CONDITION OF TEETH AND PERIODONTIUM IN THE HOME-DWELLING ELDERLY
- With Special Reference to Level of Education

Päivi Siukosaari

ACADEMIC DISSERTATION

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by the Roman numerals I – IV. In addition, some unpublished results are included.


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This study is part of the longitudinal population based Helsinki Aging Study (HAS). The study population consisted of a random sample of subjects born in 1904, 1909 and 1914 and living in Helsinki, Finland in 1990. Clinical oral and radiographical status along with an interview on background factors, oral health behavior and self-perceived need of treatment were obtained from 364 elderly aged 76, 81 and 86 years at the baseline in 1990-91. Of these 196 were dentate and the 171 dentate who had information on their education formed the baseline study group. Prior to oral examination the participants underwent comprehensive medical examination. Five years later 113 dentate elderly participated in the follow-up examinations. Background information for the non-participation analysis was obtained from the medical HAS records.

To assess any possible non-response bias we evaluated the background factors of the participants and non-participants. The multicausal analysis revealed that the strongest factors explaining non-participation were old age (OR=3.6), being edentulous (OR=2.5), having clinically diagnosed signs of dementia (OR=4.1) and a deteriorated ability to move easily (OR=5.3).

Caries was common among the participants. At baseline 71% of men and 48% of women had decayed teeth. Subjects’ DMFT (Decayed Missing Filled Teeth) index increased during the follow-up mostly as a result of tooth extractions. Although the number of teeth and root surfaces (p<0.05) at risk were higher in the high education groups, no significant differences were found in number of DRS (Decayed Root Surfaces) (0.6 ± 1.3) and RCI (Root Caries Index) (0.13 ± 0.18) in the different education groups. The only factor, which could explain the increment in root caries, was high salivary microbial counts. However, none of the salivary factors examined were directly associated with the level of education.
Many of these participants were also in need of periodontal treatment. The results of the study indicated that there are oral health disparities among this elderly population. The fact that the elderly with higher level of education had more remaining teeth than the elderly with lower level of education explained the finding that better educated elderly also had a greater need for periodontal treatment. During the five year follow-up only slight deteriorating in periodontal health was found, while the differences between education groups remained, indicating that good periodontal health is possible to maintain even with advancing age.

The major chronic oral diseases, caries and periodontal disease, share many common risk factors. While there is much evidence on the prevention of these diseases, the implementation of this knowledge into successful programs for specific groups and populations has been modest. This was also seen in the present study population with high prevalence of caries and periodontal diseases. There is an urgent need for preventive programs against caries and periodontal disease both in the community and individual level because a growing proportion of older adults retain their teeth into old age and the proportion of the older adults in the population is estimated to continue to grow.
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>CAL</td>
<td>Clinical Attachment Loss</td>
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<tr>
<td>CEJ</td>
<td>Cemento-Enamel Junction</td>
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<td>CFU</td>
<td>Colony-Forming Units</td>
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<td>CPITN</td>
<td>Community Periodontal Index of Treatment Need</td>
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<td>DFRS</td>
<td>Decayed Filled Root Surfaces</td>
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<td>DMFT</td>
<td>Decayed Missing Filled Teeth</td>
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<td>DRS</td>
<td>Decayed Root Surfaces</td>
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<td>DT</td>
<td>Decayed Teeth</td>
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<td>HAS</td>
<td>Helsinki Aging Study</td>
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<td>LB</td>
<td>Lactobacilli</td>
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<td>OR</td>
<td>Odds Ratio</td>
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<td>RPD</td>
<td>Removable Partial Denture</td>
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<td>RCI</td>
<td>Root Caries Index</td>
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<td>SDA</td>
<td>Shortened Dental Arch</td>
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<td>SEP</td>
<td>Socioeconomic position</td>
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<td>SES</td>
<td>Socioeconomic status</td>
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<td>SGH</td>
<td>Salivary Gland Hypofunction</td>
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<td>SM</td>
<td>Streptococcus Mutans</td>
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<td>SP</td>
<td>Severe Periodontitis</td>
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<td>WHO</td>
<td>World Health Organization</td>
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1. INTRODUCTION

Demographic changes during the twentieth century have led to an increase in the number and proportion of the population over 65 years old. In Finland 17% of the population is over 65–years old (Official Statistics of Finland 2010). The most rapid growth has been seen in the oldest age groups as life expectancy is steadily increasing. Today most of the older adults are living independently in their own homes and are active users of health care services. The number of home dwelling elderly is expected to continue to increase. The rate of the graying of a population varies in different parts of the world. Finland is at the moment one of the fastest aging nations in the western world (Eurostat yearbook 2011).

Oral health in the elderly has been improving since the 1970s along with the improving general health. In 1990 more than half of the elderly in Finland were edentulous (Vehkalahti et al. 1991). The decrease in the number of edentulous inhabitants is already seen among the younger generations, and the mean number of teeth has been increasing in every adult age cohort. However, with advancing age maintenance of good oral health becomes challenging. Deterioration of motoric functions, impaired vision and moreover, declining cognitive status decreases the ability to maintain proper oral hygiene. Many diseases, and especially their treatment with multiple medications, change the oral environment increasing the risk of oral diseases in the remaining dentition.

There is a clear need to have more information on the oral health status of the older population groups. There is very little information available on oral health, especially of the home-dwelling elderly in Finland.

The Helsinki Aging Study (HAS) was designed as a comprehensive medical follow-up investigation representing three different age cohorts living in Helsinki, the capital of Finland. The oral health component of HAS was intended to cover 10 years providing information on background factors of the various oral diseases among the elderly. Most of the participants of HAS had lived a major part of their lives in Helsinki and were a genetically very homogenous elderly population with
different socioeconomic backgrounds. Socioeconomic position has been reported to be one of the most important factors predicting mortality and accumulation of diseases in many adult populations (Mackenbach et al. 2003). However, its influence on oral health in the elderly age groups is not clear due to the effects of other risk factors. HAS gave an excellent possibility to study the occurrence of oral diseases in the elderly with different socioeconomic backgrounds.

Socioeconomic position has been evaluated with several indicators, of which level of education is one of the most frequently used. Therefore, the level of education was also used in the present thesis. Although oral health in Finland has dramatically improved in general in the last 20-30 years, oral health inequalities still remain, and have even widened in some populations (Suominen-Taipale et al. 2008). A particularly strong association between oral health and education level has been found in several studies (Aromaa and Koskinen 2000, Koskinen et al. 2006, Suominen-Taipale et al. 2008). The present study was based on the working hypotheses that a low level of education increases the prevalence and increment of tooth loss, caries or periodontal diseases among elderly home dwelling individuals.

Due to the attrition of the study population it was not possible to conduct clinical examination after ten-year follow-up and the follow-up articles were limited to contain five-year data. The present thesis contains four separate articles, the first of which describes the background factors affecting non-attendance in the study. The prevalence and increment of root caries as well as periodontal diseases are described in three different publications. Additionally previously unpublished data is presented.
2. REVIEW OF THE LITERATURE

2.1 Gerontology, geriatrics, and geriatric dentistry

**Gerontology** (from Greek: γέρων, geron, "old man" and -λογία, -logy, "study of") is the study of the social, psychological and biological aspects of aging and the aging process itself. The field of gerontology was developed relatively late. However, the huge increase in the elderly population in the post-industrial Western nations has led to this becoming one of the most rapidly growing fields of medicine. It is distinguished from **geriatrics**, which is the branch of medicine that studies the diseases of the elderly (Mosby 2008).

**Geriatric dentistry** or **gerodontics** is the delivery of oral care to older adults involving the diagnosis, prevention, and treatment of problems associated with normal aging and age-related diseases as part of an interdisciplinary team with other health care professionals (Mosby 2008).

2.2 The elderly

It is difficult to say when a person changes from middle aged to old as old age does not have the same meaning in all societies. A person can be considered old because of certain changes in their activities or social roles. Conventionally, a chronological calendar age of 65 years and older is used when referring to elderly persons (Taylor P et al. 2009). In Finland, as in many other western countries, this age is equivalent to the retirement age, and thus commonly used as a cut-off point in national statistics (Official Statistics of Finland 2010). However, chronological age seldom correlates with the biological age. Today many retired individuals have been successful in aging and are fairly healthy and do not perceive themselves as being old. The previously used threshold of 65 years has often been replaced with 75 years and older as many elderly define their 70's or 80's as the time they begin to feel elderly and tend to have more physical needs and functional impairments (Hodgkins 1995). However, the older adults are a very heterogeneous group of people, and an individual’s biological age, chronological age, and state of health...
have to be taken into consideration separately.

There is a plethora of terms used to describe older adults, seniors, gray panthers or the aged. Some of these terms can be discriminatory in nature, and there has been an attempt to define a politically correct word to use when talking about people aged 65 or 75 and older. Gerontologists have found it useful to define individuals who are 65-74 as “the old”, 75-84 old as “the old old” and those aged 85 years and older “the oldest old” (Pifer et al. 1986). In this work “the elderly” is used to describe a demographic group, the population aged 75 or older. “Older adults” have also been used where appropriate.

2.2.1 Demographic changes

In the industrialized countries, life expectancy has increased consistently over the last decades due to improvements in social and living conditions and standards of health care (Official Statistics of Finland 2010). At the same time there has been a decline in fertility. This has resulted in a growing number of older adults as well as a greater proportion of older adults in populations. The rate of the graying of a population varies in different parts of the world. Finland is at the moment one of the fastest aging nations in the western world (Eurostat yearbook 2011).

In Finland the proportion of people aged 65 or older increased from 13.5% in 1990 to 17.6% in 2010. At the moment people aged over 65 have outnumbered those under 16 for the first time ever (Official Statistics of Finland 2010). The older population is on the threshold of a boom at the moment as the first Baby Boomers (the very large age cohorts born during a period of rapid population growth and social change after the Second World War in 1946-1964) reach retirement age in 2010. The population of the 65 and older in 2030 is projected to be twice as large as in 2010, growing from 0.9 million to 1.8 million and representing more than 26 per cent of the total Finnish population at the latter date. The imbalance in numbers between women and men will also continue to increase.

At the same time, the elderly population is getting older, in other words “the aging of the aging”. Mortality rates of those aged 85 years or older are decreasing faster
than in any other elderly age group. The fastest growing age group also in Finland at present is the oldest old (≥85 years). The national population report has shown that in 1950 these oldest old constituted about 0.2% of the total population (n=9 500), by 1994 their proportion was about 1.3% (n= 64 000), and currently 2.1% (n=114 841). According to the population projection their number will almost double by 2030 (n=164 500 (4.1%)), and by 2040 when the Baby Boomers begin to move into this age group, their number has been estimated to be 391 900 (7.3%) (Official Statistics of Finland 2010).

This increase in the elderly population in western countries will have profound consequences to the economy, social and health institutions and services. At present those over 65 years account for one third of the health expenditures in all western nations. Their oral health care will be a demanding challenge, too.

The use of long-term care services increases with advancing age, although the majority of the elderly are living at home. Every fifth older adult over the age of 85 years lives in nursing homes or in service housing with 24-hour assistance, as compared with only one percent of those 65 to 74 years of age (Official Statistics of Finland 2012). In 2009 5.1% of all inhabitants of Helsinki aged 75 or older lived in nursing homes and 5.8% in serving housing with 24-hour assistance. In most countries, older women greatly outnumber older men (Official Statistics of Finland 2010). Elderly men also live with their spouses more often than elderly women. A total of 70% of elderly men are married whereas 70% of elderly women have become widowed in their old age. These very old ladies are often very dependent on the support of their children and the social support of their community (Aromaa et al. 2004).

