Britta Haikola

ORAL HEALTH AMONG FINNS AGED 60 YEARS AND OLDER

EDENTULOUSNESS, FIXED PROSTHESES, DENTAL INFECTIONS DETECTED FROM RADIOGRAPHS AND THEIR ASSOCIATING FACTORS
BRITTA HAIKOLA

ORAL HEALTH AMONG FINNS AGED 60 YEARS AND OLDER
Edentulousness, fixed prostheses, dental infections detected from radiographs and their associating factors

Academic dissertation to be presented with the assent of the Doctoral Training Committee of Health and Biosciences of the University of Oulu for public defence in Auditorium F202 of the Department of Pharmacology and Toxicology (Aapistie 5 B), on 5 December 2014, at 12 noon
Haikola, Britta, Oral health among Finns aged 60 years and older. Edentulousness, fixed prostheses, dental infections detected from radiographs and their associating factors
University of Oulu Graduate School; University of Oulu, Faculty of Medicine, Institute of Dentistry, Department of Oral and Maxillofacial Surgery
University of Oulu, P.O. Box 8000, FI-90014 University of Oulu, Finland

Abstract

Oral health among older people is shown to be worse compared to younger people. The aim of this study was to evaluate oral health and associating factors among ageing Finns.

A cross-sectional, descriptive epidemiologic survey was performed in Kirkkonummi in southern Finland and in the Lakeus District in northern Finland. Altogether 1,191 subjects aged 60 to 78 years, 625 from Kirkkonummi and 566 from Lakeus, were examined and interviewed. Edentulousness and poor occlusal stability were recorded clinically. Gonial angle, ramus height, condylar height and the amount of residual ridge resorption in the mandible and the presence of fixed prostheses were evaluated from panoramic radiographs. Based on the radiographs the scoring of infection foci was performed with an infection focus index. The signs of infection recorded were deep caries, periapical lesions, furcal lesions, vertical bone pockets and horizontal bone loss.

The prevalence of edentulousness was 37%, being significantly higher among women than among men and significantly higher in the northern compared to the southern region. Edentulousness was more prevalent among subjects with primary school education than among those with higher education. The mean of the gonial angle was smaller among dentate subjects than among edentulous ones. Dentate subjects had significantly greater ramus height and condylar height than edentulous subjects. Women had significantly more often than men severe residual ridge resorption in the mandible. Poor satisfaction with dentures associated significantly with poor occlusal stability in both genders. More than three quarters of the subjects had severe risk of infection, more in the southern than in the northern region. In the dentate sample women showed higher prevalence of fixed prostheses than men. In the Kirkkonummi region both men and women had more fixed prostheses than subjects in the Lakeus region.

Edentulousness was very frequent among ageing Finns. Mandibular bone morphology changed as a consequence of tooth loss. The prevalence of fixed prostheses was low and the prevalence of signs of infection of dental origin was high. The geographical differences in oral health should be considered by health authorities in order to promote good oral health in rural areas, especially focusing on older people with low socio-economical status and poor health.

Keywords: ageing, alveolar bone loss, bone remodelling, dental focal infection, edentulous mouth, fixed dental prosthesis, oral health, panoramic radiography
Haikola, Britta, Ikääntyvän suomalaisväestön suun terveydentila. Hampattomuus, kiinteät proteesit, radiologiset hammasperäiset tulehdusmuutokset ja näihin liittyvät tekijät
Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta, Hammaslääketieteen laitos, Suu- ja leukakirurgia
Oulun yliopisto, PL 8000, 90014 Oulun yliopisto

Tiivistelmä
Vanhusväestön suun terveydentila on useassa tutkimuksessa todettu huomattavaksi huonommilla. Tämän tutkimuksen tarkoituksena oli selvittää suomalaisen ikääntyvän väestön suun terveydentila ja siihen liittyvät tekijät.


Asiasanat: alveolaarinen luukato, hampaan pesäkeinfektio, hampaaton suu, ikääntyvä, kiinteä proteesi, luun uudelleen muotoutuminen, panoraamaröntgenkuvauksia, suun terveys
Acknowledgements

This work was carried out at the Institute of Dentistry, University of Oulu and at the Oral and Maxillofacial Department, Oulu University Hospital as well as at the Surgical Hospital in Helsinki University Central Hospital in collaboration with the Health Centres of Kirkkonummi and Lakeus. Lakeus at that time was a federation of municipalities comprising the municipalities of Liminka, Lumijoki, Temmes, Tyniävä and Rantsila. Both health centres offered the assisting staff, the premises and the equipment enabling data collection. I am grateful to all the above-mentioned organizations for their support with this project. I hereby express my gratitude to all the auxiliary personnel in the dental surgeries of the Health Centres, and especially to all the inhabitants who participated in this study.

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Oulu, September 2014

Britta Haikola
Abbreviations

AL attachment loss
CH condylar height
CPITN community periodontal index of treatment need
COPD chronic obstructive pulmonary disease
CVD cardiovascular disease
DM diabetes mellitus
FDP fixed dental prosthesis
FPD fixed partial denture
GA gonial angle
HbA1c glycosylated haemoglobin
HAS Helsinki Aging Study
ICMJE International Committee of Medical Journal Editors
IgG immunoglobulin G
NHANES National Health and Nutrition Examination Survey
OHIP Oral Health Impact Profile
PD pocket depth
RH ramus height
RRR residual ridge resorption
List of original articles

This thesis is based on the following original publications, which are referred to in the text by Roman numerals I–V:


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1 Introduction

The number of persons belonging to the older age groups is rapidly increasing in all Western countries. This will pose a challenge to the health care system as the frequency of functional disabilities and general and dental diseases tend to increase with advancing age (Avlund et al. 2001).

The frequency of edentulousness has decreased and it is concentrating into older age groups. Edentulousness brings along several problems in terms of appearance, speaking, chewing and nutrition, and it even impairs social relations and causes emotional problems (Allen & McMillan 2003b, Fiske et al. 1998, Daly et al. 2003, Joshipura et al. 1996a, Österberg et al. 1995). Factors related to poor general health and risky health behaviour such as smoking, cardiovascular disease, and poor dental attendance have shown to be linked with edentulousness (Ahlqwist et al. 1989, DeStefano et al. 1993, Mattila et al. 1989, Pajukoski et al. 1999, Ragnarsson et al. 1992). Dental status is also affected by socio-demographic factors like gender, income and educational level. In Finland, regional differences in the supply of dental care and even cultural factors in different parts of the country have contributed to the differences in the frequency of edentulousness (Hiidenkari et al. 1996, Nyman 1990, Suominen-Taipale et al. 1999).

Edentulousness affects the function and anatomy of the masticatory system. Along with high age and some general diseases, such as rheumatoid arthritis, it remodels the shape of the mandibular bone (Engström et al. 1985, Fish 1979, Ohm & Silness 1999, Raustia & Salonen 1997, Rönning et al. 1994). Gonial angle has been shown to be wider in edentulous individuals than in dentate ones (Engström et al. 1985, Xie & Ainamo 2004). The function and structure of the masticatory muscles affect the shape of the mandibular base, and vice versa. The ramus height and condylar height of the mandible may also be affected (Raustia et al. 1996, Rönning et al. 1994). Alveolar ridge resorption especially in the mandibular bone (Bergman & Carlsson 1985, Smith & Sheiham 1980, Tallgren 2003) may lead to problems with denture stability and retention among edentulous individuals (Newton et al. 1987, Zarb 1982).

Despite the high frequency of edentulousness in older age groups, the majority of these individuals keeps most of their natural teeth, and will do so even more in the future (Ainamo 1983, Bourgeois et al. 1998, Nyman 1983, Nyman 1990, Suominen-Taipale et al. 2004, Vehkalahti et al. 1991). Growing older, becoming frail and having many diseases may lead to increased need of dental
care for the remaining teeth (Suominen-Taipale et al. 2004, Vehkalahti et al. 1991). Attending dental care and the ability to take care of personal oral hygiene may become difficult. As a consequence, dental diseases and treatment needs increase (Suominen-Taipale et al. 2004). Periodontal diseases and dental caries with its consequences increase the risk of infectious complications (Beck et al. 1996, Caplan et al. 2006, DeStefano et al. 1993, Janket et al. 2004). Dental infections are known to increase the amount of inflammatory mediators in the body, which in turn is linked with several general health conditions, such as cardiovascular diseases and diabetes; in addition they are also known to increase the risk of infection associated with endoprostheses and immunosuppressed patients (Caplan et al. 2006, Janket et al. 2004, Karikoski et al. 2002, Mattila et al. 1989, Meurman et al. 2003b, Passoja et al. 2011, Soikkonen et al. 2000).

Detection of signs of infection of dental origin is usually based on radiographical examination (Hugoson et al. 2005, Närhi et al. 2000, Soikkonen et al. 1998, Suominen-Taipale et al. 2004). The oral cavity and dentition differ from many other parts of the body in that infection may be present in the area without major clinical features. Periapical lesions in connection with endodontic treatment, deep periodontal pockets and furcal lesions between the roots of molars can be detected also in panoramic radiography in addition to intraoral periapical radiography (Ahlqwist et al. 1986, Åkesson 1991, Molander et al. 1993).

In the earlier decades of the twentieth century the treatment methods in Finland usually included extractions and fabrication of complete dentures (Nyman 1983, Nyman 1990, Suominen-Taipale et al. 2004). As compared to the northern part of the country more dental care has been available in southern Finland (Nyman 1983, Nyman 1990), resulting in saving more teeth and fabricating fixed restorations (Suominen-Taipale et al. 2004). The treatment of partial edentulousness with fixed or removable dentures is strongly linked with economic aspects. In Finland, financial support for prosthetic treatment in private practices has been limited to war veterans only. In health centres the availability of prosthetic treatment has also been limited due to lack of resources. Thus, people with lower income in the northern part of Finland have had very limited possibilities to get advanced fixed prosthetic treatment. The frequency of provision of fixed dental prostheses has not been widely studied (Farrell & Dyer 1989, Fyffe 1992, Hugoson et al. 2005, Löfquist et al. 2000, Pine et al. 2001, Ranta et al. 1987, Silness & Berge 1990).

This study aimed to provide information on the prevalence of edentulousness and its effects on the changes in the shape of the mandible and the problems in
wearing complete dentures. Furthermore, the aim was to provide information on the prevalence of radiological signs of dental infection and the prevalence of fixed dental prostheses and single crowns among Finnish older adults, and to examine the associations of these variables with different background factors.
2 Review of the literature

2.1 Demographic changes in Finland

Life expectancy has increased continuously in Finland during the last hundred years. At the beginning of the 20th century life expectancy for a newborn baby was 43 years for boys and 46 years for girls, whereas fifty years later the corresponding figures were 63 for boys and 69 for girls. The probable lifespan for men born in the 1950s will be 74 years and for women 82 years, as a consequence of declining mortality due to improved health care and better living conditions (Official Statistics of Finland 2010). The number of older adults has therefore increased, and this tendency will continue in the coming decades. At the same time, fertility has declined, resulting in a growing proportion of older people in the population. The proportion of people aged 65 years and older was 6.4% in 1940, 7.4% in 1960, 12% in 1980, 15% in 2000 and 17.6% in 2010 (Official Statistics of Finland 2010). This trend will continue and even grow in the coming decades as the large cohorts born after the Second World War reach retirement age. It is projected that the proportion of people aged 65 years and over will be 22.9% in 2020, 26.1% in 2030 and 27.6% in 2050. In these cohorts women will continue to outnumber men in the future as well (Statistical Yearbook of Finland 2009).

According to the latest Health 2011 survey, the positive development of the improvement in health, welfare and functioning, which has been seen from the 1970s, will continue (Koskinen et al. 2012). In line with the development of better living conditions, the possibility of education has increased during the last century. Accordingly, older people are better educated now and in the future than the former age-cohorts. In 2011, only about 14% in the eldest age group had high school education while the proportion was 57% in the youngest group. Higher education brings along more knowledge of health matters, better health habits and increasing use of health care services (Koskinen et al. 2012).

Although it is expected that these older people will stay healthier than their predecessors because of health-friendly food intake, better living conditions and efficient health care, their maintenance will pose great challenges to society in the future. More resources will be needed for their accommodations as well as health care at home and in institutions, including dental care (Reports from the Ministry of Social Affairs and Health 2011:7).
2.2 Edentulousness

2.2.1 Epidemiology

Edentulousness is a common feature in elderly population in almost all countries and in most cultures. The aetiology of edentulousness differs according to the presence of various dental diseases, the supply of dental care and the cultural base whether visible missing teeth are accepted or not.

The prevalences of edentulousness in several countries around the world are presented in Table 1. Most of these countries are Western developed countries. Overall, the greatest prevalences are shown in Brazil, Japan, Turkey and India. In the Western societies edentulousness is most frequent among the elderly in Scotland, Ireland and among Native Americans.

Table 1. The prevalence of edentulousness in various countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Reference</th>
<th>Sample Method</th>
<th>Time period</th>
<th>Age group</th>
<th>n = no. of subjects</th>
<th>Prevalence of edentulousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Sanders et al. 2004</td>
<td>national</td>
<td>1979–2002</td>
<td>over 15 years</td>
<td>change from</td>
<td>change from 21% to 8%</td>
</tr>
<tr>
<td>Australia</td>
<td>Crocombe &amp; Slade 2007</td>
<td>interview</td>
<td>2004–2006</td>
<td>55–74</td>
<td>75 and over</td>
<td>14%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n=14,123</td>
<td>36%</td>
</tr>
<tr>
<td>Brazil</td>
<td>Colussi &amp; de Freitas 2007</td>
<td>local</td>
<td>60 years and over</td>
<td></td>
<td>n=277</td>
<td>48%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>McGrath &amp; Bedi 2002</td>
<td>national</td>
<td>16 and over</td>
<td></td>
<td>n=1,855</td>
<td>13%</td>
</tr>
<tr>
<td>India</td>
<td>Shah et al. 2004</td>
<td>clinical</td>
<td>60 years and over</td>
<td></td>
<td>n=1,240</td>
<td>15%</td>
</tr>
<tr>
<td>Ireland</td>
<td>McGrath et al. 1998</td>
<td>clinical</td>
<td>1995</td>
<td>65 and over</td>
<td></td>
<td>42%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n=524</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Shimazaki et al. 2003</td>
<td>local</td>
<td>1988–89</td>
<td>65 and over</td>
<td></td>
<td>47%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>institutionalized</td>
<td>clinical</td>
<td></td>
<td>n=1,929</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>Hanioaka et al. 2007</td>
<td>national</td>
<td>1999</td>
<td>men 60–69</td>
<td>over 70</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>women 60–69</td>
<td>over 70</td>
<td>26%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n=5,457</td>
<td>30%</td>
</tr>
<tr>
<td>Spain</td>
<td>Casado et al. 1994</td>
<td>local</td>
<td>56 and over</td>
<td></td>
<td>n=491</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>clinical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the Nordic countries the prevalence of edentulousness is highest among older inhabitants in Finland and Iceland (Table 2).

