important role. A number of microorganisms have been associated with periodontitis and the most potent periodontal pathogens involved are currently regarded to be *Porphyromonas gingivalis*, *Tannerella forsythia* and *Aggregatibacter actinomycetemcomitans* [30]. More recently, viruses have also been suggested as possible aetiological factors [31, 32]. Besides microorganisms, genetic disposition is considered to be a major factor for the risk of developing periodontal disease [33]. The mildest form is gingivitis, a reversible form of periodontal disease. The clinical signs of biofilm-associated gingivitis are changes in tissue colour, volume, temperature, crevicular exudate and bleeding on gentle provocation with a probe [34]. Most children and adolescents show signs of gingivitis [35], as well as 50-90% of adults worldwide, depending on the diagnostic criteria used [36, 37]. When adequate oral hygiene is performed and maintained, the inflammation in the tissue regresses and the gingiva can be restored [38]. In some individuals, gingivitis can progress to a non-reversible condition, called periodontitis. Periodontitis can either affect a part of the dentition (localized form), or affect a major part of the dentition (generalized form), and both forms appear in a chronic or aggressive type, depending on the progression rate of the disease. The severity of the inflammatory process varies considerably from one person to another, as well as between teeth and tooth sites within the person. Periodontitis, initiated by microbial biofilm, leads to a breakdown of tooth-supporting bone and connective tissue that may lead to complete loss of teeth if not treated [39] (Figure 1). The prevalence of periodontitis varies between 31% and 47% in some European countries [12, 40], but the prevalence has been reported to be as high as 87% in a German study [41]. The prevalence of *slight* and *moderate* forms of periodontitis is widespread and varies between countries and within countries [12, 42, 43], and has decreased in European countries in recent decades [44]. Only a subset of individuals will experience *severe* periodontitis. The prevalence in adults has been unchanged, and is 5-20 % in most populations, and about 2% of adolescents are affected by aggressive periodontitis during puberty [35]. However, not all sites with gingival inflammation progress to periodontitis, and predisposition to disease progression varies significantly between individuals, and is dependent on how well the immunological defence can handle the challenge from the microorganisms in the biofilm [45]. Periodontal disease has also been associated with systemic diseases, such as cardiovascular disease [46, 47], rheumatoid arthritis [19], chronic obstructive pulmonary disease [48], diabetes [17, 18, 49] and osteoporosis [50]. Periodontitis is, together with dental caries, a major cause for tooth loss, and tooth loss

has also in the past decade been associated with all-cause mortality, mortality in cardiovascular disease, as well as cancer [51, 52]. The severity of periodontal disease has also been found to relate to hypertension, independent of age, and to the prevalence of myocardial infarction in middle-aged subjects [21].

## Alveolar bone loss (ABL)

Radiographically, the normal distance between the cemento-enamel junction and the interproximal alveolar bone crest should not exceed 2 mm, according to criteria described by Källestål and Matsson [53]. In a number of Swedish studies, ABL has been divided into the following three categories: *slight* (marginal bone loss, less than 1/3 of the normal bone height), *moderate* (marginal bone loss, reaching between 1/3 and 2/3 of the normal bone height), and *severe* (bone loss, reaching more than 2/3 of the normal bone height), and/or infra-bony pockets and furcation involvements degree II and III [54].

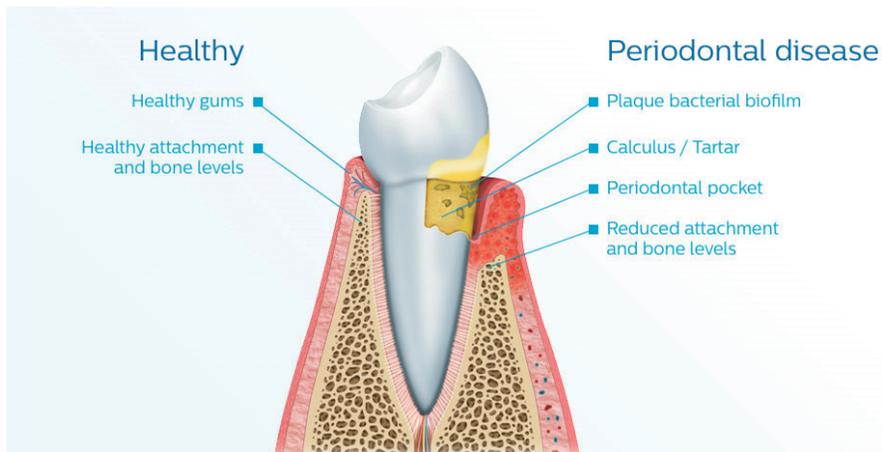


Figure 1. Healthy periodontium and periodontal disease (picture used by courtesy of Philips).

## Prevention and treatment of periodontal disease

Effective removal of biofilm (bacterial plaque) is essential to dental and periodontal health [55]. Prevention and treatment of periodontal disease includes educational interventions on periodontal disease, and related risk factors, professional oral hygiene instructions in tooth brushing and interdental cleaning. Oral hygiene instructions should be tailored to each individual patient, and a maintenance program should follow the basic oral hygiene instructions. The patients' individual behaviour is important for the success of periodontal therapy [56, 57]. In a review by Ramseier, it was shown that second to plaque control, smoking cessation was the most important measure for the management of chronic periodontitis [58]. Furthermore, treatment of

periodontal disease includes non-surgical therapy aimed at eliminating both living bacteria in the biofilm and calcified biofilm (calculus) from the tooth surface and adjacent soft tissue. The methods most commonly used are hand instrumentation, or ultrasonic scalers, to accomplish reduction of pocket depth and bleeding on probing. Re-evaluation is a vital stage and is performed 8-12 weeks after the initial therapy, to establish if further therapy is needed. If initial therapy is not satisfactory additional therapy, such as different surgery techniques can be applied [59]. Systemic antibiotics have not been proven to have an additional effect in the treatment of chronic periodontitis, but may be a useful adjunct to the mechanical treatment of aggressive forms of periodontitis. Overall, a restrictive attitude towards using antibiotics is recommended [30].

### Supportive periodontal therapy (SPT)

Several studies have pointed out the importance of SPT in individuals affected by periodontal disease [59-63]. As periodontitis is a chronic disease, SPT and good oral hygiene are essential [64-66]. The main objectives of SPT are to prevent and minimize the recurrence and progression of periodontal disease, and to prevent or reduce the incidence of tooth loss. Usually, SPT includes an update of the medical and dental histories, dental examination including radiographs, if necessary, and periodontal evaluation. Furthermore, removal of supra and/or subgingival dental plaque and calculus, PMTC, and a recheck of patients' plaque control are essential. Compliance with a periodontal maintenance program was highlighted in a study comparing tooth loss in a group who complied with maintenance therapy, with a group of erratic compliers over a 5-year period. It was found that erratic compliers undergoing SPT presented higher rates of tooth loss compared to regular compliers [67]. Similar results were found in a more recent Norwegian study that found compliance with a maintenance program to be associated with very low levels of tooth loss [68]. Patients having poor compliance are 5.6 times more likely to lose teeth following active therapy than regularly compliant patients [69].