2.2.2 Health and medication

With increasing age the prevalence of age-related changes and age-associated diseases increase. As a consequence of aging decreases in vision, hearing, muscular strength, bone strength, immunity, and nerve function take place. Muscle mass and nervous system efficiency decrease, causing slower reflex times and less physical strength. As the immune system weakens older people become more susceptible to
infections and diseases.

Arthritis and other musculoskeletal disorders, hypertension, heart disease, diabetes, and respiratory disorders are some of the leading causes of activity limitations among older people (Lawrence et al., 1998). In a Finnish population based study, the Health 2000 Survey, 82% of the elderly had at least one chronic condition, and only one quarter of persons aged 75 or over rated their health as good or fairly good. Almost every other elderly aged 85 or older reported that their health was poor or fairly poor (Aromaa et al. 2004). Elderly individuals born in 1910 and living in eastern Finland had an average of 2.5 (men) and 3.0 (women) diagnosed chronic diseases (Laukkanen et al. 1997). The prevalence of osteoarthritis and walking difficulties grew with increasing age. The prevalence of osteoarthritis increased especially rapidly in men aged 85 or older (Aromaa et al. 2004, Kaila-Kangas 2007).

These conditions were also found in the present study population (the Helsinki Aging Study). Every third subject suffered from ischemic heart disease, angina pectoris, and hypertonia. Chronic pulmonary disease was more common in men (27%) than in women (11%). Musculo-skeletal diseases were found in 40% of the elderly and were the most common cause for disability for every fourth elderly subject. Coronary disease as the main reason for disability was found in every sixth subject (Valvanne 1992). They also had impairments in several mobility categories, these impairments increased with advancing age (Tilvis et al. 1997).

Dementia is the main condition causing cognitive impairment among the elderly, and its prevalence increases rapidly with increasing age. The overall prevalence of dementia doubles for every five-year increase in age after the age of 65 (Lobo et al 2000). In a recent meta-analysis its prevalence in Europe has been estimated to be one per cent in elderly individuals aged between 65 and 69 years, and 29% of those aged 90 years or older (Lobo et al. 2000). In Finland, seven per cent of individuals 65 years or older are reported to have severe dementia (Sulkava et al. 1985), while the prevalence among the 75-year-olds and older is 23% (Rahkonen et al. 2003), and 38% in 85-year-olds and older (Polvikoski et al 2001). In the Helsinki Aging Study the overall prevalence was 14% (Juva et al. 1993).
These changes, even though they are not directly involving oral structures, can still affect oral health due to difficulties in maintaining sufficient level of oral hygiene or accessing dental practices or sustaining the necessary treatment procedures.

Older people take more medications than any other age group. Several studies have shown that the number of medications used by the elderly has been growing during the past decades (Linjakumpu et al. 2002, Jyrkkä et al. 2006). In Finland persons aged 65 or older using medication has increased from 75% in the 1960s (Klaukka 1988) to 90% in the early 2000s (Linjakumpu et al. 2002, Sulander et al. 2004, Jyrkkä et al. 2006). In a recent study the number of medication used increased from 6.3 to 7.5 in a five-year follow-up among elderly aged 75 or older in eastern Finland (Jyrkkä et al. 2006). The prevalence of polypharmacy has also increased up to 67% in the elderly population (Linjakumpu et al. 2002, Jyrkkä et al. 2006), although the World Health Organization (WHO) recommendation is three to four medicines for an elderly person.

2.3. Oral health

Oral health of the elderly has been in the focus of increasing research interest in the past decades. However, earlier studies have almost solely been targeted to the easily available institutionalized subjects, although they are the minority of all the elderly. The oral health of the dependent institutionalized elderly has been reported to be far poorer than the oral health of community dwelling elderly (Mäkilä 1979, Ekelund 1984, Pajukoski et al. 1999, Peltola et al 2004, Chalmers et al. 2005). There are only a few studies on the oral health of home living elderly in Finland. Recent articles by Syrjälä et al (2011, 2012 a,b) and Komulainen et al (2012 a,b) have reported findings of the population based Geriatric Multidisciplinary Strategy for Good Care of the Elderly (GeMS) study, conducted in eastern Finland in 2004-2005.
2.3.1 Saliva and biofilm

Saliva is essential for the maintenance of oral health. Reduction of the flow of saliva increases the risk for oral disease. It has also an important protective role against caries. The complaint of a dry mouth (xerostomia) and the objective finding of salivary gland hypofunction (SGH) are common findings in older individuals, and can produce transient and permanent oral and systemic problems (Locker et al. 2002, Ship et al. 2002, Makhija et al. 2006). An unstimulated flow rate of 0.1 to 0.2 milliliters per minute and a stimulated flow rate of 0.7 ml/minute or less has been agreed to indicate hyposalivation (Sreebny 1992, Navazesh 2003, Dawes 2004 and 2008).

Hyposalivation was once considered to be a normal sequela of aging. However, age-associated changes in salivary composition and flow are minimal in healthy older adults (Wu and Ship 1993, Närhi 1994, Ghezzi et al. 2000). Salivary flow is decreased by systemic medications, diseases and head and neck radiotherapy. Polypharmacy is a major problem in elderly populations, and it is probably a major contributor to xerostomia and SHG (Ship et al. 2002, Chew et al. 2008). Sreebny and Schwartz reported that 80 per cent of the most commonly prescribed medications cause xerostomia, and more than 400 medications are associated with salivary gland dysfunction as an adverse side effect (Sreebny and Schwartz 1997). Närhi et al. found a statistically significant difference in unstimulated and stimulated salivary flow rates between unmedicated persons and those who took four or more prescribed medications daily in the present study population (the Helsinki Aging Study) (Närhi et al. 1992).

Estimates of the prevalence of xerostomia in populations range from 16% to 72% (Osterberg et al. 1984, Locker 1993a, Nederfors et al. 1997, Pajukoski et al. 1997, Thomson et al. 1999, Bergdahl 2000, Thomson 2005). However, Ship and colleagues estimated that approximately 30% of the elderly population suffers from dry mouth and its consequences (Ship et al. 2002). In the present study population 46% of the subjects had noticed subjective symptoms of dry mouth. Continuous oral dryness was reported by 12% of the subjects (Närhi 1994).
Elderly people are often more prone to have increased amount of oral biofilm for several reasons. Reduced salivary flow, and hence fewer antimicrobial factors and slower rate of oral clearance, create a suitable environment for the growth of numerous microbes. Also inadequate oral hygiene permits large numbers of bacteria to accumulate on the tooth surfaces (Närhi et al. 1992, de Baat et al. 1993). The mutans group of streptococci (SM) have a central role in the initiation of caries and lactobacilli (LB) contribute to tooth decay in advanced caries lesions, perhaps in combination with other bacteria of the oral biofilm, although the microbial communities are probably more complex than previously presumed (Krasse 1989, Tanzer et al. 2001, Preza et al. 2008, Aas et al. 2008, Slots et al. 2011). Yeasts are aciduric and acidogenic, and they have been associated with root caries lesions (Beighton et al. 1991, Beighton et al. 1993). High counts of mutans streptococci and lactobacilli are considered risk factors for root caries (Ellen et al. 1985, Preza et al. 2008). Abundant growth of salivary microbes has been detected in the old elderly (Emilson et al. 1988, Klock et al. 1990, Scheinin et al. 1992, Närhi et al. 1993 and 1994). High microbial counts have been also been associated with decreased salivary flow rate (Brown et al. 1978, Närhi et al. 1994).

2.3.2 Edentulism and number of teeth

Although the oral health of the elderly has improved during the last decades in Finland and other industrialized countries, edentulism is still prevalent among older people. There are, however, differences between countries and between geographical regions within countries, as well as between groups with various background characteristics (Bourgeois et al 1998).

During the last decades the frequency of tooth loss has decreased in all age groups, although the rate has been slower in the older age groups (Vehkalahti et al. 1991, Petersen et al. 2004, Suominen-Taipale et al. 2008). In 1970 23% of all adult Finns were edentulous (Markkula et al, 1973) and the number of edentulous older adults (≥ 65) was still growing during the next decade from 54% in 1970 to 67% in 1980 although the total prevalence remained the same (Vehkalahti et al. 1991, Ainamo 1983). In the Health 2000 Survey the prevalence of edentulism was 44% for subjects aged 65 and older and 56% for older elderly 75+ years of age, while the
total prevalence for all adults had diminished to 13% (Suominen-Taipale et al. 2008). In a study on people aged 60-78 years in two different regions in Finland 37% of the subjects were edentulous (Haikola et al 2008).

In the other European countries the percentage of edentulousness has varied between 14% and 78% among the elderly (Ambjörsen 1986, Ahlqwist 1989, Strayer, 1993, Bourgeois et al. 1998, Petersen et al. 2005b, O’Sullivan. 2011). In the US 29% of older adults aged 65-74 years and 40% of 75 and older were edentulous in 1988-1994, ten years later the prevalence had declined to 24% in the younger age group and 31% in the older age group (Dye et al. 2007). The prevalence of edentulousness in Finland has been high compared to the other countries. The UK has been one of the only nations where the number has been even greater. This has changed in the latest national data from UK where the prevalence of edentulism has diminished, although still increasing with age. Only 15% of the people aged 65-74 were edentate compared to 30% of the 75-84 year olds and 47% of the subjects aged 85 or older. That is a clear reduction when compared to previous survey in 1998 when 34% of subjects aged 65-74 and 56% of subjects aged 75 and older were edentate (O’Sullivan 2011).

The concept of shortened dental arch (SDA) was originally introduced by Käyser (1981) and has been further documented by the Nijmegen group (Witter et al. 1999). Having 20 or more functioning teeth describes functional dentition, without the need for prosthetic rehabilitations. In the Finnish Health 2000 Survey only 23% of the elderly subjects aged 65 or older had 20 or more natural teeth when the WHO Oral Health Program goal for this age group was 50% by the year 2000. In UK 40% of dentate adults aged 75 to 84 had 21 or more natural teeth and among adults aged 85 and above only 26% had 21 or more natural teeth (O’Sullivan 2011). The average number of teeth for the dentate subjects aged 75 or more was 13.4 in the Finnish Health 2000 Survey (Suominen-Taipale et al. 2008) This was an improvement from the Mini Finland Study 20 years before, when elderly had only 11 remaining teeth (Vehkalahti et al. 1991) but less than in Göteborg, Sweden where 70 year old adults had on average 21 teeth left and 65% had 20 ≤ teeth) (Österberg et al. 2007).

Tooth retention is increasing among the aging population. This has led to increase
in tooth-related diseases and treatments, and this trend will continue in the future, as there will be still more elderly teeth susceptible to oral disease (Vehkalahti, et al. 1991, Suominen-Taipale et al. 2008).

2.3.3 Caries

The dynamics and progression of dental caries is well established. In conclusion, the prerequisites for caries development are a susceptible host, acidogenic micro-organisms colonizing the tooth surface, and fermentable carbohydrates available in the diet. Root caries has been called a condition that most concerns gerodontologists (Mojon et al. 1995, Curzon et al. 2004), although coronal caries, often around existing restorations, is also an important problem (Mojon et al. 1995, Fure 2003). Caries, especially root caries, has also been found the most common reason for tooth extractions in the elderly (Fure and Zickert 1997, Fure 2003, Richards et al. 2005). Root surface, with its exposed cementum and dentine, is more vulnerable than enamel to “the acid attack” (Stephan curve). The critical pH for demineralization in dentine is approximately pH 6.0, whereas that for enamel is around pH 5.5 (Featherstone 1994).