Table 2. The prevalence of edentulousness in the Nordic countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Reference</th>
<th>Sample Method</th>
<th>Time period year</th>
<th>Age group</th>
<th>Prevalence of edentulousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Suominen-Taipale et al. 2004</td>
<td>national clinical</td>
<td>2000</td>
<td>65–74 yrs</td>
<td>36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75 yrs and over</td>
<td>56%</td>
</tr>
<tr>
<td>Iceland</td>
<td>Axelsson &amp; Helgadottir 1995</td>
<td>national survey</td>
<td>1990</td>
<td>18 yrs and over</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>65 years and over</td>
<td>72%</td>
</tr>
<tr>
<td>Iceland</td>
<td>Bourgeois et al. 1998</td>
<td>national survey</td>
<td>65–74 yrs</td>
<td>70%</td>
<td></td>
</tr>
</tbody>
</table>
The prevalences of edentulousness in Finland from the last four decades are presented in Table 3. Both national and local studies are included, mostly concerning home-dwelling people, but also institutionalized people in some studies.

### Table 3. The prevalence of edentulousness in Finland.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample Method</th>
<th>Time period year</th>
<th>Age group n=no. of subjects</th>
<th>Prevalence of edentulousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siirilä &amp; Lindberg 1965</td>
<td>local Eastern Finland clinical</td>
<td>1965</td>
<td>15 and over, men n=1,029, women n=1,071</td>
<td>12%, 30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>65-69 years, men n=47, women n=57</td>
<td>32%, 54%</td>
</tr>
<tr>
<td>Alvesalo &amp; Ainamo 1968</td>
<td>local Hailuoto clinical</td>
<td>1968</td>
<td>20 and over n=399, 60 and over n=110</td>
<td>46%, 70%</td>
</tr>
<tr>
<td>Reference</td>
<td>Sample Method</td>
<td>Time period</td>
<td>Age group n=no. of subjects</td>
<td>Prevalence of edentulousness</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Markkula et al. 1973</td>
<td>national interview</td>
<td>1970</td>
<td>15 and over men n=477, women n=498</td>
<td>23% men, 18% women</td>
</tr>
<tr>
<td>Nyman 1983</td>
<td>national interview</td>
<td>1976</td>
<td>45-64 all men n=4,960, South Finland men n=1,458, North Finland men n=587</td>
<td>38% South, 26% North, 64% all, 59% Finland, 71% North</td>
</tr>
<tr>
<td>Nyman 1990</td>
<td>national interview</td>
<td>1987</td>
<td>55-64 yrs men n=1,771, 65 and over men n=1,739</td>
<td>36% men, 61% women</td>
</tr>
<tr>
<td>Vehkalaiti et al. 1991</td>
<td>national clinical</td>
<td>1980</td>
<td>30 and over men n=3,306, women n=3,884</td>
<td>23% men, 37% women</td>
</tr>
<tr>
<td>Hildenkari et al. 1996</td>
<td>local Turku clinical</td>
<td>1978</td>
<td>30 and over men n=208, women n=241</td>
<td>16% men, 22% women</td>
</tr>
<tr>
<td>Ainamo 1983</td>
<td>national interview</td>
<td>1970</td>
<td>15-64 yrs men n=859</td>
<td>19% men</td>
</tr>
<tr>
<td>Ainamo &amp; Murtomaa 1991</td>
<td>national interview</td>
<td>1980</td>
<td>1980 n=921</td>
<td>17% men</td>
</tr>
<tr>
<td>Hämäläinen et al. 2003</td>
<td>local Jyväskylä clinical</td>
<td>1990</td>
<td>80 years men n=65, women n=161</td>
<td>57% men, 60% women</td>
</tr>
</tbody>
</table>
The picture from the studies in the tables above is somewhat different from the information from the World Health Organization Global Oral Data Bank for the years 1986–1996 concerning people aged 65–74 years (Bourgeois et al. 1998), where Iceland had the highest rate of edentulousness (69.6%) and Italy the lowest (12.8%). In five countries, namely Hungary, the United Kingdom, Denmark, Netherlands and Iceland more than 50% of the population of this age were edentulous.

In Finland the prevalence figures before the year 1970 came from local studies, and they indicated that edentulousness was still common also in younger people (Alvesalo & Ainamo 1968, Markkula et al. 1973). During the 1970s edentulousness remained at the same level in Finland (Tuominen et al. 1983) although Ainamo (1983) had reported an increase in edentulousness among those aged over 64 which may be due to the improved supply of dental care. The number of dentists had increased, although they were still more numerous in urban than rural regions. The fact that people moved from rural regions to the

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sample Method</th>
<th>Time period year</th>
<th>Age group</th>
<th>Prevalence of edentulousness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pajukoski et al. 1999</td>
<td>local Kuopio</td>
<td>2000</td>
<td>70 and over</td>
<td>66%</td>
</tr>
<tr>
<td>Närhi et al. 2000</td>
<td>local Helsinki</td>
<td>1990–1995</td>
<td>76 and over all</td>
<td>25%–32%</td>
</tr>
<tr>
<td>Suominen-Taipale et al. 1999</td>
<td>national survey</td>
<td>1978–1997</td>
<td>45–54 yrs n=226</td>
<td>26%</td>
</tr>
<tr>
<td>Suominen-Taipale et al. 2001</td>
<td>clinical interview</td>
<td>1997</td>
<td>65–74 yrs n=1,288</td>
<td>41%</td>
</tr>
<tr>
<td>Koskinen et al. 2012</td>
<td>national interview</td>
<td>2011</td>
<td>65–74 yrs men</td>
<td>17%</td>
</tr>
<tr>
<td></td>
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<td>65–74 yrs women</td>
<td>17%</td>
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<td>75 yrs and over men</td>
<td>29%</td>
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<td>75 yrs and over women</td>
<td>47%</td>
</tr>
</tbody>
</table>
southern parts of the country also made it easier for them to access dental services, which mostly included extractions of carious and/or periodontally weak teeth and fabrication of removable dentures. In the 1980s the frequency of edentulousness decreased in all age groups (Ainamo & Murtomaa 1991).

From the year 1990 onwards the prevalence of edentulousness has decreased in Finland, but on the other hand it has accumulated in older age cohorts (Suominen-Taipale et al. 1999). During the eleven years from the Health 2000 survey to the year 2011 edentulousness decreased clearly among both men and women. In 2011 edentulousness among 55- to 64-year-olds was practically at the same level as it was in 2000 in a cohort that was ten years younger (45–54 years) (Koskinen et al. 2012).

2.2.2 Background factors of edentulousness

The background factors of edentulousness are very much the same around the world. Of these, age, gender, socio-economic status and smoking are the most common ones. Regarding age, the older people are the more likely they are to lose their teeth (Clarkson & O'Mullane 1983, Eustaquio-Raga et al. 2013, Markkula et al. 1973, Northridge et al. 2012, Shimazaki et al. 2003). Concerning gender, most studies have shown that women are more frequently edentulous than men (Tables 1, 2, and 3). The only exception is Japan where men have been reported to be edentulous more often than women (Shimazaki et al. 2003). Socio-economic status, as measured by level of education or by economic situation has a strong association with edentulousness, which also applies to those in institutional care (Gilbert et al. 2003, Pajukoski et al. 1999, Palmqvist et al. 2000, Shimazaki et al. 2003). Tobacco smoking has been shown to be a major independent risk factor for tooth loss in both genders (Ahlqwist et al. 1989, Österberg & Mellström 1986, Ragnarsson et al. 1992) and this association is strong and dose-dependent, independent of other risk factors and potential confounders (Dietrich et al. 2007).

The place of residence may also affect the prevalence of edentulousness. In general, the number of studies evaluating the association of region of residence with edentulousness is relatively low. Ethnicity has often been considered as an important variable in studies from the USA (Wu et al. 2011, Wu et al. 2012). Regional differences in edentulousness have been found in countries like Australia, Ireland, Norway and Finland, where parts of the country are sparsely inhabited (Adams et al. 2003, Henriksen et al. 2003, McGrath et al. 1998, Nyman 1983, Suominen-Taipale et al. 2004, Vehkalahti et al. 1991). As in the above-
mentioned studies, edentulousness has also shown to be more frequent in Indian rural areas compared to urban ones (19% vs. 2%), although the population density does not differ much between these areas. One explanation for these differences may be the varying amount of dental care service (Shah et al. 2004). In contrast, other studies have found no regional differences in the prevalence of edentulousness (Colussi & de Freitas 2007, Eklund & Burt 1994).

2.2.3 Influence of edentulousness on oral and general health

Influence on jaw structure and mastication

Loss of all teeth affects other parts of the masticatory system as well. Bone loss occurs generally in different parts of jaws (Allen & McMillan 2003b) leading to several changes in jaw morphology. Reduction of residual ridges occurs over time with age, decreasing the extent of the denture-bearing area. Ridge resorption is usually more marked in the lower jaw than in the upper jaw (Tallgren 2003). This reduction alters face height and facial appearance (Allen & McMillan 2003b) including changes in the soft-tissue profile, such as protrusion of the chin (Tallgren et al. 1991).

Mandibular bone shape changes owing to edentulousness can also appear as a widening of the gonial angle and shortening of the ramus and condylar heights (Fish 1979, Ohm & Silness 1999, Raustia et al. 1998). These changes are modified by age and systemic factors (Bras et al. 1982a, Bras et al. 1982b); other contributors to these changes have also been presented (Carlsson 1998).

Several studies have shown that the number of functioning teeth is an important indicator of masticatory efficiency (Fontijn-Tekamp et al. 2000, Gottfredsen & Walls 2007, Sheiham et al. 2001). The masticatory muscles change in function and structure in edentulous patients, as evidenced by decreased contractile activity and lower muscle density compared to dentate subjects (Raustia et al. 1996). The superficial masseter muscle in the gonion region has been reported to be larger in dentate than in edentulous subjects (Kasai et al. 1997). The cross-sectional areas of the masseter and medial pterygoid muscles have been shown to decrease more with age in edentulous subjects as compared to dentate subjects (Bhoyar et al. 2012, Newton et al. 1993, Newton et al. 2004). Because the masseter and medial pterygoid muscles insert into the region of the
gonial angle, the contractile power of these muscles also influences the shape of the mandibular base (Ingervall & Thilander 1974).

Ageing alone has little impact on the masticatory function. Several studies have reported that denture wearers have significantly lower bite strength than dentate individuals (Hatch et al. 2001, Helkimo et al. 1977, Michael et al. 1990). Along with bite force, chewing ability is reduced in edentulous and complete denture wearing individuals (Feine & Lund 2006, Helkimo et al. 1978, Locker 2002b). Nearly half of the variation in chewing efficiency has been explained by bite force alone (Fontijn-Tekamp et al. 2000).

Wearing of complete denture and subjective oral complaints

The majority of edentulous people wear complete dentures. Most of them are satisfied with their dentures (Muller et al. 1994). Satisfaction with wearing of dentures often does not coincide with the clinical status of the dentures (Carlsson et al. 1967). Older people are more satisfied with poorly fitting dentures and are less willing to try to adapt to new dentures (Muller et al. 1994). Many problems related to complete denture wearing have been reported, mostly poor retention of lower denture, poor chewing ability, pain in the neck or head, soreness of the denture-bearing mucosa, poor aesthetics of the dentures and overall poor adaptation to dentures (Agerberg & Viklund 1989, Bergman & Carlsson 1985, Lechner et al. 1995, Närhi et al. 1997). However, satisfaction with complete denture treatment has been reported to be relatively high, namely 65% to 75% of the patients with older dentures are reported to be satisfied with treatment results, which has been suggested to be due to remarkable human adaptation rather than the prosthodontic skill of the dentist (Berg 1993). Those patients who adapt poorly or not at all to wearing complete dentures pose a real challenge to prosthodontists and dentists. Psychological and emotional factors have an important role in adaptation, emphasizing the importance of patient-dentist relationship and psychological factors in the acceptance of new dentures (Berg 1993, Bergman & Carlsson 1985, Carlsson 1998).

Influence on oral health

Edentulousness and denture wearing have been reported to associate with oral mucosal disorders such as denture stomatitis, traumatic ulcers, angular cheilitis and oral candidosis (Jainkittivong et al. 2002), especially in the case of ill-fitting
dentures (MacEntee et al. 1998). The aetiology of denture stomatitis is multifactorial, the most important background factors being microbial plaque resulting from poor oral hygiene and infections caused for example, by Candida albicans, traumatic injuries as well as immunologic aspects (Bohnenkamp 1996, Öhman et al. 1995, Rodriguez-Archilla et al. 1996). Flabby ridges and denture irritation hyperplasia are also fairly common consequences of the use of complete dentures. Traumatic ulcers are common in the case of newly fabricated dentures, but they usually heal rapidly after the elimination of irritating overextensions or occlusal disturbances. Chronic irritation by dentures has been suspected to be a causal factor for oral carcinoma, but the evidence for this is lacking (Budtz-Jörgensen 1981, Velly et al. 1998). Angular cheilitis is associated with Candida albicans infection and also with general health factors like nutritional deficiency and immune dysfunction (Öhman et al. 1986).

Saliva is essential for the normal function of the oral cavity. It keeps the oral mucosa moist and soft, which facilitates speaking, chewing and swallowing. Saliva contains various anti-bacterial, -viral and -fungal agents, which promote the balance of the oral flora and resist fungal infections (Mese & Matsuo 2007). A decreased salivary flow causes various subjective problems such as feeling of dry mouth and difficulties in eating and speaking. The decrease in saliva secretion is most often due to medication with different drugs affecting the salivary glands (Mese & Matsuo 2007). Another important factor for a normal salivary flow is mastication capability, as bite force is associated with it (Yeh et al. 2000). Ageing itself does not weaken the function of the salivary glands (Tenovuo 1992). The negative effect of low saliva secretion thus comes from medication or lowered masticatory function, as is often the case with edentulous elders.

According to some studies edentulousness is also associated with temporomandibular disorders (Dallanora et al. 2012, Divaris et al. 2012). It has been shown that loss of all teeth, wearing of complete dentures and poor condition of dentures associate with pain-related findings of temporomandibular disorders, especially in women (Sipilä et al. 2013). Psychosocial factors have a modifying effect on these associations (Okoro et al. 2012, Sipilä et al 2013).

Influence on general health and quality of life

Edentulousness can affect general health in many ways. This relationship has been thought to be reciprocal, though the mechanisms linking poor general health and tooth loss are not yet clear (Kandelman et al. 2008). Many studies claim the
mechanism to lie in nutrition, which suffers from the lowered mastication capacity. The disability in mastication could weaken the desire to chew and swallow certain hard foods, which could further lead to an unhealthy modification of food choices and to a lower intake of fruit, vegetables, fibre and carotene and increased intake of cholesterol and saturated fats (Sheiham et al. 2001). Hence tooth loss may have a negative impact on the diet and lead to illnesses dependent on unhealthy food intake (Tsakos et al. 2010, Walls et al. 2000, Walls & Steele 2004).


The nutritional consequences of edentulousness are complex due to several factors that influence the nutritional status and food intake, including chronic disease, alterations in the gastrointestinal tract, functional abilities, chewing problems, psychological and social factors and lower socioeconomic status (Nieuwenhuizen et al. 2010, Walls & Steele 2004). There are controversial results concerning the significance of ethnicity or race on nutrition and tooth loss. Some studies have shown a clear association between them (Popkin et al. 1996), whereas others have found no association (Lee et al. 2004).

Bone mineral density or osteoporosis have been mentioned as factors associating with edentulousness or a lower number of remaining teeth (Daniell 1983, Grodstein et al. 1998, Yoshihara et al. 2005).

Edentulous people are worse off even in mortality rates than their dentate counterparts. Tooth loss was associated with disability and mortality even after adjusting for confounding factors such as socioeconomic status and health behaviour (Holm-Pedersen et al. 2008). Some studies have shown that edentulousness before the age of 65 years leads to an increased risk of earlier death (Brown 2009, Österberg et al. 2008).