### Dental caries

Dental caries can be defined as the "localized destruction of the tissue of the tooth by bacterial fermentation of dietary carbohydrates" [70]. The disease can affect both the crown (coronal caries) and root (root caries). The different stages of caries are often documented as D<sub>1</sub>, D<sub>2</sub> and D<sub>3</sub> (Figure 2). Cavitation (D<sub>3</sub>) is the final stage of enamel caries that is considered as irreversible and, in most cases, needs treatment i.e. filling. The initial stages of caries are reversible and remineralization can occur, particular in the presence of fluoride. *Streptococcus mutans* and *Streptococcus sobrinus* are recognized as the

most prevalent caries-associated bacteria [70]. Caries of enamel surfaces is particularly common in children and adolescents, whereas later in life, root-surface caries is an increasing problem. Oral diseases, including dental caries are the fourth most expensive diseases to treat and dental caries is one of the most prevalent chronic diseases of people worldwide and, if left untreated, may cause severe pain which affects children's school attendance and performance, and adults productivity at work [15, 35, 71]. Even though the prevalence of dental caries is decreasing [14, 72], dental caries is still a major problem affecting 60-90 % of schoolchildren and the vast majority of adults [15, 35]. In a recent Swedish study, covering a period of 40 years (1973-2013), the percentage of children and adults without caries or restorations increased, and up to the age of 60 years, DFT declined in 2013, compared to 2003. However, only a minor change was found for the age groups 70-80 years [12]. Despite a marked decline in caries levels, there is a tendency towards an increase in caries experience [35], and an increase in caries levels with age [73]. A longitudinal study reveals that caries increment, among older people residing in nursing homes is more than double that observed among community-dwelling older people, and among those with dementia the caries increment is even higher [74].

Decayed missing filled teeth (DMFT) is the index most frequently used for measuring the lifetime experience of dental caries in the permanent dentition.

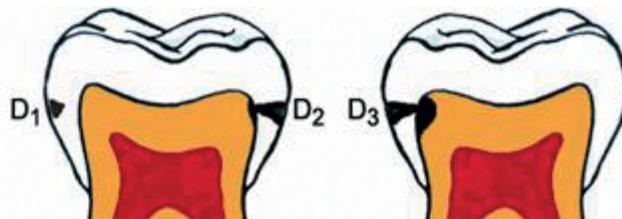


Figure 2. Different stages of dental caries.

## Prevention and treatment of dental caries

Dental caries is regarded as largely preventable, and using fluoride toothpaste and reducing sugar intake are important recommendations [55, 75-77]. The treatment of caries D<sub>1</sub> and D<sub>2</sub> is usually dietary advice, additional fluoride recommendation, oral hygiene instruction and PMTC and fluoride application. The treatment of caries D<sub>3</sub> includes removal of carious tooth substance that is replaced by a composite filling or other suitable material. Crown therapy might be considered if a larger amount of tooth substance has to be removed. When a tooth is filled once there is a risk for secondary caries lesions in the future, leading to extended fillings and in some cases, there is a need of endodontic treatment (root-filling).

## Tobacco products

### Smoking

There is evidence that gingival inflammatory response is altered by smoking [78-83]. Smoking has been proven to be a very important risk factor for periodontitis, and is the environmental factor that has the most documented evidence so far. Moderate-heavy smoking ( $\geq 10$  cigarettes/day) has been found to be associated with severe periodontal destruction, while smoking 1-9 cigarettes/day was not [84], and similar results are found in other studies [85, 86]. Although there is only limited data from long-term longitudinal clinical trials, it is concluded that smoking cessation is beneficial in periodontitis occurrence and periodontal healing, and smokers should be encouraged to quit as part of their periodontal management [87-89]. Different measures of oral health, such as tooth loss, oral cancer, dental caries, periodontitis, attachment level and socio-economic factors have been associated with smoking [90-98].

The prevalence of smoking in Sweden was 11% in 2015, with slightly more women than men smoking (11% vs. 9%) [99].

### Swedish snus

Swedish snus has a pH-level of about 8.5 [100], and the salivary pH is significantly higher with a quid of snus in the mouth than 6-8 hours after snus use [101]. The impact of snus on oral health shows contradictory results and is hard to interpret. This is partially depending on different study designs, but also because of different substances in snus/snuff in different parts of the world [102]. Although snus is associated with less systemic diseases compared to smoking, it is still considered as a harmful product that might be a gateway to smoking [103]. An association between snus use and oral cancer and other cancer types has been observed in some studies [104, 105].

The prevalence of snus use in Sweden was 11% in 2015, 19% for men, and 4% for women [99].

## Socioeconomic and socio-behavioral factors

*Socioeconomic status* is based on income, education and occupation, and any, or all, of these variables can be assessed. Education is commonly divided into low education level (e.g. preschool, primary school, secondary school), and high education level (college or university). Socioeconomic information is often used together with other data to draw conclusions about a certain matter. By finding socioeconomic patterns that conflate with something observed, it

is possible to draw conclusions, for example, the correlation between education level and oral diseases. In a study of socioeconomic differences, measuring the burden of disease with the use of disability-adjusted life years (DALYs) in Sweden, it was concluded that one-third of the burden of disease is unequally distributed, disadvantaging unskilled manual workers [106]. Being advantaged on social gradients has been found to protect against socio-behavioral factors, such as less frequent dental attendance [107], and unhealthy lifestyle [108] and more favorable attitudes about dentists and dental care [109].

## **Socioeconomic, oral health and disease**

There are social disparities in oral health. Socioeconomic status is a strong determinant for tooth loss [110], and, with respect to dental and denture status, in individuals receiving social care [111]. It has been indicated that low educated individuals have fewer remaining teeth and inferior occlusal function, compared to highly educated individuals. This indicates that lost teeth have not been replaced by fixed bridges [112]. The prevalence of dentures has been found to be highly related to income and educational background [113, 114]. Socioeconomic inequality in dental status has decreased, but disparities still remain, and low gross personal and family income have been associated with having fewer teeth [115, 116]. Low level of education, having no cash margin and being born outside of Sweden are associated with higher odds of problems with chewing and wearing prosthesis [117].

### **Socioeconomic and periodontal disease**

Single living, being unemployed, or being a widow or widower have been found to be associated with periodontitis [110, 118, 119]. Low socioeconomic status, different racial and ethnic groups have also been shown to have an impact on periodontal health [120]. However, when adjusted for smoking, associations between socioeconomic and periodontal disease diminished [121, 122].

### **Socioeconomic and dental caries**

Socioeconomic indicators, such as educational level, occupation, income, socioeconomic status, and dental visit pattern have been associated with a greater occurrence and increased risk of dental caries [123, 124]. Socio-behavioral risk factors for dental caries, such as oral hygiene and dental visit habits have also been identified [125].

### **Socioeconomic and dental attendance**

According to the Swedish Social Insurance Agency, 78% of the Swedish population visit dental care on a regular basis [126]. Individuals with high school education or equivalent, and higher income, visit dental care regularly

to a higher degree, compared to individuals with seven or fewer years of schooling and low income [114]. Irregular dental attendance is more prevalent in low socioeconomic groups and has been associated with edentulism, less sound teeth, poor self-reported oral health, problems with chewing and wearing of prosthesis [117, 127, 128].

### **The national dental insurance (NDI)**

In 1974, a national dental insurance system was launched. The government regulated the prices for dental care, and reimbursement included all types of dental care. The NDI was reformed in 1999, and profiled towards more preventive oriented dental care. In 2008, a new NDI system was introduced, including a grant system of either € 15 or € 30, depending on age. A high cost protection scheme was introduced and the compensation period consisted of twelve months. The treatment cost is paid 100% by the patient, up to approximately € 300, before the insurance is activated to contribute 50% of cost above € 300, and 85% of cost above € 1500.