Several factors are associated with root caries development among the elderly. More root surfaces have been exposed by gingival recession (Budtz-Jorgensen et al. 1996) due to periodontal infection or its treatment and/or vigorous tooth brushing. Periodontal patients have had increased risk for root caries in several studies (Ravald et al. 1986, Saotome et al. 2006, Mattila et al. 2010, Fadel et al. 2011). Increased frequency of intake of fermentable carbohydrates (cariogenic diet) (Steele et al. 2001), poor oral hygiene (Budtz-Jorgensen et al. 1996, Fure 2004, Islas-Granillo et al. 2011), presence of removable denture (plaque retention) (Mojon et al. 1995, Locker 1996, Steele et al. 2001, Nevalainen et al. 2004), and cognitive status (Avlund et al. 2004) are all known risk factors. Patients with dry mouth are an easily identified risk group, as they are consistently in the highest risk category (Curzon and Preston 2004). Studies have supported the multifactorial nature of root caries, thus attempts to develop caries prediction models have been difficult to do accurately (Curzon and Preston 2004, Sánchez-García et al. 2011).
The different study designs, diagnostic criteria, reporting methods, indexes used in clinical examinations and diversity of study populations make it difficult to estimate the prevalence, and also the increment of root caries. Some of the studies have reported only root decay while others have reported decayed and filled root surfaces. The prevalence of root caries in Scandinavia varied between 35-80% (Kirkegaard et al. 1986, Salonen et al. 1989, Fure et al. 1990, Fejerskov et al. 1991, Heegaard et al. 2010, Morse et al. 2002) in dentate subjects aged 60 and older. The mean number of root surface fillings ranges from 2.1 to 9.2, and the mean number of active caries lesions varied between 0.9 and 3.5 in these studies. In the USA 49.7 percent of people 75 years or older had root caries affecting at least one tooth (NHANES III, NCHS 1996). In a review by Fejerskov et al. (1993) the prevalence of decayed teeth was estimated to be altogether 30-40% in Scandinavia during the decade prior the present study. A review by Bourgeois and co-workers (Bourgeois et al. 1998) showed that the decayed teeth (DT) value varied between 0.4-3.2 in the 65-74 year old population in Europe. In a national survey in Finland, the prevalence of root caries was 32% in men and 27% in women over 70 years. The prevalence increased with age and it expressed the occurrence of primary root caries only (Vehkalahti 1987). The total DT was 2.5 in the population aged 65+, and the caries prevalence 68% in men and 65% in women. In another national health survey twenty years later DT was only 1.1 at the same age group and the caries prevalence had declined to 31% in women, but the prevalence in men was still 51% in the same age group (Suominen-Taipale et al. 2008).

In a five-year follow-up of a group of Swedes aged 55, 65 and 75 years at the beginning of the study the increment in decayed and filled root surfaces increased with age from 1.4 in the 60-year-olds to 2.4 and 5.5 in the 70- and 80-year-olds (Fure et al. 1990). Fure (Fure 2003, Fure 2004) also showed that the incidence of coronal caries decreased with age, while the incidence of root caries increased. In a ten-year follow-up of the same group, all the 85-year olds developed new root caries lesions, and the mean increment in DFRS (decayed and/or filled root surfaces) increased with age from 5.3 to 8.1 and 14.3 among the 65-, 75- and 85-year-olds.
2.3.4 Periodontal diseases

The two most prevalent periodontal diseases are plaque induced gingivitis (a reversible inflammatory condition of the gingiva without loss of connective tissue attachment) and chronic periodontitis (the presence of gingival inflammation at sites where there has been apical migration of the epithelial attachment onto the root surfaces accompanied by irreversible loss of connective tissue and alveolar bone) (Armitage 1995).

Chronic periodontitis is also a multifactorial disease, where short periods of tissue destructions are followed by longer periods of inactivity. The dental biofilm has an important role in the onset of the disease but a number of host-related factors have an impact on the presentation and rate of progression of the disease (Heitz-Mayfield 2005). Susceptibility to periodontal diseases varies greatly and is dependent on host responses to pathogens (Colonna-Romano et al. 2008). Smoking (Beck et al. 1990, Tomar and Asma 2000) and diabetes mellitus (Sandberg et al. 2000, Soskolne and Klinger 2001) appear to be the most significant factors in modifying the host’s response to a biofilm infection (Heitz-Mayfield 2005). However, a recent study did not find any differences in periodontal status between diabetics and non-diabetics in an older population with a high incidence of periodontitis. The authors suggested that periodontitis in older subjects might approach similar levels regardless of whether they have diabetes mellitus or not (Persson et al. 2003).

Already in 1975 Holm-Pedersen (Holm-Pedersen et al. 1975) showed that in the absence of oral hygiene gingivitis developed more rapidly in the elderly than in young subjects. However, no difference was observed in the rate of healing (Holm-Pedersen et al. 1975, Lindhe et al. 1985). It was also observed that plaque formation was more abundant among the elderly. A decreased host response to plaque microorganisms with advancing age has been suggested to lead to increased inflammatory reaction in the gingiva of the elderly (Page 1984). The greater accumulation of plaque is most likely related to the increased oral surface area available for plaque retention due to greater amount of gingival recession seen in the older person. Abdellatif and Burt evaluated the effect of age and oral hygiene on periodontal disease progression using data from the first National Health and
Nutrition Examination Survey (NHANES I, 1971-1974). Their conclusion was that the effects of age on periodontal disease progression could be considered negligible when good oral hygiene is maintained (Abdellatif et al. 1987). Thus, good oral hygiene is especially important for the dentate elderly, but despite their best cleaning efforts it is often inadequate (Morris et al. 2001, Artnik, et al. 2008, Suominen-Taipale et al. 2008).

The prevalence, extent and severity of periodontal disease has been found to increase with age, although this relationship is thought to be more related to the cumulative periodontal breakdown over time rather than factors related to the aging process itself (Albandar et al. 1999, Albandar 2002, Nunn 2003, Stanford et al. 2003, Albandar 2005). In a general review of periodontal diseases affecting older adults Locker and colleagues found that advanced periodontal disease does affect a relatively small percentage of adults and is more common in older people (Locker et al. 1998). The results of the prevalence studies are difficult to compare due to differences in the age of the subjects included, their general health and study methods used. Current epidemiological evidence indicates that mild gingival inflammation is common, many adults have mild to moderate loss of periodontal attachment at some sites of some teeth and a substantial minority have some advanced loss, often in relatively few sites (Locker et al. 1998, Sheiham et al. 2002). This was also confirmed in a recent study in the US (NHANES 2009-2010) where 70.1% of older adults aged 65 and older had periodontal disease. Mild periodontal disease was found in 5.9%, moderate in 53% and 11.2% of these elderly had severe periodontal disease (Eke et al. 2012).

In a national study in Finland 70% of people aged 65 and older had periodontal pockets ≥ 4 mm and 31% had pockets ≥ 6 mm (Suominen-Taipale et al 2008). In a recent article by Syrjälä and colleagues analyzed the same subpopulation further: 28% of the participants had one to three teeth with periodontal pockets deeper than 4mm, 15% had four to six and 26% had more than seven. One to three teeth with deep periodontal pockets (≥ 6 mm) were found in 23% of the participants and 8% of the participants had more than 4 teeth with deep periodontal pockets (Syrjälä et al. 2010),
2.3.5 Oral health behavior

Oral biofilms play a major role in the etiology of periodontal diseases, dental caries, and other oral diseases. Self-performed and professionally administered control of oral biofilms, and use of fluoride toothpaste are important in the prevention of these diseases (Löe 2000, Beikler et al. 2011, Flemmig et al. 2011).

The most common way of removing plaque at home is tooth brushing (Attin et al. 2005). The recommended frequency is brushing teeth twice a day (Löe 2000), combined with the removal of interdental plaque once a day (Axelsson 1993, Claydon 2008). Although this concept is widely recognized, only part of the dentate population follows these recommendations. In industrialized countries 40% to 97% of elderly subjects report following this recommendation (Davidson et al. 1997, Kelly et al. 2000, Morris et al. 2001, Christensen et al. 2003, Hugoson et al. 2005, Suominen-Taipale et al. 2008). Tooth brushing twice a day has become considerably more common among adult and elderly subjects during recent decades. In Finland, the change has been particularly noticeable among elderly women aged 65 and older: twice daily brushing has increased from 45% in 1980 to 69% in 2000, although the change in men was much smaller, from 32% to 39% (Suominen-Taipale et al. 2008).

Unfortunately effective cleaning of teeth is often difficult. Older people seem to be generally well informed of the importance of good oral and dental hygiene and their effect on oral health, but are less aware of the poor results despite their best effort. There are many reasons for this: diminished motivation, impaired cognition and/or reduced sight, sense of touch, vision or manual dexterity can often result in an inadequate level of oral hygiene (Vigild 1988, Ekelund 1989, Murtoma et al. 1992, Mojon et al. 1995, Nevalainen et al. 1997, Bellomo et al. 2005,). In the Health 2000 Survey 40% of elderly women and 22% of men had clean teeth, but 14% of women and 30% of men had an abundant amount of plaque, there was no difference between different educational groups (Suominen-Taipale et al. 2008).

Age seems to have very little direct influence on the oral health behavior established early in life (MacEntee et al. 1993).
2.4 Socioeconomic position (SEP)

Socioeconomic position (SEP), socioeconomic status (SES), or social class can be ascribed at birth, but is often modified by person’s own achievements, typically through education, occupation, or income. Social class as such cannot be measured comprehensively. Instead, indicators are used and they are typically based on educational attainment, income, wealth, or occupation. Although none of these indicators is ideal, they all relate to health in diverse ways (Braveman et al. 2005, Shavers 2007).

2.4.1 Level of education

Level of education is the most frequently used indicator. It has been called the most basic component of SEP and it has several advantages (Adler et al. 2002). It is comparatively simple to measure, it can be recorded for everyone regardless of age and whether working or not, and it is less likely than occupation or income to be influenced by health (Galobardes et al. 2006). Level of education usually remains fairly stable after early adulthood. It has a direct effect on other SEP components as it determines a person’s employment status and earning potential. There are several pathways through which education can influence health status indirectly (Braveman et al. 2005, Shavers 2007). Education reflects general and health-related knowledge, as well as problem solving skills. Persons with higher education are more likely to have health-promoting behaviors and lifestyles, and they have also better access to and use of health care services (Adler et al. 2002). More educated people are also better able to communicate with their physicians and interact with the health care system, and make informed choices among treatment options. The relationship between education and oral health behavior has been reported to be stronger than the relationship between income and oral health behavior. It has been suggested that the differences in attitudes, knowledge and traditions are more important than economic factors in explaining the impact of SEP. However, there are some limitations to use of education to assess SEP: its meaning changes across birth cohorts, and the quality of the education is not taken into consideration (Galobardes et al. 2006).
2.4.2 Income

Income is the indicator of SEP that is directly related to material goods, resources and conditions of an individual (Lynch 2000). Better income means better possibilities to pay for health care, higher incomes also provide better nutrition, housing, schooling and recreation (Adler et al. 2002). However, income is difficult to measure in studies due to its sensitive nature. Nonresponse for income is often higher than nonresponse rates for other variables (Turrell 2000). Especially among the retired other aspects of wealth, as well as other sources of income and the total income of the family, have an effect of on the amount of the money at their disposal. Income for older adults may be a less reliable indicator of their true SEP because income typically follows a curvilinear trajectory with age (Galobardes et al. 2006).