Due to the fact that teeth have an important role in facial appearance, speech and eating ability, it is evident that loss of teeth leads to poor oral health-related quality of life. This includes impaired mastication, denture trauma, aesthetic concerns and negative self-perception (Heydecke et al. 2004, Locker et al. 2002a, Locker 2004, Nitschke & Muller 2004). Denture wearers have decreased self-confidence, premature ageing, altered self-image and altered behaviour in socializing and forming close relationships (Fiske et al. 1998). Many people
create skills to overcome limitations due to dentures but some are unable to do so (Allen & McMillan 2003a). Results from a study using the Oral Health Impact Profile, OHIP-14 (Locker 1988, Nuttall et al. 2006), showed that the prevalence and severity of oral impacts varied according to age, level of education, number of remaining teeth and use of removable dentures. Edentulous subjects with complete dentures reported worse quality of life compared with dentate ones, and in some respects even worse than subjects using partial removable dentures (Lahti et al. 2008).

2.3 Infections of dental origin

Infections in dentition and jaws are mainly due to two conditions, caries and periodontal disease. Both diseases have been known in human history for centuries (Williams 1990). Caries is a chronic infectious disease caused by certain bacteria in the oral flora, mainly Streptococcus mutans, which produce acids from the metabolism of food residues to dissolve enamel and dentin (Shaw 1987). Caries affects teeth mainly during childhood and early adulthood whereas periodontal disease is more marked later in life. Caries destroys the hard tissue of a tooth and progresses to the pulp, from where the infection spreads to the periapical tissues outside the root. This is called apical periodontitis, which may be acute or chronic.

Periodontal disease is an inflammatory disease of the gingiva, connective tissues and alveolar bone that anchor the teeth in the jaws. The infection is caused by specific bacteria in the periodontal pocket. This disease usually begins as gingivitis and when, but not always, the inflammatory process extends to the periodontal ligament and alveolar bone, periodontal disease is called periodontitis. Besides the local effect of the bacteria the host’s systemic response to the bacteria plays an important role in the pathogenesis of periodontitis. (Williams 1990). The aetiology and pathogenesis of periodontal disease is influenced by many species of bacteria, the most important of which are Porphyromonas gingivalis, Aggregatibacter actinomycetemcomitans, Prevotella intermedia, Tannerella forsythia and Treponema denticola (Haffajee & Socransky 2005, Könönen&Muller 2014).

When the periodontal infection has spread to the periodontal ligaments and alveolar bone, it forms both horizontal bone loss and vertical bone pockets. When bone loss occurs as deep as the furcation of the roots in multi-rooted teeth it forms a furcal lesion. Periodontitis is mainly a chronic disease but it may also become
acute and form pus in the periodontal pockets. As periodontal disease destroys the
tissues that anchor the teeth to the jawbone, it is the main cause of tooth loss
especially in adult and elderly people (Williams 1990).

In recent years, a consensus regarding the criteria for defining periodontitis
and its progression has been presented. The proposed criteria for a two-level
periodontitis definition by the European Federation of Periodontology contains:
firstly the presence of proximal attachment loss of 3mm or more in two adjacent
teeth, and secondly the prevalence of proximal attachment loss of 5mm or more in
30% of the teeth present or more (Tonetti & Claffey 2005). Arbes et al (2001)
defined periodontitis as 1 or more periodontal sites with attachment loss of 3 mm
or greater and a pocket depth of 4 mm or greater at the same site. Attachment loss
(AL) was defined as the measurement from the cementoenamel junction to the
bottom of the sulcus, while pocket depth (PD) was the distance from the gingival
margin to the bottom of the sulcus (Arbes et al 2001). A similar definition was
published in the NHANES survey with definitions for moderate and severe cases
of periodontitis. Moderate periodontal disease is defined as having at least two
teeth with interproximal attachment loss of 4 millimetres or more or at least two
teeth with 5 millimetres or more of pocket depth at interproximal sites. Severe
periodontal disease is defined as having at least two teeth with interproximal
attachment loss of 6 millimetres or more and at least one tooth with 5 millimetres
or more of pocket depth at interproximal sites (The NHANES survey 1999-2004).
A report from the latest NHANES study from 2009-2010 used the following
definitions: Severe periodontitis was defined as the presence of 2 or more
interproximal sites with \( \geq 6 \) mm AL (not on the same tooth) and 1 or more
interproximal site(s) with \( \geq 5 \) mm PD. Moderate periodontitis was defined as 2 or
more interproximal sites with \( \geq 4 \) mm clinical AL (not on the same tooth) or 2 or
more interproximal sites with PD \( \geq 5 \) mm, also on the same tooth. Mild
periodontitis was defined as \( \geq 2 \) interproximal sites with \( \geq 3 \) mm AL and \( \geq 2 \)
interproximal sites with \( \geq 4 \) mm PD (not on the same tooth) or 1 site with \( \geq 5 \) mm.
Total periodontitis was the sum of severe, moderate, and mild periodontitis (Eke
et al 2012).

Making a diagnosis in cases of infections of dental origin is not always
possible by clinical examination alone. Although the actual diagnosis of
periodontitis cannot be made based on radiographs alone either, they are an
essential component of a complete periodontal examination (Armitage 2003).
2.3.1 Radiographic diagnostics

Since the introduction of panoramic radiography into general practice in dentistry its superiority compared with intraoral periapical radiography has been much discussed. After comparing panoramic radiographs with full mouth surveys with periapical and bite-wing radiographs, the conclusion was that, except for carious lesions, panoramic radiographs can be considered a useful tool in epidemiological studies of oral health (Ahlqwist et al. 1986). Panoramic radiography is sufficiently reliable for clinical assessment of alveolar bone loss but the bottom of periodontal pockets tends to be deeper than the radiographically visible defect (Soikkonen et al. 1990). Panoramic radiography should be supplemented by intra-oral radiographs when necessary (Molander et al. 1991).

However, other studies have concluded that the agreement between panoramic and intraoral radiography is not sufficient for panoramic radiography to be used alone in diagnostics of periapical lesions, marginal bone loss or caries, (Molander 1996), sclerotic lesions and most osteolytic lesions (Rohlin et al. 1989) or approximal caries (Molander et al. 1993).

When using the periapical index (Örstavik et al. 1986) in comparing periapical radiography and digital panoramic radiography, the conclusion was that teeth were best viewed on periapical radiographs, except for maxillary second and third molars which were best viewed in panoramic radiographs (Ridao-Sacie et al. 2007).

2.3.2 Epidemiology and background factors

Epidemiological surveys of dental infections have been undertaken in several countries during the last decades. Severe periodontitis showing grade 4 in the CPITN, which may result in tooth loss, has been found in 5 to 20% of most adult populations worldwide (Petersen et al. 2005).

In a study from the USA from the beginning of the 1990s, it was estimated that at least 35% of the dentate adults aged 30 to 90 had periodontitis, with 21.8% having a mild form, (including one or more teeth with a probing depth 3mm or more or one or more posterior teeth with grade 1 furcation involvement,) and 12.6% having a moderate (including one or more teeth with 5 mm or more probing depth, or two or more teeth, or 30% or more of the teeth examined, having 4 mm or more probing depth, or one or more posterior teeth with grade I furcation involvement and accompanied by 3 mm or more probing depth) or advanced form (two or more teeth, or 30% or more of the teeth examined, having 5 mm or more probing depth, or four or more teeth, or 60% or more of the teeth examined, having 4 mm or more probing depth, or one or more posterior teeth with grade II furcation involvement), and that the prevalence of periodontitis increased considerably with age. However, the prevalence of moderate and advanced periodontitis decreases in adults 80 years of age and older. Attachment loss and destructive periodontitis have been shown to be consistently more prevalent in males than females, and more prevalent in blacks and Mexican Americans than whites (Albandar et al. 1999).

In 2009–2010 the total prevalence of periodontitis in adults in the USA aged 30 years and older was 47.2%. The sum of severe, moderate, and mild periodontitis ranged from 24.4% in adults aged 30 to 34 years to 70.1% in adults aged 65 years and older. Standardized for age, the prevalence of periodontitis was significantly higher in males than in females, highest among Mexican Americans compared with all other racial and ethnic groups studied, highest among persons with lowest educational status and highest among current smokers (Eke et al. 2012).

In a study from a remote Canadian community 48.1% of the subjects had mean attachment loss of 4mm or more, while 9.6% had a mean loss of 6mm or more. Current smokers had significantly more attachment loss than non-smokers (Sbaraglia et al. 2002).

In New Zealand from 1988 to 2009 there have been significant reductions in the prevalence of periodontitis among people aged 35–44 and 65–74 years most
notably among women, but no such reductions were observed among those aged 20–24 years (Haisman-Welsh & Thomson 2012).

In the United Kingdom in 1998 43% of dentate individuals had loss of attachment greater than 3.5mm on at least one tooth and there was an increase in the prevalence with age (Morris et al. 2001). Age was the factor most strongly associated with periodontal conditions. Men had significantly higher odds of having this degree of loss of attachment as did those with low education level. It is interesting that none of the behavioural factors that were examined were found to be significant (Treasure et al. 2001).

In Pomerania, Germany, the prevalence of periodontal disease expressed as the presence of at least one periodontal pocket of 4mm or more, was higher in men aged 60–69 years 85% vs. 71% in 70- to 79-year-old men; the figures for women aged 60–69 years were 71% vs. 62% in 70- to 79-year-olds (Mack et al. 2004).

In Norway, 33% of older dentate subjects had periodontal disease, measured as having pocket depth of 4mm or more, and of those, 12% had severe periodontitis, i.e. three or more pocket depths of 6mm or more. After univariate testing, correlation with periodontal disease could be seen with daily tobacco use, high plaque score and low education level. After testing these factors in a multivariate model together with demographic status, with periodontal pockets 6 mm or more as the outcome variable, only daily tobacco use remained statistically significantly correlated with periodontal disease (Norderyd et al. 2012).

A clinical examination from Denmark showed that more than 82% of older participants aged 65–74 had pockets of 4–5mm or deeper compared to 42% in younger adults aged 35–44. In both age groups, the mean number of teeth with periodontal pockets deeper than 6mm or more was high in individuals with a low level of education (Krustrup & Petersen 2006).

A population-based study with clinical and radiographic examinations in the years 1973, 1983, 1991 and 2003 in Jönköping Sweden revealed that the mean numbers of 4–5mm pockets in the 40–80-year age groups varied between 11% and 14% in 2003. No gender differences were found in this study in 2003 (Hugoson et al. 2008).

The prevalence of endodontically treated teeth with periapical or juxtaradicular lesions was about 20% in 2003 compared to 25–30% in 1973, 1983, and 1993 in Sweden (Hugoson et al. 2005); another Swedish study showed prevalences of root-filled teeth to be 84.7% and of periapical lesions to be 31.1% (Frisk & Hakeberg 2005), while in Denmark 52.3% of endodontically treated
teeth had periapical lesions (Kirkevang et al. 2000). Socio-economic variables and dental visiting habits did not have obvious implications for periapical health (Frisk & Hakeberg 2006, Kirkevang & Wenzel 2003) nor were there any differences between age groups (Frisk & Hakeberg 2005) whereas root-filled teeth and carious lesions (Frisk & Hakeberg 2006), quality of dental treatment, regularity of dental visits and smoking were associated with periapical lesions (Kirkevang & Wenzel 2003).

Similar associating factors were also found in a study from Morocco among patients seeking routine dental treatment in a dental teaching school hospital. Periapical lesions were found in 63.8% in this population. In root-canal treated teeth the prevalence was 39.5% (Chala et al. 2011).

In Finland several nation-wide surveys about oral health have been undertaken during the last few decades. According to a clinical examination and questionnaire during the years 1977–1980 severe periodontal disease with pocket depth more than 6mm was found in 32% of men and 19% of women in Finland. In subjects aged 65 and older the figures were 43% in men and 27% in women. Age, gender and level of education were associating factors in periodontal health (Vehkalahti et al. 1991).

Twenty years later another large population oral health survey was carried out in Finland which also included panoramic radiographic examination. According to the Health 2000 Survey severe periodontitis with pockets 6mm or more was found in 21% of all subjects, in 26% of the men and in 16% of the women. The results also showed that of the dentate subjects aged 30 years or over, 31% had potential infection foci like deep infrabony bone pockets and/or periapical lesions, seen in 36% of the men and in 27% of the women. In subjects 65 years or older these potential infection foci were found in 34%, 42% of the men and 29% of the women. Compared with those with high education, subjects with a low educational level had more often vertical bone pockets; differences were also found between regions and income levels. Periapical lesions were more often found in connection with inadequate root-fillings or pulp amputation (Suominen-Taipale et al. 2004). A study using the same material reported that in the age group 65 years and over a high number of teeth with deepened periodontal pockets, i.e. pockets 4mm or deeper, was associated with high age, middle or high education and living in a rural area, and the conclusion was that on national level the greatest need for treatment is in persons aged 65–74 years, living in a rural area and having a low level of education because they are highly represented in the elderly population (Syrjälä et al. 2010).
Eleven years later a more compact study was carried out in Finland comprising a questionnaire and clinical examination. The results from this study showed that periodontitis in at least one tooth with a pocket depth of 4mm or more was found in 70% of all men and in 56% of all women. Age and gender were again associating factors, and geographical differences were also found. The authors suggested that the frequency of periodontitis in young middle-aged subjects was especially alarming (Koskinen et al. 2012).

A compact radiographic study of home-dwelling very old dentate persons aged 76, 81 and 86 years, the Helsinki Aging Study (HAS), was carried out in 1990 and 1991. Alveolar bone loss, either horizontal or vertical, was very common; it did not exist in only 5% of the subjects. Bone loss was graded to be slight in 18%, moderate in 31% and advanced in 46%. Infrabony pockets of 3mm or more were found in 51% of the subjects and furcation lesions in 28% (Soikkonen et al. 1998). Of these old dentate subjects 133 had endodontically treated teeth, 16% of which exhibited a periapical lesion; 4% of the periapical lesions were found in teeth without endodontic treatment. Lesions were most prevalent in teeth with root canal post perforation, with overfilled root canals and multi-rooted teeth with one or more unfilled roots. In endodontically treated teeth men had more periapical lesions than women; no other statistically significant differences between genders or age groups were reported (Soikkonen 1995). Five years later a follow-up study was performed, comprising 103 home-dwelling old inhabitants, all participants of the former Helsinki Ageing Study. The mean number of teeth decreased during the follow-up period and the mean number of teeth with a periapical lesion decreased in men but not in women; the changes in periodontal findings were relatively few. This study concluded that 68% of the subjects had radiographically detected signs of oral infection foci (Närhi et al. 2000).

Two studies were carried out in Kuopio in Eastern Finland, one concerning oral health of elderly subjects with or without severe heart disease, the other studying oral health of elderly home-living subjects referred to acute geriatric ward. The first-mentioned study had a control group with no heart disease. Clinical and radiographic examinations were made and a modified dental index constructed. The authors reported no significant differences in the mean number of signs of dental infection foci between the heart-disease and no-heart-disease groups, but the subjects with heart disease had worse oral health in terms of the number of teeth, suggesting that the teeth had probably been extracted because of earlier dental or periodontal infections (Meurman et al. 2003b). In the other study
clinical and radiographic examinations were conducted in 184 patients aged 67 to 96 years. The panoramic radiographs showed that 71% of the 63 dentate patients had potential infection foci in their jaws consisting of deep infrabony bone pockets (56%), periapical lesions (15%), furcation lesions (15%) and deep caries cavities (14%). Horizontal alveolar bone loss was recorded in 72% of the dentate patients. Edentulous patients also had potential infection foci in their jaws and they had high counts of salivary yeasts, which also means risk of infection in the oral cavity increasing the inflammatory burden of the system (Meurman et al. 1997).