## **Oral Health Related Quality of Life (OHRQoL)**

To be able to document the full impact of oral disorders, and to be able to capture the oral health experienced by the individual itself, Cohen and Jago (1976) argued that socio-dental indicators were necessary [129]. A large amount of research has thereafter been undertaken to develop socio-dental indicators, and the term “oral health related quality of life” (OHRQoL) was adopted to measure subjective oral health status, and this redefinition was consistent with other health-related disciplines [130]. A number of OHRQoL instruments have been developed, measuring the functional and psychosocial aspects as a complement to clinical measures. Some of these measures were reviewed at an international meeting held at Chapel Hill, North Carolina, in 1996 [131]. The majority of measures have been shown to have sufficient reliability and validity [132, 133]. The general oral health assessment index (GOHAI) [134], the oral health impact profile-14 (OHIP-14) [135, 136], oral health related quality of life –UK (OHRQoL-UK) [137], and oral impact on daily performance (OIDP) [138] are examples of socio-dental measures.

# Demography of Dalarna County

Dalarna is situated in the middle of Sweden with an area of approximately 28,000 square kilometres, and consists of 280,500 inhabitants (year 2015). The north-east part of the county is dominated by mountain and woodland (Figure 3). The administrative city of the county is Falun, with a population of 37,291 (year 2010) of the total 57,088 (year 2015) inhabitants. In 1982, the number of inhabitants in the age interval 20-79 years was 202,400 individuals. In 2002, the number of inhabitants in the age groups 35, 50, 65 and 75 years was 3,638, 3,876, 2,701 and 2,404, respectively, and in 2007, 3,277, 3,744, 3,508, 2,277, respectively, and in the age group 85 years, the number of inhabitants was 1,405 individuals. In 2012, the number of inhabitants was 176,970, in the age interval 30-85.

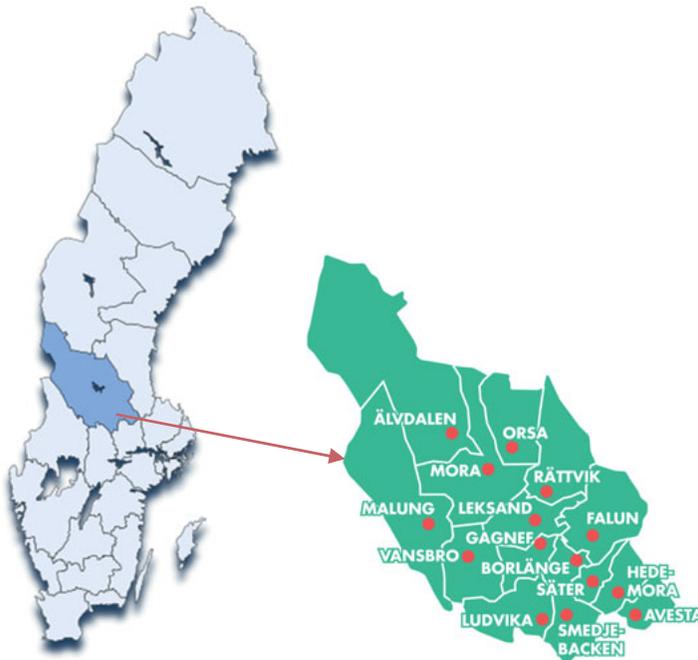


Figure 3. Sweden and the county of Dalarna.

# Aims

The aim of this thesis is to describe the development of oral health and the association with socioeconomic and socio-behavioural factors over a period of 30 years, in a randomly selected adult population stratified by age. A further aim is to describe attitudes to, and demands of dental care, and the impact of oral conditions on oral health related quality of life.

## Specific aims

### **Paper I**

To compare oral status in an adult Swedish population, between 1983 and 2008.

### **Paper II**

To investigate time trends in periodontal health in terms of ABL and socioeconomic factors using the same methodology to investigate and classify the severity and prevalence of ABL in data available from four cross-sectional epidemiological studies conducted in an adult population (35-85 years of age) in 1983, 2003, 2008 and 2013.

### **Paper III**

To investigate the prevalence of dental caries in an adult population over a 30-year period, and to assess its possible associations with socioeconomic and socio-behavioural factors, using data from 4 epidemiological cross-sectional studies conducted in the county of Dalarna, Sweden.

### **Paper IV**

To investigate attitudes to, and demands of dental care, and to assess possible associations with clinical variables over a period of 10 years. A further aim was to investigate the association between OHRQoL assessed by OIDP, and socioeconomic, dental care habits, smoking and oral status.

# Materials and Methods

## Design

Epidemiological cross-sectional questionnaire surveys combined with a clinical examination, including radiographs, all performed in the county of Dalarna, Sweden, in 1983, 2003, 2008 and 2013.

## Subjects

In all the investigations, the samples were selected from Dalarna's population register, stratified according to six geographical areas (rural and urban). On January 1<sup>st</sup> 1982, a random sample of 1012 individuals in the age groups 20-39 years, 40-59 years and 60-79 years was selected. To be able to compare data with later investigations, the sample was regrouped in four age-intervals (28-42, 43-59, 60-70 and 71-79), so that the mean age was close to 35 (mean age 35.1), 50 (mean age 51.3), 65 (mean age 64.8), and 75 years (mean age 74.2) of age, respectively, resulting in 787 individuals available for the study. On December 1<sup>st</sup> 2002, a random sample of 1542 individuals in the age groups 35, 50, 65 and 75 years was selected, and in 2007, 1800 individuals, 360 in each of the age groups 35, 50, 65, 75 and 85 years of age was selected on December 1<sup>st</sup>. In 2012, a random sample of 2244 individuals, consisting of 204 individuals in each of the age intervals 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79 and 80-85 years, was selected and grouped into five age intervals (30-41, 42-58, 59-71, 72-77 and 78-85), so that the mean age was as close as possible to 35 (mean age 35.2), 50 (mean age 50.2), 65 (mean age 65.2), 75 (mean age 74.7) and 85 (mean age 80.5) respectively.

The number of subjects and characteristics regarding gender, age groups and study year is presented in Table 1.

Table 1. *Number of subjects in the different study years, and characteristics regarding age groups and gender*

	1983		2003		2008		2013	
	n	(%)	n	(%)	n	(%)	n	(%)
Total sample	1012		1542		1800		2244	
No of participants	787	(78)	1146	(74)	1158	(64)	1133	(51)
Age group								
35	279	(36)	284	(25)	207	(18)	198	(18)
50	242	(31)	349	(31)	246	(21)	335	(30)
65	182	(23)	282	(25)	268	(23)	329	(29)
75	84	(11)	231	(20)	247	(21)	145	(13)
85	-		-		190	(16)	126	(11)
Female/male	400/387 (51/49)		591/555 (52/48)		642/516 (55/45)		599/534 (53/47)	

## Drop outs

Of the subject sample included, the percentage of drop-outs regarding both the questionnaire and the clinical examination was 22% in the study year 1983, 26% in 2003, 36% in 2008, and 49% in 2013. The highest non-respondent rate was in the youngest and the highest age groups, and men were more likely not to respond. The most frequent reason for not participating was “not motivated” (particularly in edentulous individuals), illness and transportation problems. In most cases, the reason for not participating was not given. A more complete description of the non-respondents is presented in the different papers. Data regarding age was available for 912 individuals of the total sample in 1983. To be able to create similar age groups, as in the other study years, 125 individuals in the age interval 20-27 years of age were excluded, leaving 787 individuals available for the study. The excluded individuals did not differ socioeconomically, or in oral status, compared with those included.

## Procedure

All the individuals were invited to participate by mail, and received a questionnaire and information regarding the aim of the study. Information about voluntariness was enclosed. The study subjects who returned the questionnaire were offered a clinical examination, free of charge, including radiographs. The clinical examination was performed by the participant’s regular dental practitioner. Individuals with no regular contact with a dental practitioner were offered a referral to a dental practitioner free of their choice.