2.4.3 Occupation

Occupational classifications based on skills, prestige, social influence and/or power are commonly used for analysis linking social class and health. It reflects a person’s place in society, combining the effects of income and intellect (Galobardes et al. 2006). Unfortunately it is difficult to classify people who are not working but not unemployed, such as retired people and housewives. Although previous occupation can be used for those who are retired or a husband’s occupation for a wife’s to assign SEP, this may inadequately index current social circumstances (Galobardes et al. 2006).

2.4.4 Level of education in Finland

The average educational level has significantly improved in Finland during the past decades. The proportion of adult population with only primary level education has decreased from 75% in 1970 to 50% in 1990 and further to 33% in 2010. Concomitantly, in 1970 only 9% of the adult population had the highest level of education. In 1990 the percentage was 18% and by 2010 it has reached 24%. In 1990 11% of people aged 75 or older and living in Helsinki had received university degrees, 17% had finished intermediate school and 72% had no degree or no
information on their education (Official Statistics of Finland 2010).

2.4.5 SEP and oral health

SEP is linked to morbidity, mortality, health behavior and also to disparities in oral health. Despite improvements in the oral health of the overall population during the past years, disparities remain in some population groups as classified by sex, income, age, and race or ethnicity. Level of education was strongly and consistently associated with nearly all indicators of health and functional capacity in the National Health 2000 study (Aromaa et al. 2004). The association between oral health status and educational level has been analyzed in a number of epidemiological studies, however, only a few of them have been conducted on older adults.

Dental care habits are established early in life and are highly influenced by the level of education of the mother of the family (Wierzbicka et al. 2002). The relationship between education and oral health behavior has been shown to be stronger than the relationship between income and oral health behavior, suggesting that the differences in attitudes, knowledge and traditions are more important than economic factors in explaining the impact of socio-economic status (Petersen 1990, Ronis et al. 1993).

Epidemiological studies show that edentulism is highly associated with socio-economic status. Individuals with little or no education, of low social class or income, and living in rural areas are more likely to be edentulous than persons of high social class, high level of education and income and living in urban area. The mean number of remaining teeth has also been higher among subjects with higher SEP (Slade et al 1993, Drury et al. 1999, Palmqvist et al. 2000, Aromaa and Koskinen 2002, Paulander et al. 2003, Petersen et al. 2005b, Suominen-Taipale et al 2008, Haikola et al. 2008).

The prevalence of caries is higher in certain subpopulations (Pitts et al. 2011). Although social disparities have been reported with children and adults, less
attention have been paid to older adults. Children with lower SEP experience higher rates of dental caries and untreated disease than do their more advantaged peers (Edelstein 2002). Adults aged 35–44 years with less than a high school education in the US experience untreated tooth decay nearly three times that of adults with at least some college education. Adults with lower SEP (measured by educational attainment and family income) were 6.1 times more likely to have untreated coronal decay and 7.2 times more likely to have untreated root caries in a large US study (NHANES III) (Drury et al. 1999). People with less education had fewer sound and filled teeth and more caries than had the subjects with the most education also in the National Health 2000 study in Finland: the percentage of subjects with carious teeth (DT>0) was clearly higher among subjects with a basic education (39%) than those with higher education (20%) (Suominen-Taipale et al. 2008).

Various symptoms of periodontal diseases have been associated with the level of education. Gingivitis (Oliver et al. 1998) and attachment loss have been found more often with subjects of low level of education (Österberg et al. 1986, Oliver et al. 1991 and 1998, Locker and Leake 1993, Burt and Eklund 2005). Several studies have used the Community Periodontal Index of Treatment Need (CPITN) to assess periodontal disease (Corbet et al. 2001, Dye and Vargas 2002, Shah and Sundram 2003).

In the National Health 2000 study the association between prevalence of periodontitis and educational level varied between age groups. In the younger age group (35-44) men with a basic education more often had periodontitis than men with a higher education (72% vs. 61%). The association was reversed the in older age group (55-64); periodontitis was more common in the higher than the basic education category (71% vs. 86%). The respective figures were 54% vs. 50% and 59% vs. 72% in women. Similar patterns were also seen in prevalence of the severe form and severity of periodontitis (Suominen-Taipale et al. 2008). The older adults (65≤) were further analyzed by Syrjälä and colleagues (2010). The older adults with higher education had a high need for periodontal treatment whether measured by gingival bleeding or probing depth.
3. HYPOTHESIS AND GENERAL AIMS

Many epidemiological studies on the elderly have been conducted on the targeted population. The results of the restricted samples cannot be generalized to the entire population of old people. This study was designed to evaluate the oral health of the home-dwelling elderly taking into consideration subjects’ background factors, state of health and functional capacity.

This study is based on the working hypothesis that low level of education is associated with an increasing risk of oral diseases in the elderly.

The following specific aims were set:

- to study the background factors related to non-attendance in a cross sectional population based oral health investigation of the elderly inhabitants of Helsinki

- to study the association of the level of education and salivary findings on the occurrence and increment of caries among the elderly inhabitants of Helsinki

- to study the association of the level of education on the occurrence and increment of tooth loss and periodontal diseases among elderly inhabitants of Helsinki
4. SUBJECTS AND METHODS

4.1 Study population

This study forms a part of a comprehensive longitudinal medical and oral health survey, the Helsinki Aging Study (HAS). HAS is a population-based prospective birth cohort study, which was designed to study the prognostic significance of various clinical findings in the elderly population of Helsinki, Finland.

In January 1989, a randomized sample of prospective age cohorts (n=8035), 300 subjects in each age group, born in 1904, 1909 and 1914, were selected for the HAS from the public register (Valvanne 1992). The sample was representative by gender and street address. The two oldest age groups were disproportionate to their share in the general population in order to achieve a sufficient participation rate for these age groups. From this sample, 795 were located and 651 (82%) participated in the medical examinations. The medical study was carried out from 1989 to 1990. (Figure 1)

One year later, participants of the medical study were invited to the baseline clinical oral examination. Fifty-one subjects had died between initial selection and participation in the oral component, so 600 were eligible to participate in the oral examination. An invitation letter introducing the oral study was sent to the subjects and an appointment for the interview and clinical and radiological oral examination at the Institute of Dentistry was scheduled by a phone call. If a subject was not reached after several attempts, one reminder letter was sent, with a short questionnaire and a pre-paid return envelope.

Subjects at the baseline

Of the 600 invited, 364 subjects (61%) (196 dentate and 168 edentulous) aged 76, 81, and 86 years, were examined in 1990-1991. Of the 364 elderly who underwent oral examination, 293 were examined at the Dental Clinic in the Institute of Dentistry, University of Helsinki, and 71, who were unable to come to the Institute of Dentistry either due to poor general health or due to transportation difficulties,
were examined in their homes, in old people’s homes, or in hospitals. The participation rate was 69% for men and 58% for women. The 196 dentate subjects formed the study population for Study II (Figure 1).

Non-participants at the baseline

Oral health information for 133 subjects who failed to participate in the clinical examination was obtained by a phone interview (n=67), mail survey (n=61), and from their own dentists (n=5). However, no information could be obtained for the remaining 103 subjects; 3 had deceased before the dental examinations started, 50 were institutionalized or too ill to participate, 20 refused to participate and 30 could not be located or had moved from Helsinki. Of the 364 subjects who took part in the clinical oral examination 305 subjects, and 124 out of 133 subjects with non-clinical oral data, were home-dwelling. This information was used to evaluate the factors related to non-response of the home-dwelling subjects in Study I (Figure 1).

Figure 1. Participants at the baseline and follow-up.
Subjects at the follow-up

Five years later all the participants of the clinical oral examination were invited to a follow-up examination. A letter describing the follow-up study was sent to all the available subjects (n= 250), and this was followed up by telephone to arrange appointments for clinical examinations. If a subject could not be reached by phone, another letter was sent and attempts were again made to contact them by phone. In total, 113 dentate subjects were examined and 73 dentate home-dwelling subjects with information of their level of education formed the study group in the follow-up examination.

Information on the level of education was available for 176 dentate elderly who formed the baseline population for study III. Of these subjects 71 participated in the follow-up examination 5 years later (Figure 2).

Figure 2. Participants in Study III.

A total of 170 dentate elderly had given information on their level of education and were eligible for the baseline periodontal examination using CPITN. Of the 170 baseline participants 73 participated in the follow-up examinations and a further 57 subjects met the criteria for follow-up periodontal examination. The remaining 16 subjects could not be included either because they did not have at least one sextant
with two functioning teeth, required antibiotic prophylaxis or were too fragile to take part in the clinical periodontal examination. A total of 67 subjects were examined radiographically during both the baseline and follow-up examinations. At the baseline 18 panoramic radiographs were supplemented with 19 intraoral radiographs and three panoramic radiographs were repeated. Two panoramic radiographs were supplemented with two intraoral radiographs and none were repeated in the follow-up study. These subjects formed the study population for study IV (Figure 3).

**Figure 3.** Participants in Study IV

The subjects in different age groups were pooled together for the statistical analyses as there were no significant differences in clinical parameters between different age groups at the baseline in Studies III and IV. For the periodontal data analysis the elderly in the lowest education level (group 4) were merged with group 3 due to the low number of elderly in group 4 in Study IV.
4.2 Methods

4.2.1 Medical examination and interview

Data from the medical interview and clinical examinations performed a year earlier were available for this study. Information on subjects’ housing conditions: at home or in an institution, alone or with his or her own family, and furthermore, his or her marital status, level of education, former line of work, self-perceived health level, presence of clinically diagnosed dementia and memory disturbances, level of hearing, and ability to move were gathered by the interview. The interview also included the question: "Do you have any of your own teeth left?" The answers served to describe the non-participants' dental state. The information on subjects’ medication was also obtained from the medical examination records.

4.2.2 Questionnaire

Prior to the baseline clinical oral examination the examiners reviewed the previously mailed and prefilled (by the subject) questionnaires together with the patients. Any unanswered questions were filled together with the subject. A similar protocol was also followed in the follow-up examination. This structured questionnaire was used to obtain information on subjects’ education, former occupation, oral health behavior, self perceived oral health and self rated gingival bleeding, periodontal treatment need and diet.

Level of education

The strategy developed by Helsinki City Statistical Center (Bruun 1954, Järvenpää 1964) based on the highest level of education and number of school years was used when the subjects were divided into four educational groups.

Level of education group 1 - High school and college/university degree (more than 12 years of education)
Level of education group 2 - Intermediate education (7-11 years of education);
Level of education group 3 - Elementary school and vocational training (4-6 years of education)
Level of education group 4 - Less than 4 years of education.

The subject’s last occupation was used in cases where the subject could not recall the number of school years. Groups 1 and 2 were combined to form the higher education group and 3 and 4 were combined to form the lower education group. Information was missing for 6 participants at the baseline.

4.2.3 Oral examination

A comprehensive oral examination carried out for each participant consisted of a detailed saliva samples, clinical oral examination, full mouth radiological examination, and a questionnaire. The examinations took an average of two hours per subject. The baseline examinations were carried out at the University Dental Clinic by four faculty members. The examiners were calibrated to eliminate inter- and intra-examiner errors. The clinical examination took place in a dental chair, using a standard operating light, a dental mirror, a dental explorer, and a WHO CPITN probe.

The follow-up clinical examination was performed by one of the original examiners and two other faculty members. They underwent training prior to the follow-up examinations.

Saliva was collected before the clinical examination in the morning. Unstimulated saliva secretion rate was measured first by the draining method (Birkhed et al. 1989) and after that stimulated salivary flow rate was measured. The measuring time was 5 minutes for both measurements and the rate was recorded as ml/min. Due to impairment in motor or cognitive skills, saliva collections were difficult to perform for some subjects but they were successfully completed in 167 subjects.