2.3.3 Association of infections of dental origin with general diseases

Focus of infection in the dentition is a chronic inflammatory lesion caused by periodontal infection, or caries forming periapical infections. It is a potential source of infection in delivering bacteria and their toxins into circulation. The host’s inflammatory response to a bacterial challenge is regulated by genetically transmitted traits like gene polymorphism. In periodontitis the balance between pro- and anti-inflammation has changed to pro-inflammatory activity. This situation resembles the systemic inflammatory conditions seen in several general diseases such as myocardial infarction (Karpinski et al. 2009). Activation of these immunological mechanisms is an essential phase of the pathogenesis of periodontitis (Pihlstrom et al. 2005).

Chronic periodontal lesions are usually described as loss of alveolar bone and depth of the periodontal pocket. A precise picture of the disease would arise if the non-clinical signs of periodontal disease were also measured (Beck & Offenbacher 2005). An example of this is a study which showed that the levels of antibodies to periodontal pathogens are increased in patients with coronary heart disease (Pussinen et al. 2003).

Association with cardiovascular diseases, stroke and peripheral arterial disease

The association between oral infections and cardiovascular diseases has been in the focus of interest of researchers for the last twenty-five years. Coronary heart disease, myocardial infarction, angina pectoris, atherosclerosis and hypertension have usually been included in these diseases. Several studies have shown the association of oral infections such as periodontal diseases, periapical infections
and deep caries with these general diseases, although some of them have found only a weak association.

One of the first reports evaluating the association between cardiovascular disease and dental health was the study by Mattila et al. (1989) showing that dental health was significantly worse in patients with acute myocardial infarction compared to controls. The association between dental infections and severe coronary atheromatosis in men was significant even after adjustment for age, blood lipids, body mass index, hypertension, smoking and social class. No association has been observed among the small number of women studied (Mattila et al. 1993a). In a seven-year follow-up study of 214 individuals, dental health was a significant predictor of coronary events when controlled for age, sex, socioeconomic status, smoking, hypertension, the number of myocardial infarctions, diabetes, body mass index and serum lipids (Mattila et al. 1995). In the study about age, dental infections and coronary heart disease it was found that again, dental indices were higher among patients with heart disease than among controls, but these differences were not statistically significant. The authors claimed that these results could not be affected by the confounding factors; however, the participants were older and this was most likely the reason for the findings (Mattila et al. 2000).

Several studies have shown an association between poor dental health and risk of cardiovascular disease. The risk was stronger in men younger than 50 years (DeStefano et al. 1993); the association with myocardial infarction was statistically significant only in middle-aged subjects aged 40 to 60 years (Holmlund et al. 2006). Self-reported bleeding gums, presence of dentures and known cardiovascular disease were also associated (Buhlin et al. 2002), and women with coronary heart disease showed a positive association between the number of periodontal pockets and coronary heart disease with an odds ratio of 3.8 (Buhlin et al. 2005). Subjects with coronary artery disease had higher infection index scores than matched controls in periodontitis and periapical lesions but not in caries or pericoronitis (Oikarinen et al. 2009). A statistically significant dose-dependent relationship was found between increasing scores of the periodontal risk of infectiousness and the presence of coronary artery disease (Geerts et al. 2004). Patients with acute myocardial infarction exhibited a significantly higher number of missing teeth, a higher number of periapical lesions and a higher value of periodontal screening index compared with individuals without myocardial infarction (Willershausen et al. 2009). Severe alveolar bone loss was associated with acute coronary syndrome with an odds
ratio of 5.4, and the number of stenosed arteries was linearly associated with alveolar bone loss, the number of missing teeth and periodontal pockets (Buhlin et al. 2011)

The serum IgG-antibodies to two of the most common bacteria found in inflamed periodontal tissues were determined and the findings showed that coronary heart disease was more prevalent in subjects with a high combined antibody response than in those with a low response; the conclusion was that periodontal infection or the response of the host to the infection may play a role in the pathogenesis of coronary heart disease (Pussinen et al. 2003). High antibody response to periodontal pathogens independently predicted incident cardiovascular events with a hazard ratio of 1.87 (95% CI 1.13–3.08), suggesting that the exposure to periodontal pathogens or endotoxin induces systemic inflammation leading to increased risk of cardiovascular disease (Pussinen et al. 2007).

Lesions of endodontic origin were significantly associated with time to coronary heart disease diagnosis (p<0.05), but only in participants under 40 years, while no statistically significant association was observed among those above 40 years; the authors concluded that these findings are consistent with the research suggesting a relationship between chronic periodontal inflammation and the development of coronary heart disease especially among younger men (Caplan et al. 2006).

Most studies reviewed in this chapter have reported positive associations between inflammation caused by dental infections and cardiovascular diseases. However, many studies have found no positive associations or no associations at all. Male physicians who had reported periodontal disease at baseline had after 12 years slightly elevated, but statistically non-significant, relative risks of nonfatal myocardial infarction, nonfatal stroke and cardiovascular death (Howell et al. 2001). The confirmed elimination of chronic dental infections in edentulous participants did not lead to a decreased risk of having a coronary heart disease event (Hujoel et al. 2001). Periodontitis or gingivitis does not elevate coronary heart disease risk among people with prior heart attack or self-reported cardiovascular disease (Hujoel et al. 2002). The multivariate logistic regression analysis did not prove the endodontic variables to be predictive of coronary heart disease (Frisk et al. 2003). The associations between oral health indicators and coronary heart disease are mostly explained by confounding factors, particularly those relating to health behaviour (Tuominen et al. 2003, Ylöstalo et al. 2006).
Different perspectives have been presented on the question of causality between dental infections and cardiovascular and other general diseases. Joshipura & Ritchie (2005) commented the question of whether the relationship between tooth loss and chronic disease is explained by socio-economic status. Armitage (2008) questioned the missing component in clinical trials that study the effect of periodontal therapy on general health. He suggested that criteria for successful periodontal therapy must be established. Offenbacher & Beck (2005) asked for the potential cardioprotective benefits of periodontal therapy. They wished to see studies investigating whether periodontal treatments reduce overall cardiovascular risk. A large review, aimed to critically appraise the evidence on the impact of periodontal treatment of cardiovascular diseases (CVD) biomarkers and outcomes, came to the conclusion that the main consistent finding after periodontal therapy was a reduction in serum levels of C-reactive protein and an improvement of measures of endothelial function (which represents a surrogate marker of CVD). Both biomarkers have been associated with increased future risk of CVD and therefore this would pose evidence in favour of a potential beneficial effect of periodontal therapy in reducing CVD risk (D’Aiuto et al 2013). In a consensus report on periodontitis and systemic diseases the conclusion was that there is consistent and strong epidemiologic evidence that periodontitis imparts increased risk for future cardiovascular disease but intervention trials to date are not adequate to draw further conclusions (Tonetti et al. 2013).

The formation of atherosclerotic plaque in the interior walls of cerebral or peripheral arteries is largely similar as in carotid arteries. Studies about the connection between dental infections and cerebral infarctions or stroke are sparse, but positive connections have been reported (Joshipura et al. 2003, Lafon et al. 2014, Syrjänen et al. 1989). An interesting recent finding reported that odontogenic bacteria were found in ruptured cerebral aneurysms (Pyysalo et al. 2013). Incident tooth loss was significantly associated with peripheral arterial disease, especially among men with periodontal disease, which supports a potential oral infection-inflammation pathway (Hung et al. 2003).

**Association with other diseases such as diabetes, osteoporosis, lung diseases, neurological diseases and cancer**

Several studies and reviews have reported the association of type 2 diabetes mellitus with periodontal diseases (Albandar 2002, Negrato et al. 2013, Segura-Egea et al. 2012, Tervonen et al. 2000) as well as with higher prevalence of
periapical lesions, greater size of osteolytic lesions and worse prognosis for root-filled teeth (Segura-Egea et al. 2012). The proinflammatory mediators that are implicated in hyperglycaemia have been shown to associate with periodontal disease and also with increased risk of cardiovascular disease (Albandar 2002b). Salivary lysozyme has been suggested to be a marker for the total inflammatory output from the oral cavity, contributing to cardiopathogenesis (Janket et al. 2008). Besides the finding that diabetes has an adverse effect on periodontal healthit has been shown, conversely, that periodontal disease may increase the risk for diabetes (Chapple et al. 2013). Diabetes mellitus has an adverse effect on glycaemic control and diabetes-related complications (Negrato et al. 2013) as well as on blood glucose levels (Chapple et al. 2013).

The association between skeletal bone mineral density and alveolar bone loss in periodontitis has been widely studied. In postmenopausal women oestrogen deficiency is associated with osteopenia and osteoporosis. A review article concluded that oestrogen deficiency is a risk factor for periodontal disease (Genco & Grossi 1998). Studies have shown that among postmenopausal women decreased skeletal bone mineral density is associated with alveolar bone loss and clinical attachment (Brennan et al. 2007, Mohammad et al. 2003, Tezal et al. 2000) as well as tooth loss (Mohammad et al. 2003).

The relationship between periodontal disease and bacterial pneumonia has been reported by Scannapieco & Mylotte (1996). They explain that bacterial pneumonia in adults is the result of aspiration of oropharyngeal flora into the lower respiratory tract and the failure of host defence mechanisms to eliminate the contaminating bacteria. Later Raghavendran et al. (2007) discussed the role of poor oral health as a risk factor for hospital-acquired pneumonia and questioned whether the aspiration of the bioactive molecules or the secretion of these is the risk factor for pneumonia initiation. A recent report also concluded that an association exists between periodontitis and chronic obstructive pulmonary disease (COPD) and pneumonia (Linden et al. 2013).

Studies on neurological diseases connected with oral diseases deal mostly with Alzheimer’s disease or other kinds of dementia. The possible mechanisms of how chronic periodontitis may contribute to the onset and progression of Alzheimer’s disease have been suggested to be inflammatory processes (Kamer et al. 2008, Watts et al. 2008). On the other hand, patients with dementia are at increased risk of poor oral health and poor oral hygiene (Syrjälä et al. 2012), which may partly explain the association. Studies on other kinds of neurological diseases have rarely been published in connection with oral or dental diseases. A
review article explains that oral infection or dental treatment sometimes causes brain abscess, and also discusses the possible pathways through which oral microorganisms may enter the cranium (Li et al. 1999).

Oral diseases and related factors have been suggested to be risk factors for oral cancer, especially tongue cancer. Of these factors, poor oral hygiene and sores in oral mucosa caused by dentures (Velly et al. 1998) and chronic periodontitis (Tezal et al. 2005, Tezal et al. 2007) have been studied. Furthermore, periodontitis measured as alveolar bone loss from panoramic radiographs has been shown to be an independent risk factor for head and neck squamous cell carcinoma, as modified by smoking (Tezal et al. 2009). The reports highlight the importance of collaboration between oncologists and dental professionals to improve patient care (Migliorati 2008).

**Association with adverse pregnancy outcomes, obesity and mortality**

Dental infections, especially periodontitis, have also been linked with other conditions besides general diseases. Periodontitis is a commonly found disease in pregnant women. It may be a significant risk factor for preterm low birth weight (Offenbacher et al. 1996) and preterm birth (Agueda et al. 2008) especially in the case of multiple oral infections (Heimonen et al. 2009).

The association between obesity and periodontal infection has been much studied and the results are diverse. Obesity was significantly associated with periodontitis in adult, non-smoker women, but smoking may attenuate this association (Dalla Vecchia et al. 2005). Obesity was associated with periodontitis in a homogenous group of 60- to 70-year-old European men (Linden et al. 2007). An association between body weight and periodontal infection in an exposure-response manner among non-diabetic population aged 30–49 was shown but further studies are needed to clarify the possible role of periodontal infection in obesity (Saxlin et al. 2011). In contrast, a study with a small sample of elderly did not provide any evidence of the risk of elevated body weight for periodontal infection (Oikarinen et al. 2013).

Mortality from various causes has also been linked with oral health, especially periodontal diseases. In a study of home-living elderly persons Soikkonen et al. (2000) found that vertical bone loss judged as advanced infrabony pockets from panoramic radiographs was associated with four-year all-cause mortality in elderly persons aged 76, 81 and 86 years. In a group of 33- to 69-year-old victims of sudden cardiac death, poor oral health measured with an
index of panoramic radiography findings of infectious origin was associated with sudden cardiac death compared to controls who died of other reasons (Karhunen et al. 2006). Previous inflammation in the periodontium in the early old age of 70 years tended to be associated with mortality in older age after 21 years (Avlund et al. 2009). In a homogenous group of 60- to 70-year-old Western European men those with the most severe loss of periodontal attachment were at an increased risk of early death compared with those with the lowest loss of periodontal attachment (Linden et al. 2012).

A report from a workshop on periodontitis and systemic diseases (chronic obstructive pulmonary disease, pneumonia, chronic kidney disease, rheumatoid arthritis, cognitive impairment, obesity, metabolic syndrome and cancer) declared that the reported associations do not imply causality, and concluded that the field of research is wide open and the gaps in knowledge are large (Linden et al. 2013).

2.4 Fixed prosthesis treatment among dentate elderly people

Fixed prosthesis treatment traditionally means fabrication of fixed partial dentures (FPDs) and crowns made of metals, ceramics, or their combinations, and today of composite materials as well. They are usually anchored to retainers containing natural teeth, tooth roots or dental implants.

FPDs are fabricated to replace one or more missing teeth. Crowns are made to strengthen the otherwise weak structure of the tooth. The demand for these kinds of treatments depends much on the financial situation of the patient and on the supply of these services. Removable partial dentures, made either from acrylic resin or metal base, are the alternative in cases where the financial situation does not allow a fixed prosthesis or where the number of abutment teeth is not sufficient for FPDs, or when severe ridge resorption does not allow implant-retained prosthesis. The number of missing teeth needing replacement varies according to the situation of the gap in the dental arch and its visibility. The chewing function of the dentition should be acceptable. Ten or even fewer occluding pairs of teeth should be acceptable for elderly people (Käyser 1990). Removable partial dentures, whether acrylic or metal-based, are a risk for the remaining abutment teeth to have caries and periodontal disease, which is why FPDs are preferred in replacement of missing teeth and occlusal rehabilitation (Drake & Beck 1993). FPDs are also recommended because of the easiness of their usage and because they cause less problems compared with removable dentures.
The prevalence of fixed prostheses and crowns is not widely studied. Many studies report these among other conditions in the dental arch. The prevalence of fixed dental prostheses varies much from one country and culture to another and even in different parts of one country depending on the availability of dental care. In Florida in the USA in a cohort study of adults 45 years or older, 58% of the sample had one or more crowns and 23% had one or more bridges (Dolan et al. 2001). They also reported that whites are more likely to be treated with fixed prostheses than blacks even when income, clinical factors, behavioural and attitudinal factors are taken in account. In the United Kingdom among dentate adult people 34% had at least one crowned tooth (Pine et al. 2001). In Germany in the years 1997 and 2005 the prevalence of all kinds of fixed restorations in subjects aged 65–74 years increased from 20.8% to 35.6% (Zitzmann et al. 2007). In Switzerland among a random sample aged 15 to 74 years the prevalence of crowns increased somewhat between the years 1992 and 2000 while the prevalence of fixed dental prostheses remained approximately the same (Zitzmann et al. 2008).