## Instruments

### Questionnaire variables

The questionnaire consisted of the following number of questions: in 1983, 29 questions; 2003: 63 questions; 2008: 65 questions; and in 2013, 74 questions (including 9 OHRQoL questions). The questions focused on demographic (gender, marital status), socioeconomics (e.g. occupation, financial resources for dental care, education), socio-behavioral factors (e.g. oral hygiene habits, dental care habits, attitudes and demands of dental care, tobacco use), perceived general health and medication.

In 2013, OHRQoL was measured using the Swedish version of OIDP, with the aim of measuring the individual's own experience of oral impact on daily life. The theoretical framework of OIDP was modified from the WHO International Classification of Impairments, Disabilities and Handicaps [138, 139], and amended for dentistry by Locker [140]. A cross-cultural and linguistic validation for the Swedish language has been performed with the purpose of providing it for utilization in research, and the OIDP is considered to be a valid and reliable measure for assessing OHRQoL [141].

### Clinical examination

When performing the clinical examination, a standardized protocol was used with comprehensive written instructions and illustration (Figure 2 shows the different stages of dental caries) on how to complete the examination. Variables used in the clinical examination were variables used in an ordinary dental examination, e.g. the number of existing teeth, intact and filled teeth and MC, occurrence of previous restorations and removable dentures, and probing pocket depth  $\geq 6$ mm were registered. In addition, TMD was determined by three anamnestic questions: "have you constantly or often (once a week or more) problems with ache in the jaws or face"; "are you tired or exhausted (once a week or more) in the jaws when, for example, chewing"; "have you often (once a week or more) problems with open wide or locking of the jaw", based on validated self-reported pain questions [142].

### Radiographic examination

A number of 2-4 bitewing radiographs (if necessary 6) were included in the clinical examination. Two dentists in the project group (one periodontist) established the classification of ABL in 1983, 2003 and 2008, and one dentist (the same as in 2008), and one dental hygienist established the ABL classification in 2013. The classification was based on interproximal bone loss, seen on radiographs, in the premolar and molar regions in both jaws. ABL was divided into three groups, i.e. no ABL, moderate ABL, and severe ABL.

Further details regarding the classification of ABL are presented in the method sections in Papers I and II.

All tooth surfaces were clinically and radiographically examined for MC (primary- and secondary), according to the criteria used by Gröndahl et al. [143], and MC on root surfaces, according to the criteria presented by Nyvad and Fejerskov [144]. Dental caries in the premolar and molar regions were confirmed on bite-wing radiographs by the same individuals establishing the classification of ABL.

## Statistical methods

In *Paper I*, PASW version 18.0 was used. To describe the population, frequencies, mean values and distributions were calculated. To calculate mean values, and for determine differences between groups, t-test was used. For categorical data, in calculations of statistical significance between groups and variables, Chi<sup>2</sup>-test was used. When counts in a cell were less than 5, and to determine if there were non-random associations between two categorical variables, Fisher's exact test was used.

In *Paper II*, SPSS version 19.0 was used. The mean values, frequencies and distributions were calculated. Statistical differences over time were determined by Chi<sup>2</sup>-test, with Bonferroni correction. OR and 95% CI was calculated using multiple logistic regression analyses to analyse the association between socioeconomic and socio-behavioural factors and ABL. Cohen's kappa value was calculated for inter- and intra-individual agreement between the two reviewers who performed the classification of ABL in 2013.

In *Paper III*, the analyses were made using SPSS version 21.0. The mean values, frequencies and distributions were calculated. Statistical differences over time were determined by Chi<sup>2</sup>-test with Bonferroni correction. OR and 95% CI was calculated using multiple logistic regression analyses to analyse the association between socioeconomic and socio-behavioural factors and MC.

In *Paper IV*, the analyses were made using SPSS 21.0. The mean values, frequencies and distributions were calculated. Statistical differences over time were determined by Chi<sup>2</sup>-test with Bonferroni correction. OR and 95% CI was calculated using multiple logistic regression analyses to analyse the association between attitudes and OHRQoL and ABL, MC and TMD adjusting for socioeconomic and socio-behavioural factors.

In all the studies, a p value <0.05 was regarded as statistically significant.

## Ethical considerations

In all the study years, the ethical rules for research were followed, as proposed in the Declaration of Helsinki [145]. The studies in 2008 and 2013 were approved by the Research Ethical Review Board of Uppsala University, Uppsala, Sweden (diary numbers 2007/275, and 2012/405), and a signed content was established at the time of the clinical examination.

# Results

## Paper I

### *Edentulism*

The frequency of edentulous individuals was 15.5% in 1983, and declined significantly to 2.8% in 2008 ( $p < 0.001$ ). In 2008, there were no edentulous individuals below age group 65 years. In 1983, women in the age group of 50 years were edentulous in a higher frequency, compared to men (16.8% vs. 5.3%,  $p = 0.009$ ).

### *Mean number of teeth*

The mean number of teeth was 22.7, in 1983, and was significantly higher, 24.2 ( $p < 0.001$ ) in 2008.

### *Intact teeth*

There were great differences in the mean number of intact teeth between the surveys. In the age groups 35 and 50 years, the mean number of intact teeth was twice as high in 2008, compared with 1983. Large improvements between the two surveys were seen for intact number of teeth by total number of teeth in the age groups 35 and 50 ( $p < 0.05$ ).

### *Decayed surfaces*

The mean number of DS was 0.7 in 2008, and almost three times higher, 2.0 in 1983. The mean number of decayed surfaces per tooth was 0.11 in 1983, compared with 0.03 in 2008 ( $p = 0.0001$ ). Few differences in DS were observed between younger and older age groups.

### *Prevalence of removable dentures*

In all age groups above 35 years, the number of individuals with different types of removable dentures was significantly higher in 1983, compared with 2008. The largest improvement was seen among complete denture wearers, with a decline in prevalence from 14.6% to 1.9% ( $p = 0.0001$ ). In 1983, significantly more women than men in the age group 50 years, wore complete removable dentures (16.0 % vs. 5.3 %,  $p = 0.0001$ ).

### *Periodontal disease (moderate and severe)*

The prevalence of moderate periodontitis declined dramatically from 45% in 1983, to 16% in 2008 ( $p=0.0001$ ), but the prevalence of advanced periodontitis remained similar, with a prevalence of 7% in 1983, and 9% in 2008. In 1983, women in the age groups 35 and 75 years had significantly less moderate periodontitis compared to men, and in 2008, the difference was significant in favor of the women in the age group 35 ( $p<0.05$ ). The results of all clinical variables in the different age groups are presented in Table 2.

Table 2. *Result of clinical variables in the different age groups*

	No of teeth		Intact teeth		Decayed surfaces		Dentures (complete)		Moderate periodontitis		Severe periodontitis	
	mean		mean		mean		%		%		%	
	1983	2008	1983	2008	1983	2008	1983	2008	1983	2008	1983	2008
35	26.2	27.3	9.1	20.7	2.0	0.7	1.5	0	36.9	3.9	1.1	0.5
50	22.3	26.8	5.9	14.0	2.0	0.7	11.5	0	48.2	8.5	10.8	7.3
65	17.6	23.2	5.2	7.1	2.1	0.8	27.1	2.6	54.4	24.0	16.7	17.4
75	13.4	19.9	4.2	4.9	1.9	0.8	49.2	4.5	56.7	24.7	6.7	10.0

## Paper II

In the age group 35-75 years the prevalence of severe ABL was 5% in 2003, and significantly higher, 9% ( $p<0.05$ ), in 2008. In 1983, the prevalence was 7%, and in 2013 it was 6%. In 1983, the prevalence of moderate ABL was significantly higher, 45% compared with 16% in 2008 ( $p<0.05$ ), but in 2013 it was significantly higher, 33% compared with 2008 ( $p<0.05$ ). The proportion of individuals with ABL for the different study years is presented in Figure 4. In the age group 85 years, moderate ABL was significantly higher, 52% in 2013, compared with 23% in 2008 ( $p<0.001$ ). The proportion of individuals with calculus visible on radiographs was 13% in 2003, and significantly higher 32% ( $p<0.05$ ), in 2013. Adjusted for age, number of teeth and socioeconomic and socio-behavioral factors, current/former smoking was the strongest factor associated with ABL in all the study years. In addition, in 2003, single living was associated with ABL. Other socioeconomic factors were found to have limited impact (Table 3). Among smokers, information on tobacco use and its detrimental effect on oral health were reported to have been provided at the last dental visit by 34% in 2003, and increased significantly to 61% in 2013 ( $p<0.05$ ). Information about oral hygiene was reportedly received by 88% in 1983, and decreased significantly to 52% in 2003 ( $p<0.05$ ), and was reported by 57% in 2008 and 65% in 2013.