Stimulated whole saliva was used to estimate the buffering capacity by using a Dentobuff-strip method (Orion Diagnostica, Espoo, Finland) for 159 subjects. The
results were classified into three groups by final pH: low \( \leq 4.0 \), intermediate = 4.5–5.5, and high \( \geq 6.0 \).

Salivary microbial (mutans streptococci, lactobacilli and yeast) counts were analyzed using commercial kits and according to the manufacturers’ instructions. Counts of salivary mutans streptococci were determined by the Dentocult-SM strip mutans® method. The results were categorized into four groups ranging from no growth to \( 10^6 \) colony-forming units per milliliter of saliva (CFUs/ml). Dentocult LB method® (Orion Diagnostica) was used to assess the counts of salivary lactobacilli. Growth density was categorized into five groups ranging from no growth to \( 10^6 \) CFUs/ml of saliva. Salivary yeasts were counted using the Oricult-N method® (Orion Diagnostica). Yeast counts were placed into four subgroups: 1=no visible growth, 2=1–20 colonies, 3 = 21–50 colonies, 4= 50 yeast colonies per one side of the slide (Budtz-Jørgensen, 1976). Counts of SM were estimated for 156 subjects, counts of LB and yeasts were assessed for 161 subjects at the baseline.

During the clinical oral examination, the total number of remaining teeth and the presence or absence of a removable denture (RPD) was recorded. The subjects were classified as edentulous if no natural teeth or roots were clinically present in the mouth. In all other cases the subject was categorized as dentate.

The presence of coronal and root-surface caries were recorded separately. For the diagnosis of caries lesions WHO recommendations were followed and a DMFT (Decayed Missing Filled Teeth) index was calculated (WHO 1997). Root surfaces with gingival recession of 1 mm or more were diagnosed as exposed, and their status was recorded using the definitions described by DePaola et al. (1989). Frank cavitations and secondary caries lesions on these surfaces were considered as root caries (Decayed Root Surfaces, DRS). Root surface status was recorded from 183 participants without any additional cleaning before the examination. Calibration on 19 subjects by 2 examiners resulted in high interexaminer agreement for both exposed root surfaces (93%) and their status (89%).
Root caries increment was calculated as the difference between the final and baseline values. Root Caries Index (RCI) was also calculated measuring root caries experience by relating the DRS to the number of exposed surfaces (Katz 1980).

Periodontal health status was assessed using the Community Periodontal Index of Treatment Needs (CPITN) (Ainamo et al. 1982). The sextants of dental arches were given one of five codes. If the sextant was healthy it was given code 0, code 1 if bleeding on probing was observed, code 2 if supra- and/or sub- gingival calculus was present, if one or more tooth in the sextant had 4–5 mm pockets, code 3 was used and code 4 if a pocket was 6 mm or deeper. The periodontal examination involved recordings on all surfaces of all the teeth. Recordings were made only for sextants containing at least two functioning natural teeth. The sextants were scored based on the worst finding, missing sextants were recorded separately and their number included in the data analysis. In this study, participants with the worst score of codes 3 or 4 were classified as having periodontal disease.

The radiological examination consisted of a panoramic radiograph supplemented by intraoral radiographs. The radiographs were exposed at the Department of Oral Radiology, Institute of Dentistry, University of Helsinki, before the subject’s oral examination, following the same protocol both at baseline and follow-up. Panoramic radiographs were taken with PM 2002 CC-radiograph equipment (Planmeca Co, Helsinki, Finland). GTU X-ray film (3M) and a Trimax T-16 intensifying screen were used. The quality of the radiographs was evaluated immediately after processing and intraoral radiographs from poorly visible areas in the panoramic radiograph were taken with a Siemens Heliodent 70 dental radiographic unit and Kodak Ultra-speed X-ray film. Automatic processing was used to develop the films. Two faculty members of the Department of Dental Radiology studied the radiographs under standardized conditions using Mattson’s binoculars and a viewing light of adjustable brightness when necessary. The presence of calculus and overhanging restorations, number of furcation lesions and number of teeth with vertical infrabony pockets and horizontal bone loss were also recorded. The extent of horizontal bone loss and the depth of infrabony pockets were observed at the site where they were most advanced in relation to the roots of the teeth.
4.3 Statistical analysis

Statistical analyses were performed with the statistical software program SPSS© (Version 15.0), the Glim3 computer program and Stat View for Windows program. In general, non-parametric tests were used for the evaluation of continuous variables, which followed normal distribution. Parametric tests were used for the data that were not normally distributed. Associations between two distributions were evaluated with Mann-Whitney U-test. The unpaired t-test was used to evaluate differences in mean values between two groups, whereas the paired t-test was used to study the differences in mean values between baseline and follow-up studies. ANOVA with appropriate post hoc evaluation was used to study the differences among several means. The level of significance was set to 95%. Non-parametric tests were used for the data that was not normally distributed. The Mann-Whitney U-test was used to compare two population means. Multivariable models were fitted to study the significance of several variables while controlling the rest of the factors. More detailed descriptions of the statistical analyses are given in the original publications.

4.4 Ethical aspects

Informed consent was obtained form all subjects prior to the study. The ethical committees of the Institute of Dentistry, University of Helsinki and the Helsinki University Central Hospital approved the study.
5. RESULTS

5.1 Attendance (Study I)

The mean age for all home-dwelling subjects in the oral sample was 80.0 years. The mean age for the clinically examined ones was 79.4 years, 80.7 years for those with non-clinical oral data only, and 81.8 years for those with no oral data at the baseline. The majority of the participants (68%) were female both at the baseline and follow-up, and more than half of the participants belonged to the youngest age group (54% at the baseline and 65% at the follow-up).

Age was one of the strongest factors affecting participation rate in the clinical oral examination at the baseline. The youngest age group was over-represented: 75% of the 76-year-olds participated in the oral examination but only 53% of subjects aged 81 or 86 years (P<0.001). Living close or within easy reach by public transportation of the Institute of Dentistry also strongly affected the participation rate. Subjects living in the same district as the Institute (75%) attended more often compared to subjects living further away (60%). Men (72%) participated more frequently than women, (60%) as did subjects with at least some of their own teeth (79% vs. 63%, p<0.001) and feeling healthy (67% vs. 52%, p<0.01). The subject’s functional capacity and health status were assessed in the clinical medical examinations. Good ability to move and showing no signs of dementia favorably affected the participation rate: 66% of the subjects who could move independently participated compared to 46% of subjects who needed assistance getting to the Institute (p<0.001) and 65% of subjects showing no signs of dementia vs. 48% subjects with any signs of dementia (P<0.05). The home-dwelling subjects' educational level did not affect their participation in clinical dental examinations. The odds ratios for not participating in the clinical oral examination ranged from 1.7 to 2.7. More details on the factors affecting the participation rate are presented in Table 1.
Table 1. Participation in the baseline clinical oral examination according to home-dwelling subjects’ background factors, oral status, and medical findings.

<table>
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<th>Number of subjects</th>
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<th>Odds ratio for not participating</th>
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<td>75***</td>
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<td>55</td>
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<td>1.7 1.1-2.6</td>
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<td></td>
</tr>
<tr>
<td>Dentulousness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dentate</td>
<td>221</td>
<td>79***</td>
<td></td>
</tr>
<tr>
<td>Edentulous</td>
<td>208</td>
<td>63</td>
<td>2.2 1.4-3.3</td>
</tr>
<tr>
<td>Data missing</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to move</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good/independently</td>
<td>390</td>
<td>66***</td>
<td></td>
</tr>
<tr>
<td>Poor/assisted</td>
<td>79</td>
<td>46</td>
<td>2.3 1.4-3.8</td>
</tr>
<tr>
<td>Data missing</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dementia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>422</td>
<td>65**</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>62</td>
<td>48</td>
<td>2.0 1.2-3.4</td>
</tr>
</tbody>
</table>

1Statistical evaluation by chi squared test: *** P<0.001; ** P<0.01; * P<0.05; NS P>0.05
2Compared with the first category of each factor. Odds ratio estimated only for factors showing some statistical significance in participation rates by category.
Multicausal analysis revealed that the strongest factors explaining non-participation, after controlling for other factors, were the home-dwelling subjects' old age (OR=3.6), deteriorated ability to move (OR=5.3), clinically diagnosed symptoms of dementia (OR=4.1), and edentulousness (OR=2.5). Fitting the data resulted in an exceptionally good fit, and 93% of the variance in the variables included in this analysis was explained by the fitted model.

5.2. Loss of teeth (Study IV)

Influence of the level of education at baseline

The dentate participants in high education groups 1 and 2 had significantly more teeth than participants in low education groups 3 and 4 (23.5 ± 2.8 and 17.8 ± 6.9 vs. 12.1 ± 7.6; p<0.05). Almost half of the dentate subjects in the high education group (45%) had 20 or more remaining natural teeth in contrast to 18% of subjects in the low education group.

The dentate subjects in the lower education group wore significantly more often removable dentures than subjects in the high education group (76% vs. 51%; p = 0.001). When looking at both the dentate and edentulous participants, this difference was found only in women (41% vs. 18%; p<0.05).

Influence of level of education at follow-up

The mean number of teeth in dentate subjects decreased during the follow-up in both high (from 19.6 to 18.5, p=0.001) and low (from 12.8 to 11.9, p<0.0001) education groups. The significant differences in number of teeth in different education groups did not change during the follow-up. In the follow-up 50% of the dentate subjects in the high education group and 29% of the low education group had 20 or more natural teeth. The majority (52%) of subjects in the low educational group had less than ten teeth (p<0.0001).

The decrease in the mean number of teeth during the follow-up was found only in men belonging to the low education group when we looked at the whole study
population (both dentate and edentulous subjects) (from 9.7±9.9 to 8.9±10.4) (unpublished data, Table 2). In all other groups there was an increase in the mean number of teeth, the only significant change was found in women belonging to the high education group (from 7.7±9.1 to 12.5±9.0, p<0.01).

A similar pattern was observed with participants who had more than 20 teeth. The percentage of women with functional dentition in high education group increased from 15% to 29%, p<0.05 during the follow-up, in other groups it remained stable (unpublished data, Table 2).

Table 2. Number of the elderly men and women with low and high level of education at baseline (n=332) and at five-year follow-up (n=104) study according to number of teeth.

<table>
<thead>
<tr>
<th>Level of education</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (322)</td>
<td>Low (104)</td>
</tr>
<tr>
<td>Number of teeth</td>
<td>Low: 9.7±9.9</td>
<td>Low: 8.9±10.4</td>
</tr>
<tr>
<td></td>
<td>High: 6.4±8.5</td>
<td>High: 6.7±8.5</td>
</tr>
<tr>
<td>&lt;20 teeth</td>
<td>76%</td>
<td>83%</td>
</tr>
<tr>
<td></td>
<td>24%</td>
<td>17%</td>
</tr>
<tr>
<td>≥20 teeth</td>
<td>75%</td>
<td>83%</td>
</tr>
</tbody>
</table>

*p<0.01, Fisher’s PLSD.
5.3. Caries (Studies II and III)

Occurrence of caries

At the baseline 71% of the men and 48% of the women (p=0.02) had decayed teeth (DT). The mean number of DT was 2.8 for men and 1.5 for women (unpublished data).

As the number of teeth decreased in the 5-year follow-up, a significant increase in DMFT (1.164, p < 0.0001) was consequently found. The level of education was not associated with the increment in DMFT, but the increment in DMFT was associated with frequency of brushing (p<0.05).

There was a positive correlation between female gender and DMFT, but no other factors (level of education, gender, frequency of brushing and eating) fitted the models correlated with the increments in DMFT. The predictive values of the models were poor.