In Sweden information about the prevalence of FPDs and crowns is abundant compared to other countries in Western Europe. Among subjects aged 41 to 65 years in southern Sweden the percentage of dentate subjects with fixed bridges was 27.1%. Fixed bridges were used more in the maxilla, often to restore anterior spaces (Björn & Öwall 1979). In Jönköping a cross-sectional study with about 1,000 participants was performed every ten years for thirty years from 1973 to 2003. The proportion of crowned teeth in the 50-year age group decreased from 1973 to 2003. In elderly age groups the percentages did not change much being 23.7% and 38.6% for 60- and 80-year-olds in 2003, respectively (Hugoson et al. 2005).

In Finland studies about the prevalence of fixed dental prostheses are very sparse; even large nationwide surveys did not report this information in the past decades. In a nationally representative sample of 5,028 dentate adults aged 30 years or over 10.9% of the subjects had crowns and 3.7% had bridges. Having crowns or bridges was statistically significantly associated with female gender, age, number of remaining teeth, level of income and regular dental attendance pattern. The probability of having crowns or bridges was statistically significantly decreased by a low level of education and longer distance to the nearest dental clinic (Ranta et al. 1987). In a study comprising 1,600 adults from the area of Ostrobothnia 2% of the total sample had one or more fixed bridges and 3% had one or more crowns. The fixed prosthetic constructions were reported to be more
often in acceptable condition than the removable ones (Tervonen 1988). Of a population of home-living elderly aged 76, 81 and 86 years in Helsinki, 364 participated in the dental examination. 45% of the dentate participants had fixed prosthesis, 43% had crowns and 18% had bridges (Nevalainen et al. 1996). Five years later, when 113 subjects of the same population participated in a follow-up study, 38% had fixed prosthesis in the maxilla and 18% in the mandible. This study also investigated the presence of removable partial dentures and concluded that as the use of these is associated with several oral diseases fixed partial dentures should be favoured in the prosthetic rehabilitation of the elderly. These figures are not representative of the whole country as the supply of dental care in the capital Helsinki has long been good and the economic status of inhabitants is better than in rural and more remote parts of the country (Nevalainen et al. 2004).

In a quite comprehensive study of adults 30 years old and older in Finland in the year 2000, the results did not distinguish between removable and fixed partial dentures; only spaces with or without any kind of prosthesis were reported. In the group 65 years and older the most frequent spaces with a prosthesis were in the anterior maxilla: 31% of men and 29% of women had these. The second most frequent site with prosthesis was the premolar in the maxilla, seen in 30% of the men and 32% of the women (Suominen-Taipale et al. 2004). The most recent large dental survey in Finland reported only the prevalence of complete and partial removable dentures. The prevalence of partial removable dentures had decreased from the year 2000; however, in the age group 65 years and over the prevalence had increased in men, but not in women (Koskinen et al. 2012).

Dental implants have been used in the last thirty years to replace single missing teeth or to support complete dentures. They were first developed in Sweden and Switzerland in the 1970s. The prevalence of implants has not been much studied. In 1997 in Sweden the prevalence of implants in the whole sample of 16- to 84-year-olds was 2.1% and in the age group 65 to 84 years 5% (Österberg et al. 2000). Another study, also from Sweden, reported that before the year 1993 dental implants were not registered in the surveys, but in 1993 there were four edentulous individuals with implants. Between 1993 and 2003 dental implants became an established procedure in dental care in Sweden. In the 2003 survey 18 individuals among the study subjects, both edentulous and dentate, had implants (Hugoson et al. 2005). A Swiss survey reported that 4.4% of the subjects included in the study had implants in 2002 (Zitzmann et al. 2008). In the future implant-supported complete dentures may help edentulous individuals to cope better with their dentures, and difficulties caused by residual ridge resorption may
diminish remarkably. Replacement of single teeth with implant-supported crowns will perhaps replace bridges as well.
3 Aims of the study

The aim of this study was to evaluate oral and dental health and their associating factors among ageing Finns in two different regions of the country by means of a questionnaire, clinical examinations and panoramic radiographs. Based on previous knowledge the first hypothesis of this study was that edentulousness is very frequent among ageing Finns, especially in northern Finland. Another hypothesis was that edentulousness causes morphological changes in the jaws, which bring about difficulty in denture use. The third hypothesis was that dental infections detectable by radiographs are frequent in older age groups. The fourth hypothesis was that fixed prostheses are not in common use among older Finns.

More specifically the aims were to study

1. the prevalence of edentulousness and its background factors, including socio-economic and health-related factors (Study I),
2. the association of edentulousness with the mandibular shape (Study II),
3. the associations of alveolar ridge resorption and of the occlusal stability of lower complete dentures with subjective complaints in denture wearing (Study III),
4. the prevalence of signs of infections of dental origin and their association with socio-demographic factors, health habits and general diseases (Study IV),
5. the prevalence of fixed dental prostheses and their association with socio-demographic factors and the number of visits to a dentist (Study V).
4 Material and methods

4.1 Study population

The study subjects included in this cross-sectional, descriptive epidemiologic survey were collected from Kirkkonummi, a municipality in southern Finland, and from the Lakeus Health Centre District (later referred to as Lakeus) consisting of five municipalities (Liminka, Lumijoki, Rantsila, Temmes and Tyrnävä) in northern Finland.

The target population consisted of all persons born in the years 1919, 1922, 1925, 1928, 1931, 1934 and 1937, who lived in either of the areas mentioned above. At the time of data collection in the year 1997 the groups were 60, 63, 66, 69, 72, 75, and 78 years of age.

The lists of eligible subjects were drawn from the official population register in the year 1996. The target population comprised altogether 1,733 subjects: 722 in Lakeus and 1,011 in Kirkkonummi. The subjects received a postal invitation to participate in the study. Two reminders were sent if needed. The final sample examined and interviewed consisted of 1,191 subjects, 625 from Kirkkonummi and 566 from Lakeus, corresponding to a participation rate of 62% in Kirkkonummi and 78% in Lakeus. Basic characteristics of the study population are presented in Table 4. Non-attendants (n=542) were due to death (n=24), illness (n=26), unwillingness to participate (n=72), visiting own dentist only (n=22), and unknown reasons (n=398).
Table 4. Study subjects in the two regions (Kirkkonummi and Lakeus) by gender, age and education level.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Kirkkonummi</th>
<th>Lakeus</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>subjects total</td>
<td>625</td>
<td>566</td>
<td>1,191</td>
</tr>
<tr>
<td>men</td>
<td>304 (49)</td>
<td>253 (45)</td>
<td>557 (47)</td>
</tr>
<tr>
<td>women</td>
<td>321 (51)</td>
<td>313 (55)</td>
<td>634 (53)</td>
</tr>
<tr>
<td>age 60</td>
<td>147 (24)</td>
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</tr>
<tr>
<td>age 63</td>
<td>135 (22)</td>
<td>93 (16)</td>
<td>228 (19)</td>
</tr>
<tr>
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<td>89 (14)</td>
<td>98 (17)</td>
<td>187 (16)</td>
</tr>
<tr>
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<td>85 (13)</td>
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</tr>
<tr>
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<td>82 (13)</td>
<td>85 (15)</td>
<td>167 (14)</td>
</tr>
<tr>
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<td>58 (9)</td>
<td>62 (11)</td>
<td>120 (10)</td>
</tr>
<tr>
<td>age 78</td>
<td>29 (5)</td>
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<td>221 (35)</td>
<td>102 (18)</td>
<td>323 (27)</td>
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<tr>
<td>primary school or less than 6 years in school</td>
<td>274 (44)</td>
<td>430 (76)</td>
<td>704 (59)</td>
</tr>
<tr>
<td>data on education level missing</td>
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<td>4 (1)</td>
<td>17 (2)</td>
</tr>
</tbody>
</table>

Subgroups

The group for Study I was collected according to the clinical examination. Of the total number of 1,191 study subjects 438 (37%) were edentulous.

In Study II the inclusion criterion was the visibility of the structures in the panoramic radiographs for the measurements described below. A total of 1,036 subjects (482 men and 554 women) of whom 369 were edentulous and 667 were dentate were included in this study.

Of the edentulous study subjects from Study II a total of 326 (115 men and 211 women) subjects wearing lower complete dentures were included in Study III.

The participants in Study IV comprised 660 dentate subjects (344 men and 316 women). Here the inclusion criterion was the visibility of the periodontal and periapical area of the whole dentition on the radiographs.

Of the in total 1,069 panoramic radiographs taken 1,050 were included in Study V. Altogether 574 subjects (287 men and 287 women) living in Kirkkonummi and 476 subjects (210 men and 266 women) living in Lakeus were included. Of these, a total of 687 were dentate, 456 in Kirkkonummi and 231 in Lakeus. The inclusion criterion for the dentate subjects was the visibility of the structures in panoramic radiographs for evaluation of fixed prostheses.
Edentulous subjects were included to achieve the prevalence numbers for the whole population.

4.2 Methods

4.2.1 Questionnaire

The questionnaires were filled in advance by the subjects and completed during the clinical examination by the examining dentist or dental assistant, if necessary. The questionnaire included questions on general health status, medication, smoking habits, alcohol consumption, health care utilization including dental care, dental health habits, and oral health.

General health

Self-rated general health status was classified as “good” or “poor/not known”. The use of medication, both prescription and over-the-counter drugs (regular/not using) was inquired, and the subjects were also asked to bring along all their prescriptions for regularly used medication. The number of drugs in regular use was recorded and categorized for the analysis as no regular drugs, 1 drug, 2 to 4 drugs and 5 or more regular drugs. Drugs reducing salivation were determined by the examiner according to a pharmaceutical list ("Finnish Dental Association" "Finnish Pharmacists Association" 1989). The use of alcohol (on a scale yes/no/ have ceased) and the history of smoking (on a scale currently smoking/never smoked/ceased smoking) were inquired and recorded. The subjects were asked if they had any of the following diseases: coronary disease, other heart disease or heart failure, other blood circulation disorder or high blood pressure. In the analysis “cardiovascular disease” was present if the subject answered positively to at least one of these above-mentioned alternatives, and absent if all the alternatives were answered negatively. The subjects were also asked about asthma and rheumatoid arthritis.

Dental health

The subjects were inquired about their access to dental care as follows: “How easily can you get dental treatment”? The alternatives were “good access”, “poor
access” and “no access”. At analysis, “poor access” and “no access” were combined.

The number of visits to dental care was asked and the answers were grouped as once in two years or more and less than once in two years.

The subjects were also asked how they rated their complaints linked with denture wearing with the following questions:
- “How do you rate your chewing ability?” with response options “good”, “moderate” and “poor”
- “How do you rate your satisfaction with your dentures?” with response options “completely satisfied”/”satisfied”/ “unsatisfied”
- “Have you had ulcerations in denture-bearing areas, sore areas, difficulties in denture wearing, or difficulties in eating with dentures?” each with response options “No” and ”Yes”.

Background factors

Age was counted from the year of birth and seven cohorts aged 60, 63, 66, 69, 72, 75 and 78 years were formed. Gender was obtained from the population register. Region was decided according to the place of residence in the population register. Level of education was obtained from the questionnaire and was classified into three categories: 1. University degree or senior high school (12 or more years in school), 2. Vocational school or junior high school (8 to 12 years in school) and 3. Primary school (6–8 years in school) or less than 6 years in school or other.

4.2.2 Clinical oral examination

The clinical oral examinations were carried out by two dentists, one in Kirkkonummi and the other in Lakeus district, in a public dental office with adequate equipment. Subjects who were not able to attend were examined at their homes or in the institutions where they lived. Edentulousness was recorded if no teeth were visible in the mouth. The majority of the edentulous subjects in this study had complete dentures in both jaws; only 15 subjects (3%) had no dentures and 47 subjects (11%) only had a denture in the upper jaw. The number of teeth recorded in the radiographs coincided with clinical findings in only 75% of the radiographs, mostly because of findings such as unerupted teeth and root remnants. Poor occlusal stability was recorded in the clinical examination if any
movements of the lower denture were registered when the examiner guided the mandible to the centric occlusion.

Mucosal lesions, caries and periodontal disease were registered only roughly, no exact status of the dentition was registered. Calibration of the clinical examiners was therefore not needed. These clinical findings are not included in this study. The findings concerning caries and periodontal disease used in this study are all based on radiographic examination.

4.2.3 Panoramic radiographic examination

Panoramic radiography was carried out using PM 2002 CC apparatus (Planmeca, Helsinki, Finland) or Cranex DC 2 (Soredex, Helsinki, Finland). The exposure parameters, 63–81 kV and 4–12 mA, were selected individually. The films used were either Cronex 4 or Agfa HT-G (Agfa, Mortsel, Belgium) with a Kodak Lanex medium 400 screen. The films were processed in an automatic processor. Panoramic radiographs were scanned with an Agfa Duoscan HiD flatbed scanner (Agfa Gevaert, Mortsel, Belgium) as 8-bit greyscale images at a resolution of 300 dpi and saved as jpeg and imported into Dimaxis Pro imaging software, version 3.3.1 (Planmeca, Helsinki, Finland) and calibrated.

A panoramic radiograph was taken of 1,069 subjects (90%). 122 (10%) subjects refused the radiological examination, or it was not carried out due to physical limitations or poor general health of the subject.

All radiographs in studies II, III and IV were evaluated by the same specialist in oral and maxillofacial radiology using Dimaxis Pro imaging software and Kodak 2MP monochrome displays. The resolution of the monitor was 1,200x1,600 pixels. The examiner was free to apply any image enhancement function to obtain the best possible assessment. Intra-observer agreement in Study IV was assessed by calculating Cohen’s Kappa after rescoring 30 randomly selected radiographs for deep caries, periapical lesion, furcal lesion, vertical bone pockets and horizontal bone loss. Intra-observer agreement score resulted in Kappa value 0.978 indicating good reproducibility in the factors included in Study IV.

In Study II gonial angles (GA) were measured by tracing a line on acetate paper of the panoramic radiographic films tangential to the most inferior points at the gonial angle and the lower border of the mandibular body, and another line tangential to the posterior borders of the ramus and the condyle (Figure 1). The
intersection of these two lines formed the gonial angle, which was measured on the right and left sides of the mandible (Mattila et al. 1977). The outlines of the condyles and the ascending rami on both sides were also traced. A line was drawn between the most lateral points of the condyle and the ascending ramus on the film (Figure 1). To this line, (“the ramus tangent”) a perpendicular line was drawn from the most superior point of the condyle. The vertical distance from this line on “the ramus tangent” to the most lateral point of the condyle projected on the ramus tangent was measured. This distance was called condylar height (CH). The distance between the two originally marked most lateral points was called ramus height (RH) and was measured (Habets et al. 1988).

Fig. 1. Illustration of the measurements of gonial angle (GA), ramus height (RH) and condylar height (CH). Reprinted with the kind permission of John Wiley & Sons.

For Study III mandible ridge height and the amount of residual ridge resorption were categorized from the radiographs according to the classification which was a modification from Xie et al. (1997a):

- Light residual ridge resorption: the crest of the residual ridge was above the mental foramen and mandibular canal on both sides of the mandible.
Severe residual ridge resorption: the mandibular canal and/or mental foramen were at the top of the crest of the residual ridge or with a partially resorbed border on one or both sides.

In Study IV only the radiographs with adequate quality (n=1,035, 97%) were included. The sample of this study comprised only dentate subjects (n=660). The number of teeth was counted from the radiographs and was categorized as 1 to 10 teeth and those with 11 teeth or more.