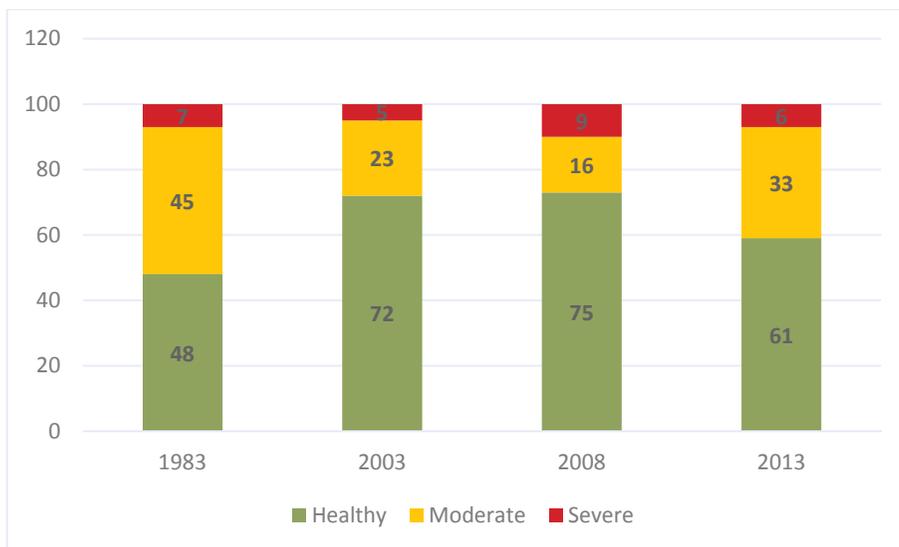


Figure 4. Proportion of individuals with ABL for the different study years (age group 85 years excluded).

Table 3. Result of the multivariate logistic regression analysis

	1983		2003		2008		2013	
	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)	OR	(95%CI)
Smoking	2.75	(1.79–4.23)	3.17	(2.28–4.40)	2.53	(1.83–3.50)	3.22	(2.34–4.42)
Irregular visits	1.61	(0.94–2.76)	1.22	(0.76–1.99)	1.34	(0.80–2.24)	1.19	(0.76–1.86)
Snus	1.47	(0.80–2.71)	1.59	(0.79–3.21)	1.75	(0.86–3.55)	1.19	(0.66–2.12)
Single living	0.98	(0.64–1.51)	1.69	(1.21–2.38)	1.23	(0.88–1.72)	0.87	(0.62–1.22)
Daily medication	0.91	(0.59–1.41)	0.78	(0.56–1.10)	0.84	(0.60–1.18)	1.31	(0.95–1.79)
Financial limits	1.05	(0.17–6.64)	1.47	(0.95–2.27)	1.54	(0.97–2.43)	1.40	(0.85–2.30)
Not working	0.71	(0.43–1.15)	0.86	(0.55–1.34)	1.18	(0.76–1.84)	1.33	(0.90–1.98)

### Paper III

The proportion of individuals with at least one manifest caries lesion (MC) was 58% in 1983, and significantly lower, 40% in 2003, 34% in 2008, and 33% in 2013 ( $p < 0.05$ ) in the age group 35 to 75 years. The mean number of DS was 2.0 in 1983, and significantly lower, 1.1 in 2003, 0.8 in 2008, and 1.1 in 2013 ( $p < 0.05$ ). In the age group 85 years, the mean number of DS was somewhat higher in 2013, 2.4, compared with 1.2 in 2008. The mean number of DFS was 36.6 in 2003, compared with 32.8 in 2013 ( $p < 0.05$ ). In the univariate analysis, associations between MC and irregular dental visits were found in all study years, and limited financial resources for dental care and low level of education were found in 2003, 2008 and 2013, with single living

found in 2003 and 2013, and smoking in 2003. Adjusted for study years, age and number of teeth, socioeconomic and socio-behavioral variables were associated with MC. The OR for the different variables and for the likelihood of having MC is described in Figure 5.

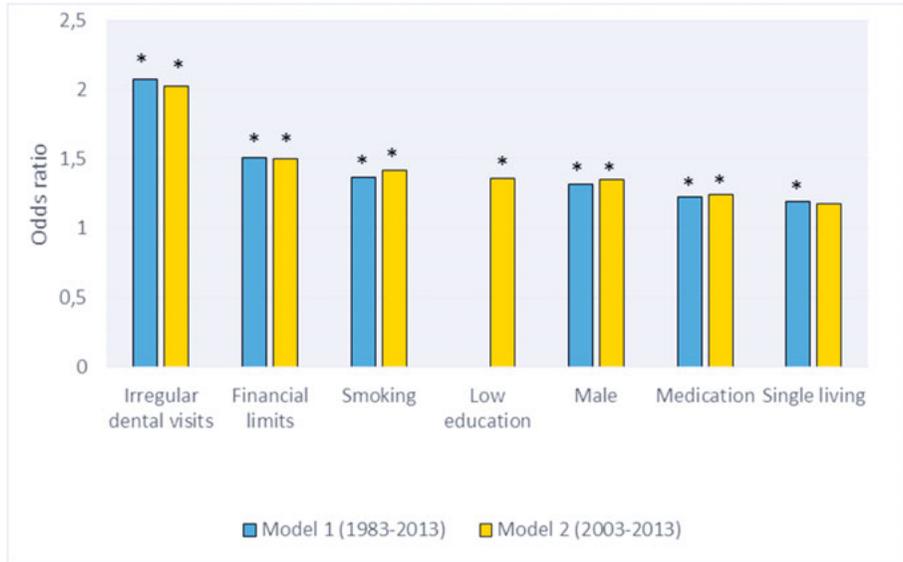


Figure 5. OR for different variables and for the likelihood of having at least one DS. *Model 1*, all variables, except educational level (not investigated in 1983) included, and adjusted for age, study year and number of teeth. *Model 2*, all variables including educational level, and adjusted for age, study year and number of teeth. \* indicates significant difference.

## Paper IV

In the age group 35-75 years the importance of preventive treatment, meeting the same caregiver as on previous visits, and information about treatment cost were reported to a significantly lower degree in 2013, compared with 2003, and 2008 ( $p < 0.05$ ), and regular recalls and safe and gentle treatment were reported as less important in 2013, compared with 2008 ( $p < 0.05$ ). A significantly higher proportion of the participants reported difficulty in booking treatment time in 2013, compared with participants in the two other study years ( $p < 0.05$ ) (Figure 6).