Occurrence of root caries

Baseline

Root caries was found more often in men (52%) than in women (35%) (p< 0.05) at the baseline. The mean number of DRS (decayed root surfaces) (2.0 vs. 1.0; p <0.01) and DFRS (decayed and/or filled root surfaces) (6.6 vs. 3.8; p <0.01) was significantly higher in men than in women. Root caries was also found more in the older (81- and 86-years old) age groups (65%) than among the youngest (76-years old) age group (40%) (p=0.06) and the mean number of DRS was also higher in the oldest age group.

Follow-up

A significant increase was found in RCI (0.081, p < 0.0001) but not in DRS (-0403, ns.) in the 5-year follow-up.
Association between level of education and occurrence and increment of root caries

Although the number of teeth and root surfaces (p<0.05) at risk were higher in the high education groups, no significant differences were found in the number of DRS (0.6 ± 1.3) and RCI (0.13 ± 0.18) for different education groups.

The level of education was not associated with the increment in RCI during the follow-up.

None of the measured factors (level of education, gender, frequency of brushing and eating) fitted in the model correlated with the increments in DRS or RCI. The predictive values of the models in general were poor.

Association between root caries and salivary findings

Both unstimulated and stimulated salivary flow rates were lower in women than in men: 0.1 ml/min vs. 0.2 ml/min, and 1.3 ml/min and 1.7 ml/min, respectively (p<0.01).

The correlation analysis showed that DRS and DFRS correlated (r = 0.16 to 0.26) with salivary microbial counts (SM, LB and yeasts). High microbial counts were also the only analyzed values found to increase the risk for root caries, the odds ratios were 2.0, 95% CI 1.0–3.9 for SM; OR 3.5, 95% CI 1.8–6.7 for LB and OR 2.9, 95% CI 1.5–5.6 for yeasts. Decayed root surfaces were recorded in 46 to 57% of the subjects with high SM, LB, or yeast counts. There was no correlation between DRS and the subjects’ salivary flow rates.

After evaluating by a log-linear model high SM and yeast counts together with male gender were associated with a greater occurrence of root caries (Table 3).
**Table 3.** Association between DRS and subjects’ gender, age and salivary findings at the baseline: a log-linear model.

<table>
<thead>
<tr>
<th>Interaction with presence of DRS</th>
<th>Estimate</th>
<th>SE</th>
<th>OR$^1$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male)</td>
<td>0.25</td>
<td>0.80</td>
<td>1.3</td>
<td>0.3-6.2</td>
</tr>
<tr>
<td>Old age (81-86 years)</td>
<td>0.59</td>
<td>0.51</td>
<td>1.8</td>
<td>0.7-4.9</td>
</tr>
<tr>
<td>Flow rate (low)</td>
<td>1.40</td>
<td>0.93</td>
<td>4.0</td>
<td>0.7-24.</td>
</tr>
<tr>
<td>SM count (high)</td>
<td>1.05*</td>
<td>0.50</td>
<td>2.8</td>
<td>1.1-7.6</td>
</tr>
<tr>
<td>LB count (high)</td>
<td>0.94</td>
<td>0.53</td>
<td>2.6</td>
<td>0.0-7.2</td>
</tr>
<tr>
<td>Gender (male) and SM (high)</td>
<td>-2.52**</td>
<td>0.98</td>
<td>0.1</td>
<td>0.0-0.5</td>
</tr>
</tbody>
</table>

*P<0.05; **p<0.01.  
General mean = -1.82; SE=0.48; deviance=25.19; d.f.=3.16; coefficient of determination=0.54

$^1$Compared with 76-year-old women with ideal salivary findings (stimulated saliva flow rate $\geq 0.7$ ml/min, and SM and LB counts $<10^6$ CFUs/ml).

**Influence of the level of education on salivary findings (unpublished data)**

At baseline men with a high level of education had more often high counts of mutans streptococci that did men with low level of education (p<0.05). In the follow-up this difference did not occur. No other associations between level of education and salivary factors were found (unpublished data).

**Influence of the level of education on tooth brushing**

Most of the elderly in the higher education groups (75%) reported brushing their teeth more than once a day, when the elderly in the lowest level of education groups (68%) brushed only once a day. Fluoride toothpaste was used by 72% of the subjects, no association with level of education or gender was found.
5.4. Periodontal diseases (Study IV)

The influence of level of education on periodontal status at the baseline

Periodontal treatment need was measured at the sextant level. There was a mean of 3.6 sextants present per person at baseline. The elder individuals in the high education groups had more healthy (CPI 0) sextants (0.6 ± 1.6 in group 1 and 0.8±1.7 in group 2) than those in the low education group 3&4 (0.2 ± 1.0) (p<0.05). The elderly individuals in the highest education group also had the highest number of sextants with deepened periodontal pockets (CPI 3 and 4) (1.7 ± 2.1 in group 1 and 1.1±1.7 in group 2 vs. 1.0 ± 1.4 in groups 3&4, p < 0.05). Subjects in intermediate education group had the best periodontal status when compared to the other groups. They had the highest number of healthy sextants (0.8 ± 1.7) and one of the lowest numbers of sextants with periodontal disease (1.1 ± 1.7).

Radiographic examination

Furcation lesions (1.1±1.5 vs. 0.4±0.7; p<0.01) and teeth with restoration overhangs (2.9±2.7 vs. 0.9±1.5; p<0.0001) were found significantly more frequently in the higher education groups than the lower education groups at the baseline. No difference was found in relation to mean number of teeth with calculus and or bone loss between the high and low groups on radiographic examination.

Periodontal status and self-perceived need for treatment at baseline

The elderly subjects in our study were not fully aware of their periodontal status. Only 30% of the subjects with highest CPI score 3-4 considered themselves in need of periodontal treatment when 15% of subjects with highest CPI score 1-2 believed they needed periodontal treatment.

Gingival bleeding was reported more often as the CPI score increased, however only half of the subjects have noticed gingival bleeding even when the highest CPI score was 4. No difference in occurrence of reported gingival bleeding was found
between the different educational group levels.

**Periodontal status at the follow-up**

The periodontal status remained relatively stable during the 5-year follow-up period. There was an increase in mean number of healthy sextants from 1.08 ± 1.8 to 1.48±2.2 in the high education group but a decrease from 0.3±1.2 to 02.± 0.8 in the low education group at the follow-up. However, the differences were not statistically significant. There was also a significant decrease in the mean number of sextants with deepened periodontal pockets in both groups (1.08 ± 1.6 to 0.5 ± 1.0, p=0.05 in high group and 1.13±1.7 to 0.6±1.0, p=0.05 in low group). The radiographical status showed only minor changes during the five-year follow-up and seemed to stay relatively stable.
6. DISCUSSION

The purpose of the present study was to investigate whether level of education had an influence on oral health, especially the prevalence and increment of tooth loss, caries and periodontitis of old elderly home dwelling inhabitants of Helsinki, and further, to investigate the factors related to their non-attendance in a comprehensive oral study. The study consisted of a questionnaire and clinical oral and radiographic examinations at baseline and at the 5-year follow-up. The elderly in Helsinki had high levels of root caries and periodontal treatment need regardless of their level of education. However, older persons with more education had retained more teeth and had a higher need for periodontal treatment. During the five-year follow-up the number of teeth decreased, RCI increased and periodontal treatment need remained stable and the differences between educational groups remained the same.

6.1. Subjects

This study group was derived from the Helsinki Aging Study (HAS), in which a representative sample of the general home-dwelling elderly population of Helsinki City had had a comprehensive medical examination, laboratory tests and interviews (Valvanne 1992). A year later the participants were invited to the HAS Oral study. The study design for the follow-up was longitudinal, with the same subjects examined first at the baseline and then again at the follow-up five years later. This study was intended to last ten years but due to the erosion of this very elderly study population it was not possible to give the subjects clinical examinations. The medical team, however, collected data on morbidity from the Death Register of Finland ten years after the commencement of HAS.

In epidemiological studies participation rates of around 60% to 80% have been considered reasonable goals, although these goals have rarely been reached in studies on elderly individuals living independently (Hunt et al. 1985, Locker et al. 1990, Locker 2000, Heegaard et al. 2010). Response rates are lower when the survey requires participants to physically attend a clinical examination (Locker et al. 1990, Locker 2000, Matthews et al 2012). We tried to enhance the participation
rates and obtain some information of the non-attendees in several recommended response-enhancing strategies: multiple callbacks, offering help to arrange transportation, offering a written health status and copy of the radiographs, offering an incentive, and offering the refusals a possibility for an abbreviated clinical examination at their homes or finishing the survey on the phone (Locker 2000). We also had data from medical examinations and interview available to gather information on the non-respondents. The baseline data was used to compare participants and non-participants in the follow-up study.

The participation rate for the present study at the baseline was high (63%) especially considering the advanced age of the home dwelling subjects in the sample and their physical limitations.

Non-response bias is a concern in all surveys, despite the response rate, and it should not be ruled out until an analysis of non-response has been undertaken. Age was one of the strongest factors affecting the participation rate at the baseline. The majority (51%) of the participants belonged to the youngest age group (76 years) and were female (71%), although the men were more willing to participate than the women, 72% and 60% respectively. This was also reported by a Swedish study on 70-year-olds (Eriksson et al 1987) but was different from the numbers in a paper on 70-year-olds in New England (Joshi et al. 1994). The gender ratio was similar to the sample population but the youngest age group was over-represented: 75% of the 76-year-olds participated in the dental examination but only 53% of subjects aged 81 or 86 years. This is in line with other studies (Locker et al. 1991, Heegaard et al. 2010).

Problems related to mobility, dependency on help and general tiredness has shown to limit utilization of dental services (Avlund et al. 2001). Also in this study subjects with a good ability to move, in relatively good physical condition or having no signs of dementia tended to participate in the clinical dental examinations more frequently than did their counterparts. These findings are in line with earlier studies in Scandinavia: on elderly men by Janzon and coworkers (Janzon et al. 1986) and on 70-year-olds by Eriksson and coworkers (Eriksson et al. 1987). More than half of the subjects in the oldest age group in this study population had
difficulties walking for over 0.5 km outdoors and walking up more than 10 stairs, this compares to onethird of the persons in the youngest age group who reported these difficulties (Tilvis et al. 1997).

Also the dental status of our subjects had an influence on their participation rates in favor of the dentate elderly: there were 79% of them but only 63% of the edentulous were clinically examined. A similar finding was reported in a 3-year follow-up study on adults aged 50 years or older in Ontario, Canada (Payne et al. 1991). Some studies with quite low participation rates (Eriksson et al. 1987, Locker 1990) reported that the responders had more oral or dental diseases than did their counterparts. A recent study on Danish elderly individuals found that old age, poor health and being edentulous were the most common reasons for nonparticipating (Heegaard et al. 2010).

In our study the level of education did not have an effect on participation rate, which is in contrast to other studies (Heegaard et al. 2010, Matthews et al. 2011) where the participants had higher levels of education.

In the Danish study the results could not be generalized to other populations as the oral diseases were thought to be potentially underestimated in the study cohort (Heegaard et al. 2010). The underestimation of oral disease has also been found to be a source of potential non-response bias in another study (Matthews et al. 2011) although Locker et al (1990) showed that the differences between crude and adjusted estimates of treatment need were not substantial. The potential for bias must be taken into account in reporting prevalence of edentulousness and number of teeth, and most probably also the prevalence of other dental diseases as these figures could be optimistic also in this present study population. However, this kind of skewing has much less influence on studies that are concerned with associations between risk factors and oral diseases.