Table 5. The components of the infection focus index in panoramic radiographs of dentate ageing Finns. The index was developed for this study. The focus index score consisting of the arithmetic sum of points of infectious lesions could range from 0 to 420. The scale of individual severity of infectious changes was divided as follows: no risk (score 0–2), mild risk (3), moderate risk (4–9) and severe risk of infection (10–max).

<table>
<thead>
<tr>
<th>Lesion</th>
<th>points</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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</tr>
<tr>
<td>none</td>
<td>0</td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>deep caries</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>missing crown or residual root</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Periapical lesions</td>
<td></td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>none</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>widened periodontal ligament</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>periapical lesion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Furcal lesion in any molar</td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>none</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>lesion exists</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Vertical bone loss</td>
<td></td>
<td></td>
<td>96</td>
</tr>
<tr>
<td>none</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vertical bone pocket=&lt;=3mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pocket extending to the mid 1/3 of the root</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pocket extending to the apical 1/3 of the root</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Horizontal bone loss counted if the sextant of the dentition contains at least 2 teeth</td>
<td>0</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>none</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bone loss extends less than within the marginal 1/3</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bone loss extends to the mid 1/3 of the length of the root</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bone loss extends to the apical 1/3 of the root</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The scoring of infection foci was performed with an infection focus index modified slightly for this study from the index of Mattila et al. (1989). The radiographic signs of infections recorded were deep caries, periapical lesions,
furcal lesions, vertical bone pockets and horizontal bone loss. The severity score of infection ranged from 0 to 3 points for each of the above-mentioned lesions. The scores were then summed to produce an individual focus index for each subject ranging from 0 to 420 points (Table 5).

The scale for risk of infection per subject from the focus index score was determined as follows: no risk = score 0–2, mild risk = score 3, moderate risk = score 4–9, severe risk = score 10–max. The risk of infection of dental origin, described as the sum of infectious points, formed the outcome variable and was dichotomized to severe risk (10 points or more) and no or mild/moderate risk (0–9 points). Missing teeth were not regarded as indication of infection.

For Study V the presence of single crowns, FPDs, resin-bonded FPDs and implants was evaluated from the panoramic radiographs (n=1,050). The evaluation was performed by one observer specialized in prosthetic dentistry (RN). The presence of single crowns and FPDs was analysed by subject, i.e. how many subjects (%) of the whole study sample and of the dentate subjects had crowns or FPDs. If the subject had both crowns and FPDs, the subject was included in all groups. If two or more crowns were soldered together, the crowns were still counted as single crowns. The prevalence of resin-bonded FPDs and implants was so low that no further analyses were performed on that treatment option.

4.3 Variables

4.3.1 Outcome variables

The outcome variables used in this study were edentulousness (Study I), gonial angle, ramus height and condylar height (Study II), alveolar ridge resorption and poor occlusal stability of lower denture (Study III), focus index score and risk of infection (Study IV), as well as the presence of single crowns and fixed partial dentures (Study V).
4.3.2 Explanatory variables

Socio-demographic variables

The socio-demographic variables used were age, gender, place of residence and level of education.

General health-related variables

Variables related to general health and health behaviour were self-rated general health status, number of drugs in regular use, use of drugs reducing salivary flow rate, use of alcohol, smoking, and presence of cardiovascular disease, asthma or rheumatoid arthritis.

Dental health-related variables

Dental health-related variables were status of dentition (dentate/edentulous) from the clinical examination, number of teeth counted from the radiographs, and the following self-reported variables: access to dental care, number of visits to dental care, lower denture in use, satisfaction with dentures, chewing ability with dentures, difficulties in wearing dentures, difficulties in eating with dentures, and ulcers or sore spots in denture-bearing area.

A summary of the outcome and explanatory variables is shown in Table 6.
Table 6. Summary of the outcome and explanatory variables in Studies I – V.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Outcome variables</th>
<th>Explanatory variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-demographic factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age</td>
<td>I, III, IV, V</td>
<td></td>
</tr>
<tr>
<td>gender</td>
<td>I, II, III, IV, V</td>
<td></td>
</tr>
<tr>
<td>region</td>
<td>I, IV, V</td>
<td></td>
</tr>
<tr>
<td>level of education</td>
<td>I, III, IV, V</td>
<td></td>
</tr>
<tr>
<td>General health-related factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>self-rated status of health</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>number of drugs in daily use</td>
<td>I, IV</td>
<td></td>
</tr>
<tr>
<td>use of drugs reducing salivary flow rate</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>use of alcohol</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>smoking</td>
<td>I, IV</td>
<td></td>
</tr>
<tr>
<td>cardiovascular disease</td>
<td>I, IV</td>
<td></td>
</tr>
<tr>
<td>asthma</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>rheumatoid arthritis</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>Oral and dental health-related factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dentate/edentulous</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>number of teeth</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>gonial angle</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>ramus height</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>condylar height</td>
<td>II</td>
<td></td>
</tr>
<tr>
<td>alveolar ridge resorption</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>poor occlusal stability of lower denture</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>focus index</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>risk of infection of dental origin</td>
<td>IV</td>
<td></td>
</tr>
<tr>
<td>single crowns</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>fixed partial dentures</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>access to dental care</td>
<td>I</td>
<td></td>
</tr>
<tr>
<td>number of visits to dental care</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>lower denture in use</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>satisfaction with denture</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>chewing ability with denture</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>difficulties in wearing denture</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>difficulties in eating with dentures</td>
<td>III</td>
<td></td>
</tr>
<tr>
<td>ulcer/sore areas in denture-bearing area</td>
<td>III</td>
<td></td>
</tr>
</tbody>
</table>
4.4 Statistical methods

Cross-tabulation was used to analyse bivariate associations between outcome and explanatory variables. Chi-square tests were used to evaluate the statistical significance of the associations between the following variables:

- edentulousness and potential related factors (age, gender, region, level of education, access to dental care, number of drugs in regular use, smoking history, self-rated status of health and cardiovascular disease) as stratified by dentate and edentulous subgroups (Study I)
- edentulousness and radiographical measurements of mandibular shape (Study II)
- alveolar ridge resorption, occlusal stability and subjective denture complaints as stratified by gender (Study III)
- risk of infection and potential related factors (age, region, gender, level of education, number of regular drugs, use of drugs reducing salivation, use of alcohol, smoking, cardiovascular disease, rheumatoid arthritis, asthma and number of teeth) (Study IV)
- presence of single crowns and FPDs and potential related factors (age, gender, region, level of education, number of visits to dental care) (Study V).

Results from multivariate models are mainly presented as risk estimates with 95% confidence intervals (95%CI), which is in accordance with the Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals (ICMJE 2013). Logistic regression analysis was used as a multivariate model to assess the associations between outcome variables and those explanatory and background variables that showed statistical significance in the chi-square tests (Studies I and V).

In Study II independent samples 2-tailed t-test was used to compare the means of the gonial angle, condylar and ramus heights between dentate and edentulous subjects and between genders. To compare the measurements on the right and left sides paired samples t-test was carried out. A linear regression analysis was used as a multivariate model to assess the associations of the mandibular measurements and the factors that showed statistical significance in the bivariate analysis. The results were shown with regression coefficients (B) and 95% confidence intervals (95%CI).

Negative binomial regression model was used to account for overdispersion of the focus index distribution in the study of risk of infection of dental origin in
Study IV. The factors that showed statistical significance in the bivariate analysis were selected into the regression model. The relationships between focus index and background factors were described by risk ratios (RR) and their 95% confidence intervals (95%CI).

The analyses were performed using SAS 9.1.3. Service Pack 2 (produced by SAS Institute Inc., Cary, NC, Software Release) and using SPSS versions 15, 16 and 18 (SPSS Inc., Chicago, IL, USA.).

4.5 Ethical aspects

Informed consent was obtained from all participants before examinations and the study protocol was approved by the Ethics Committee, Department of Surgery of the Hospital District of Helsinki and Uusimaa, and by the Ethics Committee of the Northern Ostrobothnia Hospital District.
5 Results

5.1 Prevalence of edentulousness and its associating factors

The overall prevalence of clinically registered edentulousness among all subjects studied was 37%. The prevalence of edentulousness was slightly higher among older compared to younger age groups, and it was significantly higher among women (43%) than among men (30%, p<0.0001). Those who lived in the northern region of Lakeus showed a significantly higher prevalence of edentulousness (53%) than those in the southern region of Kirkkonummi (22%, p<0.0001). Edentulousness was more prevalent among subjects with primary school education or less (47%) than among those with university degree or high school education (10%, p<0.0001) (Table 7).
Table 7. The number of clinically dentate and edentulous subjects in Lakeus and Kirkkonummi Health Centre Districts in Finland in 1997.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Dentate</th>
<th>Edentulous</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>Age n=1,191</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>60</td>
<td>186 (79)</td>
<td>50 (21)</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>173 (76)</td>
<td>55 (24)</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>120 (64)</td>
<td>67 (36)</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>103 (57)</td>
<td>78 (43)</td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>88 (53)</td>
<td>79 (47)</td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>56 (47)</td>
<td>64 (53)</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>27 (37)</td>
<td>45 (63)</td>
<td></td>
</tr>
<tr>
<td>Gender n=1,191</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>men</td>
<td>392 (70)</td>
<td>165 (30)</td>
<td></td>
</tr>
<tr>
<td>women</td>
<td>361 (57)</td>
<td>273 (43)</td>
<td></td>
</tr>
<tr>
<td>Place of residence n=1,191</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Kirkkonummi</td>
<td>489 (78)</td>
<td>136 (22)</td>
<td></td>
</tr>
<tr>
<td>Lakeus</td>
<td>264 (47)</td>
<td>302 (53)</td>
<td></td>
</tr>
<tr>
<td>Level of education n=1,174</td>
<td></td>
<td></td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>high school or university degree</td>
<td>133 (90)</td>
<td>14 (10)</td>
<td></td>
</tr>
<tr>
<td>middle stage school</td>
<td>235 (73)</td>
<td>88 (27)</td>
<td></td>
</tr>
<tr>
<td>primary school or less than 6 years in school or other</td>
<td>372 (53)</td>
<td>332 (47)</td>
<td></td>
</tr>
<tr>
<td>Number of drugs in regular use n=1,186</td>
<td></td>
<td></td>
<td>&lt;0.006</td>
</tr>
<tr>
<td>0</td>
<td>207 (67)</td>
<td>101 (33)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>163 (68)</td>
<td>75 (32)</td>
<td></td>
</tr>
<tr>
<td>2–4</td>
<td>259 (62)</td>
<td>157 (38)</td>
<td></td>
</tr>
<tr>
<td>5–15</td>
<td>122 (54)</td>
<td>102 (46)</td>
<td></td>
</tr>
<tr>
<td>Smoking n=1,189</td>
<td></td>
<td></td>
<td>&lt;0.064</td>
</tr>
<tr>
<td>never</td>
<td>399 (61)</td>
<td>260 (39)</td>
<td></td>
</tr>
<tr>
<td>ceased</td>
<td>107 (64)</td>
<td>59 (36)</td>
<td></td>
</tr>
<tr>
<td>current</td>
<td>247 (68)</td>
<td>117 (32)</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular disease n=1,191</td>
<td></td>
<td></td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>yes</td>
<td>372 (59)</td>
<td>262 (41)</td>
<td></td>
</tr>
<tr>
<td>no</td>
<td>381 (68)</td>
<td>176 (32)</td>
<td></td>
</tr>
</tbody>
</table>

*p-values refer to chi-square tests performed to evaluate the associations between dentate and edentulous subgroups and the variables listed below. The total number (n) varies because of missing values.

In the multivariate analysis edentulousness was positively associated with high age (OR 1.09, 95%CI 1.06–1.12), female gender (OR 2.06, 95%CI 1.43–2.94), northern place of residence (Lakeus) (OR 2.01 95%CI 1.45–2.78) and low level of education (OR 7.09, 95%CI 3.18–15.81). In the whole sample, smoking was
associated with edentulousness only when current smokers were compared with those who had never smoked (OR 1.73 95% CI 1.17–2.55). After stratifying by gender, the association was significant among men also when ceased smokers were compared with those who had never smoked (OR 2.96 95% CI 1.44–6.05).

In the whole sample present cardiovascular disease was associated with edentulousness (OR 1.51, 95% CI 1.03–2.21). After stratifying by gender, present cardiovascular disease increased the risk for edentulousness among women more than two-fold (OR 2.08, 95% CI 1.24–3.49) (Table 8).

Table 8. Associating factors of clinical edentulousness. Odds ratios (OR) and 95% confidence intervals (95% CI) based on a multivariate logistic regression model.

<table>
<thead>
<tr>
<th>Associating factor</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
</tr>
<tr>
<td>eldest vs. youngest</td>
<td>1.09 (1.06–1.12)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>women vs. men</td>
<td>2.06 (1.43–2.94)</td>
</tr>
<tr>
<td>Place of residence</td>
<td></td>
</tr>
<tr>
<td>Lakeus vs. Kirkkonummi</td>
<td>2.01 (1.45–2.78)</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
</tr>
<tr>
<td>middle vs. high</td>
<td>5.13 (2.24–11.73)</td>
</tr>
<tr>
<td>primary or less vs. high</td>
<td>7.09 (3.18–15.81)</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td></td>
</tr>
<tr>
<td>yes vs. no</td>
<td>1.51 (1.03–2.21)</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
</tr>
<tr>
<td>ceased vs. never</td>
<td>1.50 (0.90–2.50)</td>
</tr>
<tr>
<td>current vs. never</td>
<td>1.73 (1.17–2.55)</td>
</tr>
<tr>
<td>Number of drugs used</td>
<td></td>
</tr>
<tr>
<td>1 vs. 0</td>
<td>0.78 (0.48–1.27)</td>
</tr>
<tr>
<td>2-4 vs. 0</td>
<td>0.84 (0.53–1.33)</td>
</tr>
<tr>
<td>5 or more vs. 0</td>
<td>0.57 (0.32–1.02)</td>
</tr>
</tbody>
</table>

5.2 Influence of edentulousness on the shape of the mandible

The mean of the gonial angle on the right side was 125.2° (SD=7.2°) among dentate subjects, and 127.9° (SD=7.8°) among edentulous subjects (p<0.001). The corresponding values on the left side were 125.1° (SD=7.1°) among dentate and 127.7° (SD=7.9°) among edentulous subjects (p<0.001). Women had greater gonial angle values than men (p<0.001).
Dentate subjects had significantly larger ramus height on both sides than edentulous subjects (p<0.001). The ramus height was significantly greater in men than in women (p<0.001). Dentate subjects had larger condylar height than edentulous subjects (p=0.001 on both sides). Condylar height was significantly larger in men compared with women on both sides (p=0.008 on the right side and p=0.007 on the left side).

The linear regression analysis showed that edentulousness (right side B=2.49, 95%CI=1.49–3.48, and left side B=2.44, 95%CI=1.49–3.43) and female gender (right side B=3.53, 95%CI=2.61–4.44, and left side B=2.89, 95%CI=1.97–3.81) associated with larger gonial angle; these same factors also associated with smaller condylar height on both sides and with smaller ramus height on the right side.