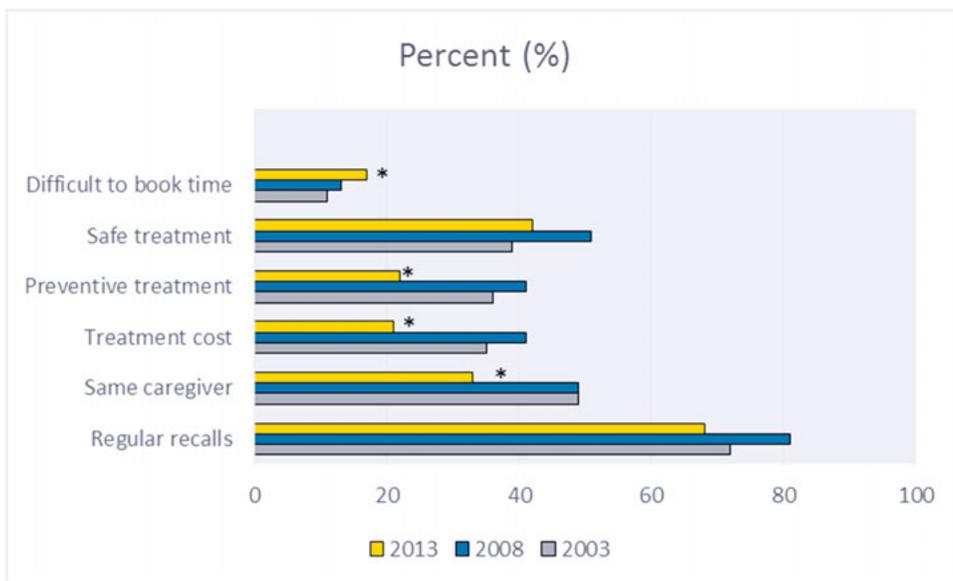


Figure 6. Frequency distributions and changes of attitudes in the different study years and in age groups 35-75. \* indicates significant difference between study years 2003 and 2013 ( $p < 0.05$ ).

In 2003, importance of preventive treatment, regular recalls and safe and gentle treatment were reported by a significantly lower proportion among individuals with at least one MC lesion, compared with individuals without MC ( $p < 0.05$ ). In 2008 and 2013, information about treatment cost was significantly more important among individuals with MC ( $p < 0.05$ ). Individuals with at least one MC lesion reported to a higher degree difficulty in booking treatment time in all study years ( $p < 0.05$ ).

Meeting the same caregiver as on previous visits was reported as important in individuals with ABL, in all study years ( $p < 0.05$ ). Preventive treatment and safe and gentle treatment were reported as important to a lower degree by individuals with ABL, in study years 2003 and 2008 ( $p < 0.05$ ). Regular recalls were reported to a significantly higher degree as important by individuals with ABL, in 2013.

In individuals with TMD, regular recalls were reported to a significantly lesser degree in 2003, and information about treatment cost was reported to a significantly higher degree in 2013, compared with individuals without TMD ( $p < 0.05$ ).

In the age group 85 years, safe and gentle treatment was reported by significantly fewer individuals in 2013 (29%), compared with 42% in 2008 ( $p = 0.029$ ), and booking treatment time was reported as more difficult in 2013, (15%), compared with 3% in 2008 ( $p < 0.001$ ). In 2008, preventive treatment was reported as important to a significantly lower degree by individuals with MC, 19%, compared to 34% among individuals without MC ( $p = 0.030$ ). In

2013, regular recalls were reported as important to a lower degree by individuals with MC, 62%, compared to 86% among individuals without caries ( $p=0.004$ ).

At least one OHR impact was reported by 31% in the age groups 35-85 ( $n=335$ ) in 2013, and frequent OHR impact was reported by 10% ( $n=104$ ). The most frequently reported discomfort was discomfort with eating. A significantly higher proportion (38% and 36%) of individuals in the age groups 35 and 50 years reported OHR impact, compared to 21% in the age group 75 ( $p<0.05$ ). In the age groups 65 and 85 years, 27% and 24%, respectively, reported OHR impact. Irregular dental visits and limited economy for dental care were associated with OHR impact, and when adjusted for age daily medication was associated with OHR impact. Manifest caries, TMD and  $< 20$  remaining teeth were associated with OHR impact, even after adjustment for socioeconomic and socio-behavioural factors (Figure 7).

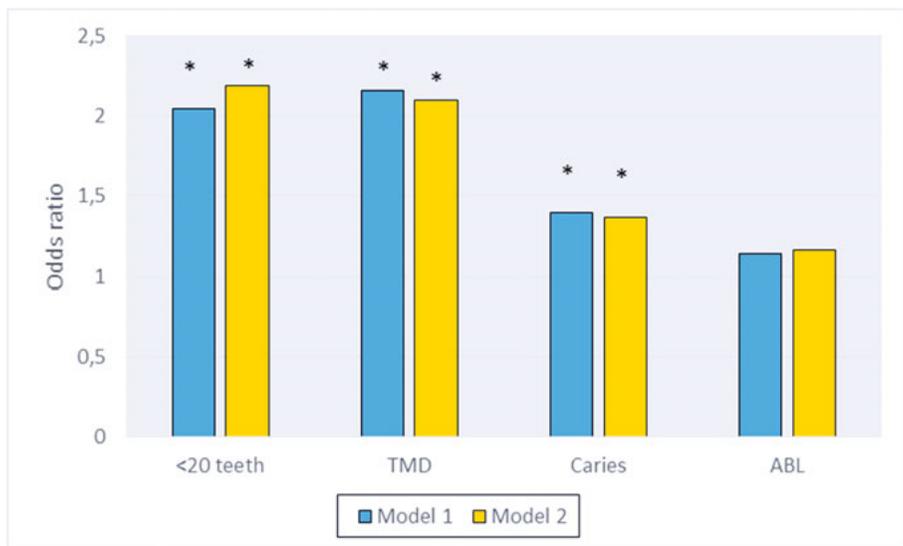


Figure 7. Odds ratios for having oral impact on daily performance. *Model 1*, socioeconomic, socio-behavioral, and clinical variables included in the model. *Model 2*, socioeconomic and socio-behavioral variables included in the model\* indicates significant difference, compared with individuals with  $\geq 20$  teeth, no TMD or MC.

# General discussion

The aim of this thesis is to describe oral health in a 30-year perspective, and assess and consider influences of socioeconomic and socio-behavioral factors. Previous research has focused on biomedical measures to estimate oral health, but during recent decades there has been an increased interest in patients' perspective on oral health. Therefore, OHRQoL was investigated in the most recent study year (2013), aiming to investigate the association between OHR impact and clinical measures of oral health.

## Oral health and disease

During the period 1983-2008, oral status improved considerably, which is in accord with other studies [27, 28]. Manifest caries and ABL decreased considerably, but still affect a relatively large part of the population. It has to be acknowledged that only MC, and not initial caries, was investigated in this study, so there is a possibility that the actual caries prevalence could be higher if initial caries lesions are included. The reason for improvement in oral health can be several, such as: increased access to dental care, improved preventive strategies in general dentistry, and an increased awareness of oral health in the population. In 2013, a new epidemiological study was performed, and a surprising finding revealed a rather substantial increase in moderate ABL, between 2008 and 2013. In comparison with other studies with similar study design and time period [146], the proportion of individuals suffering from periodontal disease in the county of Dalarna was somewhat lower up until 2008. The data in 2013 reveals a somewhat higher proportion of individuals with moderate ABL, compared with a similar study [12], but is in line with others [147, 148]. Furthermore, calculus visible on radiographs has more than doubled between 2003 and 2013. Few studies have reported on the presence of calculus in radiographs in clinically examined patients. However, in a recent study by Norderyd and co-workers (2015), an increase in calculus was found, especially in the age group 20 years [12], and calculus, together with overhanging margins of restorations, was found in up to 41% of the sample, in a study by Ajwani and co-workers [148]. The number of dentists has decreased, and it is difficult to recruit dentists to the rural areas. This has resulted in a greater variety in the tasks for dental hygienists, earlier working mostly with prevention of periodontal disease, including removal of calculus, and has also

resulted in longer intervals between examinations. The majority of the respondents in our study reported visiting dentistry regularly, i.e. intervals no longer than two years. However, these intervals might have been extended due to higher workloads in dental offices. In addition, calculus has been found to be common in adults, increasing with age [36, 37] and often reflects the individuals' oral hygiene. The prevalence of severe ABL has been, more or less, unchanged over this period of 30 years. Although prevalence estimates differ on the basis of how the disease is defined. The prevalence of severe ABL in the present study is in accord with other studies [12, 35, 149].