A high attrition rate is common in population based follow-up studies, particularly in the very old, and it was also evident in this study. At the time of the five-year follow-up one third of the baseline population were deceased, which was in accordance with the mortality rate of the general Finnish population of that age.
The participation rate in the follow-up was relatively low: only 40% of the original study group resulting in only small numbers of people with teeth being available for the analysis. The participants in the follow-up study enjoyed both better general health and oral health than the dropouts. The subjects in this study represent the survivors of their age groups and formed a very special study group as not many studies have been undertaken on the community-dwelling older people aged 75+ years earlier in Finland.

6.2 Methods

The level of education was assessed based on the information from the questionnaire. The SEP gradient we chose to use was the level of education of the individual. Actual income would have been difficult to define for this group as pensioners often have various sources of income and wealth. Also, the majority of the participants were women and a large proportion of these women had been housewives at least for part of their lives. The total family income and wealth would have had an effect on the amount of money at their disposal. This income may not have bearing on social attitudes to oral health for these women. Level of education can be defined on the same grounds for both the economically active and inactive population and it is fairly stable throughout adult life. Education has probably larger effect than income and occupation to the production of adult health (Elo et al. 1996). Further, education is a powerful determinant of health throughout life, but to a greater extent because of its impact on behaviors rather than its association with resources (Cutler 2008).

The information on subjects’ medication was obtained from a questionnaire and later confirmed by physicians who had performed the medical examinations earlier. As a reduced salivary flow rate have been reported earlier for the present study population taking more than three different medications daily (Närhi et al. 1992), we used the same classification instead of categorizing medicines into groups based on the possible xerostomic side effect. In the previous report medicines were further divided into 11 subgroups based on their possible xerostomic effects (Närhi et al.1992).
Four faculty members at the Institute of Dentistry carried out the clinical oral and radiological examinations. The 14% of the subjects who were too ill or too tired to come to the Institute of Dentistry were examined in their homes or hospitals. This figure is in accordance with a recent paper by Fairhall et al (2009) where he studied the differences between home- and clinic-based dental examinations for older people. Calibration on 19 subjects by examiners resulted in high interexaminer agreement for both exposed root surfaces (93%) and their status (89%). The examiners also had every opportunity to discuss with each other about criteria, diagnoses and possible problems to improve reliability as the examinations at the Institute of Dentistry were carried out simultaneously and the home examinations by pairs of researchers. The comprehensive, but exhausting, oral, radiological and microbiological examinations and interviews took on average two hours to complete. Considering the age of the participants and the chair side time reserved for the clinical examination we selected to use the Community Periodontal Index for Treatment Need (CPITN) index (Ainamo et al. 1982). That was also the reason to use panoramic radiograph supplemented with some periapical radiographs, which has many advantages: a small dose of radiation, low price, speed, and convenience (Molander et al. 1995).

CPITN recording has been widely used worldwide, since it has been recommended by the WHO for the epidemiologic recording of periodontal diseases (WHO 1997, Pilot et al, 1987, Petersen et al 2005a) to increase international uniformity. The major advantages of the CPITN are its simplicity, speed, reproducibility, and international uniformity (Cutress et al. 1987). CPITN also shows the prevalence of healthy sextants as well as the presence of actual treatment need as sextants with deep pockets. Probing depth does not provide an accurate measure of periodontal tissue destruction accumulated over a person’s lifetime as reliably as assessments of bone loss or clinical attachment loss (CAL) measured from the cemento-enamel junction (CEJ) to the bottom of the pocket, this has been considered a limitation of CPI (Pilot et al. 1987, Baelum et al. 1996, Papapanou 1999). Much of the attachment loss in an elderly has been said to the result of gingival recession (Holm-Pedersen et al. 2006). Gingival retraction with no infection can be a result of the cumulative effect of occlusion, vigorous tooth brushing and/or past periodontal or restorative treatment. There are cases when probing depth can be misleading as
an indicator of active periodontal disease. Increased probing depth can also be a result of periodontal disease and its successful treatment and not necessarily in need of further treatment or well-treated periodontitis with almost total loss of alveolar bone may give a CPITN score of 0 (no infection, no calculus, no bleeding on probing). In this study bone loss was assessed with a radiological examination.

In the CPITN system the highest score of an individual is derived from the highest score of one or more sextants. It is possible that an individual may have an increased probing depth in only a few sites and thus only one sextant with that score, this might lead to overestimation of periodontal disease, although CPITN has also been criticized to underestimate the prevalence and severity of periodontal attachment loss among elderly adults (Baelum et al. 1995).

### 6.3 Tooth loss and caries

The prevalence and severity of dental caries is dependent upon the number of teeth present in the mouth. Tooth retention has increased during the past decades in the elderly population and this trend will still continue in the future. As the number of teeth increases, the number of susceptible tooth surfaces also increases and this will have an important impact on the oral disease burden and the anticipated need for dental treatments in the coming years. Being completely edentulous and having a lower number of remaining teeth have been associated with lower level of education in several studies (Vehkalahti et al. 1991, Drury et al. 1999, Avlund et al. 2003, Petersen et al. 2004, Suominen-Taipale et al. 2008). The dentate participants in our study had significantly higher mean number of teeth in the higher education groups than in the lower education groups (22.6 and 17.8 vs. 11.3 and 9.7), and consequently root surfaces at risk. In a Danish study on 75 year olds the figures were 16.6 in the high education group and 13.3 in the low education group (Paulander et al. 2003). Our elderly in higher education groups had more retained teeth than the elderly aged 75 and older in the National Health 2000 Survey where elderly individuals in high and intermediate education groups had 18.5 and 12.8 mean number of teeth respectively, but less in the basic education group where the mean number of teeth was 12.2 (Suominen-Taipale et al. 2008). Our more educated
dentate elderly practically reached the WHO goal of every other elderly should have at least 20 remaining teeth. At the baseline 45% and at the follow-up 50% of them had more than 20 teeth. Only 18% of the dentate elderly in the lower education group at the baseline and less than one fifth of the total study population had a functional dentition. The disparity between different levels of education seemed to be larger in Helsinki. This can be the consequence of treatment decisions made earlier in life. The healthy elderly individuals have not received any reimbursement for the dental treatments from the national health institution or been entitled to access the public dental health care system in Helsinki until recently. Therefore, the cost of the treatment, lack of time and attitudes has had an influence on their decisions to opt for extractions rather than conservative treatment as treatment choice. The situation has improved in Finland since our study; in a recent national Health 2011 survey almost half of the population aged 65+ reached this goal (Koskinen et al. 2012).

The number of teeth decreased in the five-year follow-up in all education groups, while the significant differences between groups remained. After the examination at the baseline the dentate participants were given a copy of their panoramic radiograph and explained their treatment needs. Most probably the teeth with poor prognosis were extracted. Another explanation can be their deteriorating general health and ability to maintain oral hygiene resulting in loss of teeth due to caries or periodontal disease.

There was a gender-related difference in the prevalence of root caries in our study population, the mean numbers for DRS, DFRS and number of teeth with root caries were higher in men than in women. Similar disparities have been reported in other epidemiological studies (Vehkalahti et al. 1983, Papas et al. 1992, Fejerskov et al. 1993). However, no significant differences were found between education groups at the baseline in DRS, RCI or DMFT, although in NHANES III persons in the lower SES categories were 7.2 times more likely to have untreated root caries when compared to higher categories (Drury et al. 1999) and in the Health 2000 Survey the elderly aged 65 and older had more carious teeth in the basic education than in the high education group (Suominen-Taipale et al. 2008). The prevalence of root caries has been shown to increase with age (Fure 2004) this was also seen among
the present study population.

High counts of SM were found more often in men with a high level of education at the base line, this was the only salivary finding that had an association with level of education. High counts of salivary microbes were correlated with DRS and DFRS, however they were poor predictors for caries in this population. Although past root caries experience has been shown to have a high predictive value for root caries increment (Scheinin et al. 1992, 1994) it was not fitted into our log-linear analysis. To use the number of filled surfaces in cross-sectional studies may be slightly misleading as some of the fillings were not made to restore root caries lesions (DePaola et al 1989). The number of daily medicines or salivary flow rates were not correlated with the presence of root caries. This was an interesting finding as persons with dry mouth are consistently in the high risk category of root caries (Kitamura et al.1986, Curzon et al. 2004). Our finding was however confirmed by Beighton and colleagues (Beighton et al. 1991) who reported higher root caries prevalence in men although salivary flow rate was significantly lower in women.

During the five year follow-up a significant increase was found in RCI. This increase in RCI was also confirmed in elderly populations in Germany (Splieth et al. 2004), and increase in DRS in Sweden (Fure 2003), Denmark (Palmqvist et al. 2000) and China (Luan et al. 2000). The increase in RCI was not associated with the level of education or with tooth brushing or eating frequencies.

The findings in this study emphasize the multifactorial nature of caries, and how difficult it is to assess the risk factors of root caries for a subject. No single risk factor has been identified in the literature suggesting the need for assessment for both behavioral and socioenvironmental factors in oral diseases. The high prevalence of root caries and increase in RCI and DMFT among the very old subjects in this study indicate that causal treatment of the caries disease has not been successful in this population, and these people are indeed a caries active group. This puts even stronger emphasis on the well known and effective means for preventive and non-operative treatment strategies to treat caries disease successfully (Caries, Current Care 2009). There will be a growing need for caries prevention measures in the increasing population of elderly people who will retain
even more teeth into old age in the future.

6.4 Periodontal diseases

The elderly population in our study reported a high prevalence of periodontal disease regardless of their level of education. Treatment need was higher among the well-educated elderly, both clinically and radiographically detected periodontal lesions were more common with this group. This is in disagreement with some of the other investigations where periodontitis was more common among elderly individuals with lower levels of education (Beck et al. 1995, Kelly et al. 2000, Corbet et al. 2001, Borrell et al. 2004, Krstrup 2006, Borges-Yañez et al. 2006). In a national Mini-Finland study severe tissue destruction was found more often in subjects with low levels of education, although differences were small between educational groups, no clear association was found with level of income (Vehkalahti et al. 1991). This difference can be related to the differences in study population. Our study population was older, and our elderly with low level of education were more often completely edentulous or were frequently using removable partial dentures. Only 18% of the subjects with low level of education had 20 or more teeth, which is far below the WHO goal for the year 2000, stating that at least 50% of the elderly should have a minimum of 20 teeth (WHO 1982). Of the subjects in the high education group 45% had 20+ teeth. No assessment was made for the reasons of their tooth loss, but apparently many periodontically involved teeth have been extracted. This is the most probably the reason why our study failed to show that the periodontal health status is related to level of education. Disease experience in our study is based on observation of teeth that are “healthy survivors”. Consequently, lifetime disease experience is likely to be underestimated. However, tooth loss has no effect on measures of treatment need or current disease activity. This situation is most likely going to change in the future as number of teeth are increasing in all social classes in Finland.

Our findings were confirmed by recent studies in Finland and Sweden. Syrjälä and coworkers (Syrjälä et al. 2010) investigated elderly individuals aged 65 and older in Finland as part of the Health 2000 Survey. The prevalence and extent of periodontal disease was highest among the elderly with a higher level of education, as was the
situation also in our study population. Periodontal diseases were found to be more common than in our study group and high number of teeth with deepened periodontal pockets was associated with being very old (80 years or older). The KEOHS project has evaluated the oral health status of generally healthy, community-dwelling persons aged 80 years and over living in the Swedish capital (Holm-Pedersen et al. 2006). Over half of the study population was reported to have severe periodontitis (SP), and persons with higher levels of education were more likely to have SP (crude OR 2.0, 95% CI 0.9, 4.7). The periodontal treatment need has remained high in Finland after our study. In Health 2011 survey 71% of the women and 86% of men aged 75 years or older were reported to have at least one tooth with a 4 mm or deeper probing depth (Koskinen et al. 2012).