5.3 Association of ridge resorption and poor occlusal stability with subjective complaints

Women had significantly more often radiographically diagnosed severe residual ridge resorption than men (p=0.0001). Women were significantly more often satisfied with their dentures than men (p=0.017). They also reported less difficulty in eating than men (p=0.011) and had significantly more often sore and painful areas in denture-bearing areas compared to men (p<0.001). Among women, severe residual ridge resorption associated significantly with poor chewing ability (p=0.002), low satisfaction with dentures (p=0.041) and poor occlusal stability (p=0.001). Among men, residual ridge resorption did not associate with subjective complaints or clinically assessed occlusal stability (Table 9). Poor satisfaction with dentures associated significantly with poor occlusal stability in both genders (p=0.038 for men; p=0.013 for women). Other subjective complaints did not associate significantly with occlusal stability.
Table 9. The association of mandibular residual ridge resorption (RRR) with subjective complaints linked with denture-wearing and clinically assessed occlusal stability of the lower denture in 326 edentulous ageing Finns. The numbers illustrate percentages.

<table>
<thead>
<tr>
<th>Associating factor</th>
<th>Light RRR n=191</th>
<th>Severe RRR n=135</th>
<th>Total n</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men n=115</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjective findings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulties in wearing dentures</td>
<td>25.0</td>
<td>15.8</td>
<td>63</td>
<td>0.420</td>
</tr>
<tr>
<td>Difficulties in eating with dentures</td>
<td>38.6</td>
<td>26.3</td>
<td>63</td>
<td>0.346</td>
</tr>
<tr>
<td>Ulceration in denture-bearing area</td>
<td>13.6</td>
<td>21.1</td>
<td>63</td>
<td>0.460</td>
</tr>
<tr>
<td>Sore/painful areas</td>
<td>52.3</td>
<td>68.4</td>
<td>63</td>
<td>0.235</td>
</tr>
<tr>
<td>Poor chewing ability</td>
<td>56.4</td>
<td>66.7</td>
<td>105</td>
<td>0.347</td>
</tr>
<tr>
<td>Not satisfied with dentures</td>
<td>26.7</td>
<td>31.0</td>
<td>115</td>
<td>0.656</td>
</tr>
<tr>
<td>Objective findings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor occlusal stability, mandible</td>
<td>7.0</td>
<td>17.2</td>
<td>115</td>
<td>0.104</td>
</tr>
<tr>
<td>Women n=211</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjective findings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulties in wearing dentures</td>
<td>12.8</td>
<td>16.4</td>
<td>102</td>
<td>0.609</td>
</tr>
<tr>
<td>Difficulties in eating with dentures</td>
<td>23.4</td>
<td>12.7</td>
<td>102</td>
<td>0.159</td>
</tr>
<tr>
<td>Ulceration in denture-bearing area</td>
<td>17.0</td>
<td>23.6</td>
<td>102</td>
<td>0.410</td>
</tr>
<tr>
<td>Sore/painful areas</td>
<td>63.0</td>
<td>81.8</td>
<td>102</td>
<td>0.878</td>
</tr>
<tr>
<td>Poor chewing ability</td>
<td>46.0</td>
<td>67.4</td>
<td>188</td>
<td>0.002</td>
</tr>
<tr>
<td>Not satisfied with dentures</td>
<td>11.5</td>
<td>22.1</td>
<td>208</td>
<td>0.041</td>
</tr>
<tr>
<td>Objective findings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor occlusal stability, mandible</td>
<td>2.9</td>
<td>15.4</td>
<td>209</td>
<td>0.001</td>
</tr>
</tbody>
</table>

*p-value calculated from chi-square test

5.4 Prevalence of signs of infection of dental origin and their associating factors

The subjects from Kirkkonummi were on average younger and had more teeth than those from Lakeus. They had more often high focus index scores (>22 points) compared with the subjects from Lakeus. The highest proportion of the focus index points consisted of horizontal bone loss, followed by periapical lesions and carious lesions, vertical bone loss and furcal lesions representing a minority.

Deep caries was found in the panoramic radiographs among 255 subjects (38.6%), periapical lesions in 302 subjects (45.8%), furcal lesions in 127 subjects (19.2%), vertical bone pockets in 127 subjects (19.2%), and horizontal bone loss indicating marginal periodontitis in 620 subjects (93.9%).
The focus index scores ranged from 0 to 91 points (mean 22, standard deviation 14) per subject; the median scores according to the number of teeth are shown in Figure 2. Altogether 331 subjects (50.2%) had an index score of 20 points or more. The severity of risk of possible infection showed that no risk (score 0-2) was observed in 21 subjects (3.2%), while 13 subjects (2%) had mild (score 3), 109 subjects (16.5%) moderate (score 4-9), and 517 subjects (78.3%) had severe risk (score 10 or more).

The pair-wise analysis showed that some demographic (age, place of residence, level of education) and some health-related factors (alcohol use, use of saliva reducing drugs, suffering from cardiovascular disease, asthma or rheumatoid arthritis) associated with the risk of possible infection whereas gender and smoking did not.
The negative binomial regression model showed that the focus index score associated with high educational level compared to low level (RR 1.28, 95%CI 1.02–1.62) and Kirkkonummi region compared to Lakeus region (RR 1.32, 95%CI 1.10–1.59) (Table 10).

**Table 10.** The association of various background factors with the focus index, i.e. the score from radiological signs of infection in dentate Finns aged 60 to 78 years in 1997. Significance is expressed as risk ratio (RR) and 95% confidence interval (95% CI) from the negative binomial regression model.

<table>
<thead>
<tr>
<th>Factor</th>
<th>RR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>over 70</td>
<td>0.94</td>
<td>0.75–1.16</td>
</tr>
<tr>
<td>65-70</td>
<td>1.11</td>
<td>0.92–1.34</td>
</tr>
<tr>
<td>vs. 60-64</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirkkonummi</td>
<td>1.32</td>
<td>1.10–1.59</td>
</tr>
<tr>
<td>vs. Lakeus</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>women</td>
<td>0.84</td>
<td>0.71–0.99</td>
</tr>
<tr>
<td>vs. men</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>high</td>
<td>1.28</td>
<td>1.02–1.62</td>
</tr>
<tr>
<td>middle</td>
<td>1.13</td>
<td>0.94–1.36</td>
</tr>
<tr>
<td>vs. primary or less</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Use of alcohol</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>1.02</td>
<td>0.84–1.23</td>
</tr>
<tr>
<td>ceased</td>
<td>0.88</td>
<td>0.96–1.39</td>
</tr>
<tr>
<td>vs. no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>0.88</td>
<td>0.85–1.04</td>
</tr>
<tr>
<td>vs. no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>0.78</td>
<td>0.55–1.10</td>
</tr>
<tr>
<td>vs. no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>0.88</td>
<td>0.66–1.17</td>
</tr>
<tr>
<td>vs. no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Use of drugs reducing salivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>0.89</td>
<td>0.69–1.15</td>
</tr>
<tr>
<td>vs. no</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
5.5 Prevalence of single crowns and fixed partial dentures and their associating factors

In the whole sample the prevalence of FPDs was higher among women, 8%, than among men, 5%, and in the dentate sample women showed higher prevalence of both single crowns, 20.7%, and FPDs, 13.6%. In the Kirkkonummi region both men and women had more single crowns and FPDs, 23%, than in the Lakeus region, 5%. The difference of prevalence was emphasized among dentate subjects (Table 11).

Table 11. The prevalence of single crowns and FPDs in 60- to 78-year-old dentate subjects in the southern (Kirkkonummi) and northern (Lakeus) regions of Finland.

<table>
<thead>
<tr>
<th>Region</th>
<th>Dentate men</th>
<th>Dentate women</th>
<th>All dentate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Kirkkonummi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>245</td>
<td>54</td>
<td>211</td>
</tr>
<tr>
<td>Single crowns</td>
<td>56</td>
<td>23</td>
<td>56</td>
</tr>
<tr>
<td>FPDs</td>
<td>21</td>
<td>9</td>
<td>36</td>
</tr>
<tr>
<td>Lakeus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>118</td>
<td>51</td>
<td>113</td>
</tr>
<tr>
<td>Single crowns</td>
<td>6</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>FPDs</td>
<td>3</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjects</td>
<td>363</td>
<td>53</td>
<td>324</td>
</tr>
<tr>
<td>Single crowns</td>
<td>62</td>
<td>17</td>
<td>67</td>
</tr>
<tr>
<td>FPDs</td>
<td>24</td>
<td>7</td>
<td>44</td>
</tr>
</tbody>
</table>

Five men and five women in Kirkkonummi had resin-bonded FPDs (six metal-based and four glass fibres reinforced). In the Lakeus region one woman had metal-based resin-bonded FPD.

Implant-supported single crowns had been fabricated for one man and one woman in Kirkkonummi, and for one woman and none of the men in the Lakeus region. No implant-supported removable dentures or FPDs were observed.

In the multivariate analysis the presence of crowns and FPDs was significantly associated with a southern place of residence (OR 3.9, 95%CI 2.4–6.4), a high (OR 5.6, 95%CI 3.3–9.4) or a middle level of education (OR 3.2, 95%CI 2.0–5.0) and a frequent number of visits to a dentist (OR 4.2, 95%CI 2.7–6.6). Neither age nor gender was significantly associated with the presence of crowns or FPDs.
A summary of the prevalences of edentulousness, severe risk of possible infection and single crowns and FPDs from studies I, IV and V is shown in Table 12.

Table 12. The prevalences of edentulousness, severe risk of possible infection and single crowns and fixed partial dentures (FPDs) in ageing Finns according to age, gender, region and level of education.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Edentulousness</th>
<th>Severe risk of possible infection</th>
<th>Crowns and FPDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-64</td>
<td>24%</td>
<td>81%</td>
<td>17%</td>
</tr>
<tr>
<td>65-70</td>
<td>33%</td>
<td>89%</td>
<td>15%</td>
</tr>
<tr>
<td>over 70</td>
<td>43%</td>
<td>70%</td>
<td>12%</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>men</td>
<td>30%</td>
<td>81%</td>
<td>14%</td>
</tr>
<tr>
<td>women</td>
<td>43%</td>
<td>76%</td>
<td>15%</td>
</tr>
<tr>
<td>Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kirkkonummi</td>
<td>22%</td>
<td>85%</td>
<td>23%</td>
</tr>
<tr>
<td>Lakeus</td>
<td>53%</td>
<td>67%</td>
<td>5%</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high</td>
<td>10%</td>
<td>88%</td>
<td>39%</td>
</tr>
<tr>
<td>middle</td>
<td>27%</td>
<td>82%</td>
<td>22%</td>
</tr>
<tr>
<td>primary</td>
<td>47%</td>
<td>72%</td>
<td>6%</td>
</tr>
</tbody>
</table>
6 Discussion

6.1 Main findings and their significance

6.1.1 Prevalence of edentulousness and its associating factors

More than one third of the subjects aged 60 to 78 and more than half of those 75 or older examined here were edentulous: the finding corresponds well with previous Finnish studies in similar age groups (Suominen-Taipale et al. 2004). Edentulousness is more frequent in Finland than in other Scandinavian countries (Österberg et al. 1995) and these prevalence rates are higher than in other European countries (Bourgeois et al. 1998).

An increase in the frequency of edentulousness with increasing age, as seen in our study, has been shown in many studies (Adams et al. 2003, Ainamo 1983, Axelsson & Helgadottir 1995b, Clarkson & O'Mullane 1983, Pajukoski et al. 1999, Suominen-Taipale et al. 2004, Suominen-Taipale et al. 1999, Vehkalahti et al. 1991). Edentulousness is a result of various dental diseases that affect the oral health of older people more than that of younger people. The impact of age on edentulousness is also a social factor. Older individuals may value their oral health less and at least they have had fewer possibilities for dental care in Finland as compared to the young generation (Nyman 1983, Nyman 1990, Suominen-Taipale et al. 2004).

In agreement with the present findings, women are more often edentulous than men (Clarkson & O'Mullane 1983, McGrath et al. 1998, Pajukoski et al. 1999, Suominen-Taipale et al. 2001), and this might be due to differences in dental health behaviour between men and women. Women are assumed to appreciate their dental and facial appearance more than men and prefer getting dentures instead of having open spaces in their dental arch. One explanation could also be the role of oestrogen deficiency and osteoporosis especially among postmenopausal women. Oestrogen deficiency and osteoporosis increase tooth loss due to periodontal diseases (Brennan et al. 2007, Daniell 1983, Genco & Grossi 1998, Grodstein et al. 1998, Inagaki et al. 2001, Krall et al. 1998, Mohammad et al. 2003, Yoshihara et al. 2005). Today, gender differences in edentulousness are not as prominent as they used to be (Suominen-Taipale et al. 1999).
The differences in edentulousness between individuals in southern and northern Finland in this study are in line with findings of other studies where poor availability of dental care, poor estimation of dental health, differences in income levels and place of residence (urban vs. rural regions) as well as other social and cultural factors have been associated with edentulousness (Adams et al. 2003, Bouma et al. 1986, Henriksen et al. 2003, Kalsbeek et al. 1991, McGrath et al. 1998, Suominen-Taipale et al. 2004, Suominen-Taipale et al. 2001).

Here, level of education had the most powerful impact on edentulousness. However, the association between edentulousness and low education level varied between the subjects from southern and northern parts of the country. The process that leads to edentulousness may differ in the two regions examined and may also be related to socio-demographic factors. The statistical interaction between the variables was taken into account by using multiple logistic regression analysis. Level of education and social class have been shown to be associated with edentulousness (Adams et al. 2003, McGrath & Bedi 2002, Suominen-Taipale et al. 1999).

Smoking was strongly associated with edentulousness, and this is in accordance with previous studies (Ahlqwist et al. 1989, Norlen et al. 1996, Österberg & Mellström 1986, Ragnarsson et al. 1992). The association was more marked in men than in women. In the first half of the twentieth century women smoked less than men in non-urban areas in Finland (Nissinen et al. 1987, Terho et al. 1987).

In our study, edentulousness as an indicator for poor oral health is associated with cardiovascular diseases, the association being more evident among women than men. This connection has been widely discussed in the literature (Buhlin et al. 2005, Cabrera et al. 2005, DeStefano et al. 1993, Hung et al. 2004, Joshipura et al. 1996b, Joshipura et al. 1998, Joshipura et al. 2003, Mattila et al. 1989, Mattila 1993b, Mattila et al. 1995, Ragnarsson et al. 2004, Tuominen et al. 2003, Ylöstralo et al. 2006). Cardiovascular diseases and poor oral health might not have a causal relationship, as they are both fairly complex phenomena. Patients with myocardial infarction have worse oral health than their controls and several factors in health behaviour, such as dietary or smoking habits, may affect this association (Meurman et al. 2003b). Interestingly, the significance of oral health factors in cardiovascular diseases has been shown to vanish after smoking is controlled (Ragnarsson et al. 2004).
6.1.2 Influence of edentulousness on the shape of the mandible

Edentulous subjects 60 years or older had larger gonial angle and smaller ramus and condylar height than dentate ones. Similar changes in the form of the gonial angle have been shown in earlier studies (Ohm & Silness 1999, Raustia et al. 1998, Xie & Ainamo 2004). This may be due to the decreased functioning of masticatory muscles as a result of tooth loss.

A difference was observed in gonial angle and ramus height between edentulous men and women and also between dentate men and women, which is in disagreement with previous reports (Ohm & Silness 1999, Xie & Ainamo 2004). One explanation could be that men have higher masticatory forces than women (Bakke et al. 1990) and they lose more masticatory capacity than women when they become edentulous.