Dental caries in adults and influencing factors have received little attention in the literature. Between 1983 and 2008, the proportion of individuals with MC, the mean number of DS, and the proportion of DS in relation to the total number of surfaces decreased significantly. In the 1960s, fluoride dentifrices was introduced and it is proposed to be a major factor behind the reduction of caries [150]. The youngest respondents in the 1983 study were born in 1963, and may have used fluoride dentifrice, while the oldest respondents, born at the beginning of the 1900s probably had not. In 2013, the oldest respondents were born in 1928, and probably had used fluoride dentifrice from approximately 30-35 years of age. This might have contributed to the decline in MC over this period of 25 years. However, between 2008 and 2013 no further reduction in dental caries could be found. Moreover, in the highest age group, the mean number of DS was higher in 2013, compared with 2008, indicating a possible break in the positive trend of caries prevalence in this age group, or the beginning of an increase. As discussed earlier, the present epidemiological studies did not investigate the prevalence of initial caries, indicating that the prevalence of caries disease might be somewhat underestimated. A comparable study by Norderyd and co-workers (2015) included initial caries, and the mean number of decayed surfaces was somewhat higher, compared with the present study [12]. The possible break in the trend of declining prevalence of dental diseases needs to be monitored thoroughly in order to find new preventive strategies in the future. This is specifically important for the older age groups as there is evidence suggesting increased caries levels by age, and among older people residing in nursing homes, and also a decrease in routine dental attendance in higher age [73, 74, 151]. Furthermore, the intake of prescribed medicines increased dramatically over this period of 30 years, and people age 80 and over, use an average of 5.8 prescribed medicines each [152]. It is well known that polypharmacy could cause hypo-salivation, which may increase the risk of dental caries [153, 154]. The increase in individuals 80 years and older between 2015 and 2035, is expected to be 76 percent, from 500 000 individuals to almost 890 000 individuals [155], challenging healthcare as well as the dental care.

Oral diseases, including dental caries, is the fourth most expensive chronic disease to treat, according to the WHO, and the cost is considerable to both the individuals affected and the whole of society [15, 71]. Promotion of oral

health is a cost-effective strategy to reduce oral disease and maintain oral health and quality of life. Promotion of oral health among older people, development of oral-health information systems and promotion of research in oral health have been proposed to be particularly emphasized [156].

## Associated factors

During recent decades, there has been an increasing interest in the association between oral diseases and behavior patterns, such as smoking and dental care pattern. Numerous investigations of the relationship between smoking and periodontal disease have been performed [122, 157, 158], and similar to the results in our study, the association is unambiguous. The amount of cigarettes smoked was not investigated, but the association between smoking and periodontal disease seems to be dose dependent, suggesting 9-10 cigarettes or more per day to be the lower limit for an association [84, 159]. The risk for periodontal disease declines after smoking cessation, even if the risk remains elevated for a long period of time [160]. An association between smoking and dental caries is less evident, and an association was found only in the study year 2003. However, in the multiple logistic regression analysis, the association remained, but might be due to other confounding factors, such as dietary habits that were not investigated. An association between snus use, and ABL or MC, was not found, which is in accord with other studies [96, 161, 162]. An encouraging finding was the increase in reported information on tobacco use and its detrimental effect on oral health among smokers, given by dental personnel. Al-Shammari and co-workers found in a cross-sectional study that smokers were significantly less aware of the oral health effects of smoking than non-smokers [163]. This illuminates the importance of tobacco information in dental practice, and, if possible, the offer of information, or referral to smoking cessation. Meticulous oral hygiene is essential in patients with periodontitis, and in patients with caries, dietary habits are also important [55, 164]. Information about oral hygiene decreased between 1983 and 2013, but the reported use of interproximal devices a few times a week, or more, increased. Individuals with ABL used interproximal devices more often, compared to individuals with no ABL, probably due to more frequent dental visits, and SPT aimed at maintaining good oral health behavior. In contrast to other studies [112, 118, 120], socio-behavioral and socioeconomic variables, apart from smoking and single living, in the 2003 study, were not associated with ABL in our study. However, the results accord with the result in a systematic review, concluding that including smoking in the multiple regression model, other socioeconomic variables appeared to be of less importance [122]. This further raises the importance of smoking prevention, encouraging and providing help with smoking cessation. The majority of socioeconomic and socio-

behavioral variables were associated with MC, which is similar to other studies [112, 165-167]. Moreover, inequalities in dental health, due to socioeconomic differences, did not improve after the NDI was reformed in 2008 [168]. As dental caries is a multifactorial disease, strongly correlated with behavioral, social and environmental factors [35, 169], this finding demonstrates the importance of early risk assessment, and continued and improved efforts in promotion of oral health and prevention of dental caries.

## Attitudes, demands and OHRQoL

Knowledge of the patient's attitudes and satisfaction with dental care are important for the development of health strategies, with the aim of improving dental care and developing oral health strategies. Furthermore, the interaction between the patient and the dental care provider is an important part of dentistry. Attitudes and beliefs about oral health and dental care are known to predict oral disease [109, 170], and individuals with a low level of disease have more positive oral health attitudes and behaviors [171-173]. There has been a shift in attitudes and demands towards a less positive view regarding items important for oral health over this period of 10 years. Receiving preventive treatment became less important which is a worrying finding, as the prevalence of ABL has increased and the declining trend in the prevalence of MC seems to be broken. However, in individuals with ABL, meeting the same caregiver and regular recalls were important. Treatment of periodontal disease, and following supportive therapy is a lifelong commitment. The relationship between the patient and the caregiver is crucial, and the interpersonal relationship between the patient and the dental team are of importance in the treatment and control of periodontitis [174-176]. It has emerged that dental hygienists, who most often treat patients with periodontal disease, feel a responsibility to build a trustful relationship with the patient [177]. This, together with the chronic nature of the disease, might be a reason for the desire to meet the same caregiver in individuals with ABL. Information of treatment cost was more important among patients with MC or TMD. Restorative treatment, such as dental fillings, root canal fillings and crown therapy is expensive, despite today's dental care benefit system. Limited financial resources have been found to correlate with dental caries [123] and may be a reason why patients considered information about treatment cost as important. To book time for treatment was reported as more difficult in the 2013 study, compared with the previous study years, and individuals with MC reported difficulties to a higher degree, compared with individuals without MC. Individuals with MC also reported the importance of regular recalls to a lower degree, indicating that they did not visit dentistry on a regular basis, and may not have an established contact with dentistry, aggravating the possibilities of obtaining time for treatment.