The radiological findings confirmed the need for periodontal treatment in this group of elderly individuals. However, no difference between different education levels were found in vertical bone infrabony pockets or mean number of teeth with calculus. Although furcation lesions and teeth with restoration overhangs were found significantly more often in higher education groups than lower education groups at the baseline, this finding was associated with higher number of retained teeth, especially molars, with these subject. The baseline radiographic periodontal findings including bone loss have been reported elsewhere (Soikkonen et al. 1998). The radiological study, like the clinical study, concluded that periodontal disease was highly prevalent in this elderly population. These results showed similar levels of periodontitis progression also in men and women in all the three age groups.

Various factors could explain the influence of level of education in periodontal status. Oral health behavior has been reported to have a stronger relationship with education than with income (Ronis et al. 1993). It has been proposed that educational level is related to distinct patterns of behavior and knowledge and health attitudes exist within certain social groups (Petersen 1990) suggesting that the differences in attitudes, knowledge and traditions that are linked to educational level are more important than economic factors in explaining the impact of socio-economic status. Smoking is well known risk factor for periodontal disease, and people with lower education have a higher smoking frequency than people with higher education (Tillgren et al 1996). In a review (Klinge et al. 2005) found that
smoking can be a confounding variable to socio-economic variables in studies where smoking as a factor was not included. In studies where the smoking factor has not been analyzed, the effect of socio-economic factors on periodontal diseases could be masked. In our study group only eight (4%) dentate subjects were current smokers and 28 (18%) were former smokers, this result was in line with a prospective study where the effect of educational level on periodontal disease progression was found to be significant in never smokers (Paulander et al. 2003).

In our study the elderly were not aware of their periodontal treatment need despite their level of education, although they became increasingly aware of their treatment need with worsening periodontal condition. Only half of the subjects noticed gingival bleeding even though their highest CPITN score was 4, and only 30% of the elderly thought they needed periodontal treatment although they had high CPITN scores of 3 and 4. There are many reasons for this low subjective treatment need. The elderly person’s ability to notice bleeding can be diminished due to poor vision and their oral hygiene efforts too gentle and ineffective to produce any bleeding during tooth brushing due to weakened motor skills. Thus in our study, most of the elderly even with a poor periodontal condition considered themselves healthy with no need for periodontal treatment. Correlations between clinical examination by a dentist and patient’s subjective need of treatment is often weak (Locker et al. 1994), this was also shown in our study. People with higher education have often better knowledge of oral diseases and they have also better access to and use of health care services, unfortunately this did not show in this study. It is important to increase elderly individuals’ awareness of oral diseases through health education, and for dentists and oral hygienists to offer elderly patients professional guidance and support.

6.5 Tooth brushing practices

Oral hygiene is one of the factors associated with progression and control of carious lesions and gingivitis. A little over two thirds of the elderly in this study followed the common recommendation and brushed their teeth twice a day. However, only 42% of the elderly with the lowest level education reported brushing more than
once a day. This is a higher rate than in other Finnish studies (Vehkalahti et al. 1991, Suominen-Taipale et al. 2008) but similar rate than reported in Denmark, UK, USA and Canada (Payne and Locker 1992, Davidson et al. 1997, Kelly et al. 2000, Christensen et al. 2003) and in a recent Health 2011 survey where 47% of the men and 68% of men aged 75 and older reported brushing twice daily (Koskinen et al. 2012). Higher social status has been shown to be associated with higher tooth brushing frequency and interdental cleaning habits (Suominen-Taipale et al. 2008, Christensen et al. 2003, Ronis et al. 1993) although we did not find a significant difference in this study. Also Paulander and coworkers (Paulander et al. 2003) did not find an association between level of education and tooth cleaning measures in 75- year-old subjects.

Fluoride toothpaste was used by 72% of the subjects, no association with level of education or gender was found. This is in line with Health 2000 Survey where 76% of the over 65 year olds reported using fluoride toothpaste (Suominen-Taipale et al. 2008).

We failed to show differences in brushing twice a day and using fluoride toothpaste between gender and level of education. Our study population was more educated and had retained more teeth than elderly individuals in other parts of Finland. It is possible that their knowledge and practice of good oral self-care were earlier established than in other subpopulations. More than two thirds of our study population reported good oral self-care behavior, despite this they had high level of oral diseases. One explanation might be that their ability to clean their teeth was inadequate. In Health 2000 Survey only 40% of women and 22% of men in the age group 65 or over, had clean teeth, no marked differences between educational categories were found (Suominen-Taipale et al. 2008). The amount of dental plaque of the participants or bleeding on probing were not registered, this is a weakness of this study, but we did report that subjects in the high education group had on average 0.8 healthy sextants and the subjects in the low education group had 0.4 healthy sextants, indicating that their level of oral hygiene was not very high. It is well known that oral self-care becomes more difficult with age because of compromising somatic and cognitive conditions (de Baat et al. 1993). It is crucial that the promotion of self-care behaviors is supported at dental visits and is a
priority in dental treatment plans. Professional preventive measures should be offered to the elderly who are not able to maintain adequate level of oral hygiene. This becomes even more important in the future where growing number of elderly are retaining more teeth.

6.6 Strengths and weaknesses of the study

Many studies on the oral health of the elderly have been conducted with focused groups of subjects. At the commencement of HAS there was relatively little information on the oral health status of home dwelling elderly in Finland in general. One of the major advantages of this study is that for the first time it was possible to retrieve comprehensive data on several aspects of oral health among the elderly population of Helsinki representing three birth cohorts, gender distribution and areas of living. This can also be seen as a limiting factor since the elderly in Helsinki are not a representative group of all elderly populations in Finland.

The extensive oral examination allowed the collection of data on several aspects of oral health. Indexes that are frequently used in population-based studies to describe the conditions of oral health were also applied in this study. This makes data comparisons possible, while it also limits the amount of data for follow-up examinations. For example the DMFT index recommended by WHO is not the best indicator for caries experience among the populations with a high number of missing teeth. The increase in the index during the follow-up was mostly related with loss of teeth and therefore is not a reliable indicator for the increment of caries among the study population. The DMFS index would have given more reliable information about caries in general. The accuracy of cariological status would probably have benefitted from the use of bitewing radiographs. However, the oral examination took altogether two hours and we decided to focus the caries examination on the occurrence of root caries, which is the specific caries problem among the older persons. Data on pocket depth, loss of attachment, bleeding of probing and the presence of plaque would have provided more reliable information on the periodontal health than the used CPI index, which only describes the need for periodontal treatment among the study population. Detailed information about
caries and periodontal conditions would have allowed the use of more sophisticated statistical models for the evaluations of risk factors of these conditions. This would have been important especially for the follow-up examinations.

At the commencement of the HAS sample size was calculated to be sufficient for medical examinations. Due to the fact that it was not possible to conduct oral health examinations for all the elderly individuals who participated in the medical examinations the sample size became rather limited for the follow-up study. This came apparent at the time of 10 years follow-up, which could not conducted because too few participants were alive and available for examination. Larger sample size would have better tolerated the high drop out rate. This study was designed to be longitudinal, but due to high attrition rate only limited amount of information was available at the follow-up and the findings are mainly cross-sectional. This makes it more difficult to draw conclusions concerning causal relations. However, the results may have some useful clinical implications.

Another limitation is that we were not able to verify the data on the level of education from any official records. This was not a major problem for those who had a professional degree from educational institutions. Some of the elderly in the lower education groups could not exactly remember the number of years they had been in school and might have been placed into the wrong educational level. This, however, was not big concern since for the data analysis the two lower and two higher educational groups were combined into one low or high educational group.

6.7 Implications for the future

The education level in Finland is rising steadily and the new cohorts of elderly individuals are better educated than the elderly have ever been in Finland. At the same time edentulousness is declining at a fast rate and the mean number of teeth is growing, thus leaving the older people more at risk of caries, periodontal disease and other oral diseases. The expectations regarding to acceptable oral health are also changing. The older people of today are more motivated to retain their teeth into old age and don’t easily accept becoming edentulous as an inevitable part of
aging. The decision to extract teeth was very uncommon in Finland during the first decade of this century (Koskinen et al. 2012). The adults now entering older age, “the heavy metal generation”, have retained much or most of their natural dentition, but in a state that requires a lot of more complex restorative treatment and maintenance if they want to retain their natural dentition and avoid dentures. The disparities in oral health have remained, even here in Finland where the financing and delivery of oral health care have been a public responsibility.

The old elderly in this study population are a special group as they have lived beyond the normal life expectancy of their age cohorts in Finland. They have been successful in aging and it is most likely that they have, and have had, many positive health behaviors regardless of their levels of education, and yet they had high levels of oral treatment need. Unless significant improvements are made, oral diseases and oral health-related problems will increasingly generate major impact on the general health and the quality of life of older people and impose a significant financial burden on the individuals and society.

Another challenge is to identify older adults whose positive oral health behaviors are about to change due to decline in cognition, functional ability and other effects of age–related disease, and help them to protect their oral health from deteriorating. As oral diseases share many common risk factors with several chronic diseases, WHO encourages national health authorities to use common risk factors approach to integrate interventions for oral health among older adults into general health programmes of chronic diseases, as well as of health promotion (Petersen et al. 2005b, Petersen 2003, 2008). We should be able to decrease the impacts of oral diseases on the general health and quality of life of older adults, and improve the oral health of high risk groups such as older adults, thereby alleviating disparities in these vulnerable subgroups requiring significant one-to one special oral care.

We have to remember that good oral health is a human right and essential to general health and the quality of life.
7. CONCLUSIONS AND RECOMMENDATIONS

The participation rate was reduced by high age and female gender. The participants were more mobile, were more often dentate and seldom showed signs of dementia. This will lead the prevalence figures on number of teeth being too optimistic for the entire elderly population.

Level of education was associated with the number of retained teeth and periodontal treatment need in our cohort of older adults of Helsinki. The number of teeth was higher and both periodontal treatment need and radiographically detected periodontal lesions were more common among the older adults with higher education levels. The mean number of teeth decreased and only modest changes in periodontal health were detected during the five-year follow-up while the disparities prevailed. Most of the older adults did not consider that they were in need of periodontal treatment even with though their periodontal condition was poor. The occurrence of root caries was high and more prevalent in men. There was a clear increase in RCI during the five-year follow-up. However, this increase was not directly associated with the level of education.

On the basis of the findings of this thesis and the previous scientific literature, the following recommendations can be made:

1) The oral health literacy levels of older adults should be increased so they would be able to seek treatment and preventive care in time. Good health behaviors and preventive treatment should be made a priority in oral treatment plans and public health interventions delivering oral health promotion activity should be linked to general health promotion. Older adults should be encouraged and supported to enable them to achieve effective self-care and overcome the obstacles old age might bring. Professional preventive measures should be offered to the older adults who are not able to maintain adequate levels of oral hygiene.
2) The older adults continue to have high caries rates. The emphasis should be changed from restorative treatment to preventive and non-operative treatment strategies to treat caries disease successfully. There will be a growing need for caries prevention measures and complex restorative treatments in the future.

3) Periodontal diseases are still a major oral health burden among older adults. Early diagnosis of periodontal disease signs, analysis of risk factors and proper treatment plan should be part of everyday practice. Well organized maintenance periodontal care is recommended.

4) Education and training of health care professionals providing oral healthcare services for older people should be prioritized to equip them with the clinical and communication skills needed to treat older patients. This should be covered in the undergraduate curriculum and both CPD and postgraduate courses should be offered.

5) The disparities in oral health between older adults should be decreased and even eliminated.
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