The number of teeth among dentate persons varied between one tooth and full dentition with 32 teeth. Data on the type of dentures were not collected and thus their use could not be controlled. It should be noted that the type and quality of the dentures may affect the ability to chew and may also affect the muscle strength. Bite force is reduced along with a decreasing number of teeth (Helkimo et al. 1977), and bite force alone explains nearly half of the variation in chewing efficiency (Fontijn-Tekamp et al. 2000). Persons with removable dentures have only 25% of the bite force compared to subjects with natural teeth (Michael et al. 1990). Prosthodontic rehabilitation improves masticatory function and can prevent the widening of the gonial angle (Casey & Emrich 1988, Yanikoglu & Yilmaz 2008). Maintaining satisfactory masticatory function into older age requires construction of conventional or implant-retained prosthesis in order to prevent various negative processes in the jaws, face and masticatory muscles.

6.1.3 Association of ridge resorption and poor occlusal stability with subjective complaints

Residual ridge resorption was associated with subjective complaints related to complete dentures and poor occlusal stability, especially among women. Problems related to denture wearing are mostly linked with ridge resorption. Subjects with unstable dentures in both genders were more often unsatisfied with their dentures than subjects with stable dentures. However, occlusal stability in the mandible did not have an influence on difficulty in denture wearing, eating or the presence of ulceration or other painful or sore denture-bearing areas. Based on
this finding we concluded that in older subjects there is a discrepancy between normative need and perceived need of complete denture (Allen & McMillan 2003b, Hoad-Reddick et al. 1987, Smith & Sheiham 1980). Denture satisfaction is not only linked with anatomic problems but also related to other factors such as emotional problems (Bolender et al. 1969, Guckes et al. 1978, Reeve et al. 1984), psychogenic factors, including the relationship between patient and dentist (Eitner et al. 2006) as well as cultural background (Scott et al. 2001).

Similarly to other studies, women had more often residual ridges with severe resorption compared to men (de Baat et al. 1993), which may be due to the fact that women had been edentulous for a longer time than men of the same age, as has been reported in Finnish studies (Ainamo 1983, Suominen-Taipale et al. 1999). Namely, it has been reported that the duration of edentulousness increases the extent of resorption (Kalk & de Baat 1989). However, another study found no significant association between the degree of ridge resorption and the duration of edentulousness (Xie et al. 1997); instead advanced resorption in the mandible was suggested to be more influenced by systemic than local factors. Oestrogen deficiency accelerates bone loss in the skeleton. The height of the edentulous ridge correlates with total body calcium and mandibular mass in postmenopausal women with osteoporosis, suggesting that individuals with severe osteoporosis retain less alveolar bone when teeth are extracted (Kribbs et al. 1989).

As compared to dentate subjects, complete denture wearers have more difficulty in chewing hard foods (Wayler & Chauncey 1983). The masticatory functioning and bite force of edentulous individuals is below the level of dentate subjects (Heath 1982, Helkimo et al. 1977, Österberg et al. 1996). The relatively frequent problems related to edentulousness and wearing of complete dentures here underline the importance of prosthetic rehabilitation for older individuals.

**6.1.4 Prevalence of signs of infection of dental origin and their associating factors**

The prevalence of signs of infection of dental origin was high, as more than three fourths of the subjects had a high focus index score indicating a severe risk of possible infection.

The majority of focus index score points were due to horizontal bone loss which also formed a major part of the infection burden, followed by periapical lesions and deep caries lesions. Vertical bone pockets and furcal lesions formed a minority in the infection burden. The role of horizontal bone loss in the possible
risk of infection may be contradictory as part of these findings in radiographs may appear for instance because of former disease, now recovered, or because of extraction of a neighbouring tooth.

In a Finnish study among dentate subjects aged 76 to 86 years from the capital Helsinki (Ainamo 

et al. 1994) the prevalence of periapical lesions was about the same as here and vertical bone pockets and furcal lesions were more frequent while caries lesions were less frequent than in our study. These differences may be due to the higher age of the study subjects compared with the study subjects in the present study. In the Health 2000 Survey among Finns aged 65 and over horizontal bone loss was observed almost as frequently as in the present study and the prevalences of periapical lesions and vertical bone pockets were higher (Suominen-Taipale et al. 2004).

Diseases, such as cardiovascular disease, asthma and rheumatoid arthritis, use of several drugs, use of alcohol and number of teeth associated in the pair-wise analysis with the severity of dental infection. In the multivariate analysis a weak association was found between signs of infection and place of residence and education level. This result may be influenced by the amount of lost teeth or by the uncertainty of the role of horizontal bone loss in the infection burden. The relatively high age of the subjects and the quite narrow age range limit the generalization of the results of the present study. The age range has been much younger in studies where an association with general diseases has been found (Caplan et al. 2006, DeStefano et al. 1993, Mattila et al. 1989, Mattila et al. 1993a), and the association has been found especially in subjects under 50 years of age (Karhunen et al. 2006, Mattila et al. 2000). Our results are more in line with other studies that have found no association between dental infections and cardiovascular diseases (Howell et al. 2001, Hujoel et al. 2002, Tuominen et al. 2003). It is understandable that subjects having more teeth are accordingly more at risk of having dental infection foci. The number of teeth was not included as a co-variable in the multivariate analysis as it would have covered the influence of all other variables.

6.1.5 Prevalence of single crowns and fixed partial dentures and their associating factors

In the present study population 12.3% had single crowns and 6.5% had FPDs. The numbers of resin-bonded FPDs and implant-supported prostheses were minimal. On the other hand regional differences were significant as the prevalences of
crowns and FPDs were much higher in semi-urbanized Kirkkonummi than in rural Lakeus. The prevalence of fixed prostheses among the older inhabitants in Helsinki was 38% in the maxilla and 18% in the mandible (Nevalainen et al. 2004). These figures are higher than in Kirkkonummi in this study, even though the two cities are located quite near each other in southern Finland. The differences in the prevalences between the northern and southern part of Finland are more significant than those found in earlier Finnish studies. When the results of this study from the year 1997 are compared with those from 1982–83 (Tervonen 1988) and 1988–90 (Hartikainen 1994) it can be seen that the prevalence of fixed prostheses has remained at the same level in northern Finland.

The regional differences found here were related to the level of education and the difference in attitudes towards dental care as seen in the number of visits to dental care. The number of dentists has been higher in the southern part than in the northern part of Finland for the most part of the 20th century, although the situation has evened out in the last thirty years. However, a greater proportion of the population is still edentulous in the northern part of Finland than in the southern part (Suominen-Taipale et al. 2004), which may clearly have an effect on the prevalence of fixed prostheses.

In Sweden, the National Insurance System has reimbursed prosthetic treatment since 1974 and the prevalence of fixed prostheses is higher than in Finland (Hugoson et al. 2005, Löfquist et al. 2000). Higher prevalence levels have also been found in other countries as compared to the Finnish population; 34% of dentate adults in the UK were reported to have at least one crowned tooth and the prevalence of crowns was almost 40% in those aged 65 years or older (Pine et al. 2001).

Only minimal gender differences were found in the prevalence of fixed prosthesis as 12.4% of men and 12.1% of women had single crowns, and 4.8% of men and 8.0% of women had fixed partial dentures. Among dentate subjects women had more fixed prosthetic constructions than men, but this difference was not significant. In contrast, a significant gender difference in the prevalence of FPDs has been shown in the UK (Pine et al. 2001).

No correlation was found in the present study between age and the prevalence of crowns and FPDs. The age of the subject has been shown to be a factor related to complications in fixed prostheses, especially in subjects over 60 years (De Backer et al. 2007). However, a cut-off point in subject age for surviving restorations was not found and it was concluded that fixed prostheses can still be recommended as durable restorations for older people as well. The age of the
subject does not seem to limit the treatment decisions of practitioners and patients (Nevalainen et al. 2004).

6.2 Strengths and weaknesses of the study

This study was a cross-sectional, epidemiological survey of the prevalences of some important factors concerning the oral health of ageing people during the year 1997. It also described some interesting associations with these factors and highlighted various background factors of oral health among the ageing.

6.2.1. Study population

The population sampling method from the two regions was relevant and the samples were sufficiently large for the purposes of the study. The strength of this study was the relatively high participation rate, 62% in Kirkkonummi and 78% in Lakeus. These samples represent well the age groups studied in these two regions in Finland, but not elderly, 75 years and older, as their number is rather limited. The validity of the results should therefore be considered to be good and applicable to older population groups in similar parts in Finland.

Edentulousness lowers participation rates in clinical studies (Vehkalahti et al. 1996); accordingly edentulous individuals may have been over-represented among non-attendants and thus under-represented in this sample.

6.2.2. Methods

Inferring causal conclusions in this study is not possible because of the cross-sectional study design.

The material is comprehensive enough for the purpose, including radiographic and clinical examinations as well as questionnaires with an interview. However, due to practical reasons related to the large study population and lack of resources, comprehensive clinical dental examinations were not performed, which is a limitation of the study.

Information about the duration of edentulousness was not available. It could only be deduced indirectly from the subjects’ last visit to a dentist, which had often been the occasion when their last teeth had been extracted. This interval was usually more than ten years, often decades. This calculation is supported by the fact that from the 1950s to the 1970s adult dental care in Finland largely
comprised extractions and fabrication of complete dentures, especially in northern rural regions (Nyman 1983, Tuominen et al. 1983).

Occlusal stability was recorded only as part of denture stability, which is a limitation of the study. In the clinical measurements, we focused on the evaluation of occlusal stability as it was supposed to be the most important variable affected by residual ridge resorption. Chewing ability was only evaluated with subjective evaluation, which has been suggested to be more relevant than objective tests (Allen & McMillan 2003b). Patient-assessed measures of chewing function tend to be more positive than objective measures (Boretti et al. 1995).

Panoramic radiography has been considered as a suitable method in epidemiological studies in dentistry (Ahlqwist et al. 1986, Åkesson 1991). Panoramic radiography is cost-effective and relatively safe in terms of radiation dose (Molander et al. 1995). Radiographic examination provides essential information for classification of the severity and type of periodontal bone loss and caries lesions (Ahlqwist et al. 1986, Åkesson 1991, Molander et al. 1993). In panoramic radiography minor antero-posterior shifts and tilts are associated with only small variations in vertical measurements (Batenburg et al. 1997). Also mandibular angular measurements can be done with a high degree of accuracy when proper patient positioning is achieved (Mattila et al. 1977). A disadvantage was that the dental status was based solely on panoramic radiography, which is why the information of occlusal status was not available. All the radiographic registrations of fixed prostheses (Study V) were carried out by one observer, which excludes the risk of inter-examination errors. In studies II, III and IV all the radiographs that were adequately visible for examination were evaluated by a specialist in oral and maxillofacial radiology. Intra-observer agreement score resulted in a Kappa value of 0.978 indicating good reproducibility in the factors included in Study IV.

Although radiographs do not portray dental infections directly, infectious changes in tissues are found sufficiently well for epidemiological survey purposes. However, alveolar bone loss may be under-estimated based on radiography (Molander et al. 1991, Soikkonen et al. 1990). From a radiograph the difference between an ongoing periapical infection and fibrous healing of a past periapical lesion may not be distinguishable, but as the latter is a trace of a former lesion, this circumstance is not important.

The total dental index by Mattila et al. (1989), with its several modifications, has been widely used in studies on periodontal diseases and their associations with general health (Janket et al. 2004, Karhunen et al. 2006, Mattila et al. 1993a,
To assess the risk of infection sufficiently accurately for our purposes we used scores from 0 to 3 for every lesion and summed these for an individual focus index. The major component of the index was horizontal bone loss followed by deep caries, periapical lesions, vertical bone loss and furcal lesions. Lesions of periodontal infection diagnosed only from radiographs do not reveal the point of time of the infection, since it may be current or may have formed in the past. This detail could not be taken into account because of the cross-sectional study design. The same applies in the case of teeth extracted in the past as possible sources of infection.

6.2.3. Variables and confounding factors

Dental infections are often a possible reason for tooth loss. Due to the lack of information concerning the reasons for extractions, data on lost teeth could not be included in the analyses, which may have had an effect on the results. The number of teeth is a critical variable in the context of the issues addressed in Study IV, but its influence on multivariate analysis could not reasonably be controlled. In the analysis the subjects were grouped into two groups, those with 1–10 teeth and those with 11 teeth or more, and the results did not show any additional associations. When analysing the associated factors with multivariate model, the negative binomial model did not include the number of teeth as a confounding variable because the focus index itself describes the risk caused by increased inflammatory burden better than focus index per tooth.

The only variables showing association with the risk of possible infection were the socio-demographic variables in contrast to health-related factors. One limitation of this study is that the information on general health, diseases and medication was not collected from medical records but through a questionnaire, completed by an interview. This may also be the reason why the number of subjects with some diseases was rather low, except for those with cardiovascular disease, which may partly be due to ignorance of the diseases. Self-reported cardiovascular diseases agreed tolerably well with medical records (kappa 0.73–0.80) while diseases with non-established diagnostic criteria did not (Haapanen et al. 1997).

The prevalence of fixed prostheses was evaluated including single crowns and FPDs. However, the treatment modalities of these are based on separate indications. Crowns restore defective teeth while FPDs replace missing teeth and
their treatment indications are to some extent comparable to removable partial dentures.

The prevalence of dental implants was very low, constituting only 0.3–0.4% of the total sample. The only implant-supported prostheses found were single crowns. The subjects were examined in 1997, and it is probable that the prevalence of implants is higher today among older adults in these communities.
7 Summary and conclusions

According to the results of this study, all our hypotheses were confirmed. Edentulousness was very frequent among the 60 to 78 year-old Finns, which confirms the first hypothesis, and it was positively associated with high age, female gender, living in rural area, low level of education, presence of cardiovascular disease and smoking. The level of education was the most significant socio-demographic factor related to edentulousness.

Mandibular basal bone morphology changes as a consequence of tooth loss, manifesting as widening of the gonial angle and shortening of the ramus and condylar heights and as resorption of the alveolar ridge. These changes caused poor occlusal stability and difficulty in denture wearing. These findings confirm our second hypothesis and highlight the importance of prosthetic rehabilitation of the masticatory system in order to maintain good functioning of the masticatory muscles. Among older people, accessibility of prosthetic rehabilitation, including conventional or implant-retained prosthesis, should be focused on to improve the functioning of the masticatory muscles, thus avoiding ridge resorption and difficulties in denture wearing and promoting the chewing of healthy food.

Finns aged 60 to 78 years had a relatively high prevalence of signs of infections of dental origin, which confirms our third hypothesis. Furthermore, signs of dental infections were associated with place of residence and level of education. Better access to high-quality dental care with careful diagnostics based on clinical examinations and radiographs as well as comprehensive dental treatment is essential. It is recommended that all health authorities and those attending to the welfare of older people, not just dental professionals, should pay attention to the oral health care of these citizens.

In 1997 the prevalence of crowns and FPDs was relatively low in older citizens in Finland, whereby our fourth hypothesis was confirmed. The present study showed that socio-demographic factors and utilization of dental health care were associated with the prevalence of fixed dental prostheses. Regional inequality was observed between the northern and southern parts of Finland in the provision of high-quality dental treatment for the ageing.

The geographical differences in dental health should be considered by health authorities in order to make decisions promoting good oral health in remote rural areas. The welfare of older people with low socio-economical status and poor health should be a key issue. The possibility of maintaining natural dentition or at
least a functioning dental occlusion for as long as possible is hence a universal goal.
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EDENTULOUSNESS, FIXED PROSTHESES, DENTAL INFECTIONS DETECTED FROM RADIOGRAPHS AND THEIR ASSOCIATING FACTORS