OHRQoL has been widely used in order to assess the patient's perspective on oral health, and possible impact on daily life. In this series of studies in the county of Dalarna, this was assessed for the first time in 2013. Approximately, one third (31%) of the sample reported at least one OHR impact, which is somewhat lower, compared to other studies using the same instrument of measure OHRQoL [141, 178]. Socioeconomic and socio-behavioral factors were found to be predictors for OHR impact and there is evidence suggesting that individuals attending dentistry irregularly are more likely to suffer from oral symptoms and less likely to have good OHRQoL [151, 179-181]. This supports the principle of encouraging regular dental attendance for preventive care among older individuals. Temporomandibular disorder and less than 20 remaining teeth were associated with impaired OHRQoL, and this accords with other studies [141, 178, 182]. In contrast to other studies, an association between MC and OHRQoL was found in the present study [178, 183] which needs further attention. Different methodology and diagnostic criteria may be a reason for the discrepancy in results, but MC could be painful and burdensome and it seems reasonable that it has an impact on quality of life. There is evidence that quality of life is negatively impacted by ABL, and periodontal disease measured by GOHAI and OHIP 14 [184-186]. However, this was not confirmed in our study, revealing no association between ABL and OHRQoL, and in accord with another study using the OIDP [178].

## Methodological considerations

One strength with our study was the geographical stratification aimed at reflecting the total population in the county of Dalarna, irrespective of living area. The geographical stratification was the same in all study years, as well as the methodology used. The selection of the various age categories, 35, 50, 65, 75 years, and in the two latter investigations, 85 year olds, was made in accordance with recommendations made by the Swedish National Board of Health and Welfare [11], and in order to obtain data within an age range that could represent the entire adult population in the county. Similar age cohorts have been used in other national and international studies, enabling comparisons regarding oral health [27, 42, 84, 112, 187, 188].

The design of the present series of epidemiological investigations is cross-sectional, and does not say anything about the incidence of disease and the different factors influencing oral health. However, due to repeated cross-sectional studies, we can predict in what direction evolution is going and can form an opinion of the risks associated with oral disease. The questionnaire used in the investigations was expanded during this period of 30 years, as new issues regarding oral health emerged. A pilot study was performed when new questions had been added to test the validity of the questionnaire. Some ques-

tions might have provided recall error, as those concerned received information on the last dental visit, which could have been up to two years, or more, previously, which might result in frailties of memory. However, the questionnaire, with questions which contained multi-item choices, giving suggestions, is proposed to be effective in aiding memory recall, thus obtaining the best possible answer [189]. The questionnaire data was collected before the clinical examination took place, suggesting that the questionnaire reports were not confounded by the dental examination results. The response to some of the questions corresponded well with the result of the clinical examination, which strengthens the internal validity of the questionnaire.

The clinical examination was performed by the individual's regular dental examiner, which means a large number of examiners. This entails a risk of misclassification and, in order to mitigate the risk, the classification of ABL was made by two of the authors. In the most recent study year (2013), a Cohen's kappa analysis was performed, revealing an inter-individual agreement of 0.77, which is considered a substantial agreement [3]. There is a risk of underestimation of marginal bone loss reviewed on radiographs [190], implying a possible underestimation of ABL. All radiographs were reviewed by two of the authors, in order to confirm MC diagnosed by the examiners.

The non-respondent rate increased over the study years, and in 2013 it was 49%, limiting the interpretation of the data. It is reasonable to believe that the non-respondents were not healthier than the respondents, as studies have shown that non-respondents are generally less healthy and more numerous in economically disadvantage groups [191-194], reducing the risk of an overestimation of oral disease.

## Clinical implications

One challenge for dentistry is to retain oral health and to encourage the population to continue practicing good oral health behaviors and dental care habits. Even though oral health in the county of Dalarna has improved considerably, implying that dentistry has had the right strategy concerning prevention and health promotion, there are signs of a decline in periodontal health, and a stagnation in the positive trend concerning caries prevalence. As life expectancy has increased and natural teeth are retained high up in age, the risk of oral disease increases, and caries and periodontal disease have to be monitored. As dental caries and periodontal disease are preventable, and have a negative impact on quality of life, health promotion and prevention are crucial, as well as encouraging to regular dental attendance, and existing efforts need to be highlighted and further developed. Promotion of oral health is a cost-effective strategy in reducing the burden of oral disease and maintaining oral health and quality of life, and should be highly prioritized.

## Conclusions

The mean number of teeth and intact teeth increased significantly between 1983 and 2008.

The proportion of individuals with removable dentures, manifest caries and alveolar bone loss decreased between 1983 and 2008.

The proportion of individuals with moderate alveolar bone loss increased significantly between 2008 and 2013, and smoking was the overall strongest factor associated with alveolar bone loss.

Manifest caries declined significantly between 1983 and 2008, and leveled out between 2008 and 2013, in the age groups 35-75. In the age group 85 years, manifest caries increased between 2008 and 2013. Irregular dental visits, limited financial resources for dental care, smoking, low level of education, male gender and daily intake of prescribed medicine were found to be associated with manifest caries.

Receiving preventive treatment, regular recalls, meeting the same caregiver as on previous visits, and receiving information about treatment cost became less important. The possibility of booking treatment time was reported as difficult, to a significantly higher degree in 2013, compared with 2003 and 2008.

Oral impact on daily performance was reported by approximately one third of the sample, and irregular dental visits, limited economy for dental care, less than 20 remaining teeth, manifest caries and temporomandibular disorder were significantly associated with oral impact on daily performance.

## Future research

In our effort to give inhabitants in the county of Dalarna the best available dental care, based on evidence, the results in our studies highlight the importance of further epidemiological studies, to investigate if there is a break in the trend of improved oral health, regarding alveolar bone loss and dental caries.

OHRQoL, including the severity of OHR impact, as well as attitudes to dental care and oral health need to be further investigated, as it seems that attitudes that are important for oral health and oral health care and behavior, seem to have become less important. This could advantageously be performed with a qualitative approach, e.g. interviews or focus group interviewing to accomplish a better and deeper understanding of the issues concerned.

# Svensk sammanfattning

Syftet med denna avhandling var att beskriva munhälsans utveckling över en 30 årsperiod samt undersöka eventuella samband med socioekonomiska faktorer och tandvårdsvanor. Syftet var också att undersöka attityder till tandvård samt munhälsorelaterad livskvalitet.

Urvalet utgjordes av ett slumpmässigt urval från Dalarnas befolkningsregister om 787-1158 individer 35-85 år, åren 1982, 2002, 2007 och 2012. Studierna utfördes 1983, 2003, 2008 och 2013 och bestod av en enkät och en klinisk och röntgenologisk undersökning.

Studierna visade en väsentlig förbättring av munstatus vad gäller medeltal tänder, intakta tänder och avtagbar protetik under denna 30-årsperiod. Andelen individer med alveolär benförlust minskade signifikant mellan 1983 och 2008 men ökade signifikant mellan 2008 och 2013. Rökning var den faktor som visade sig ha starkast samband med benförlust efter justering för socioekonomiska faktorer, tandvårdsvanor, antal tänder och ålder. Tandsten synlig på röntgen ökade signifikant mellan 2003 och 2013. Andelen individer med manifest karies minskade signifikant mellan 1983 och 2008 och ser därefter ut att plana ut mellan 2008 och 2013. Socioekonomiska faktorer och oregelbundna tandvårdsvanor visade ett signifikant samband med manifest karies. Att få förebyggande tandvård, träffa samma vårdgivare som vid tidigare besök och information om tandvårdskostnad rapporterades som mindre viktigt 2013 jämfört med 2003 och 2008 och svårigheter att få tid för behandling rapporterades av en signifikant högre andel av respondenterna 2013. Vikten av att få regelbundna kallelser rapporterades av signifikant färre respondenter 2013 jämfört med 2008. En tredjedel av respondenterna rapporterade munhälsorelaterad påverkan på livskvaliteten och oregelbunden tandvård, begränsad ekonomi för tandvård, individer med mindre än 20 kvarvarande tänder, manifest karies eller bettfysiologiska besvär rapporterades i signifikant högre grad munhälsorelaterad påverkan på livskvaliteten.

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