OULU 2014
D 1264

ACTA UNIVERSITATIS OULUENSIS

Britta Haikola

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

ACTA UNIVERSITATIS OULUENSIS
D Medica 1264

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

UNIVERSITY OF OULU, OULU 2014

Copyright © 2014
Acta Univ. Oul. D 1264, 2014

Supervised by
Professor Kirsi Sipilä
Professor Kyösti Oikarinen
Docent Sisko Huumonen

Reviewed by
Professor Timo Närhi
Docent Kimmo Suomalainen

ISBN 978-952-62-0613-4 (Paperback)
ISBN 978-952-62-0614-1 (PDF)

ISSN 0355-3221 (Printed)
ISSN 1796-2234 (Online)

Cover Design
Raimo Ahonen

JUVENES PRINT
TAMPERE 2014

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

Acta Univ. Oul. D 1264, 2014

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. Hampaattomuus, kiinteät proteesit, radiologiset hammasperäiset tulehdusmuutokset ja näihin liittyvät tekijät

Oulun yliopiston tutkijakoulu; Oulun yliopisto, Lääketieteellinen tiedekunta, Hammaslääketieteen laitos, Suu- ja leukakirurgia

Acta Univ. Oul. D 1264, 2014
Oulun yliopisto, PL 8000, 90014 Oulun yliopisto

Tiivistelmä

Vanhusväestön suun terveydentila on useassa tutkimuksessa todettu huonommaksi kuin nuoremmilla. Tämän tutkimuksen tarkoituksena oli selvittää suomalaisen ikääntyvän väestön suun terveydentilaa ja siihen liittyviä tekijöitä.

Epidemiologinen poikkileikkaustutkimus tehtiin Kirkkonummella Etelä-Suomessa ja Lakeuden terveyskeskuksen alueella Pohjois-Suomessa. Tutkimukseen ja haastatteluun osallistui yhteensä 1191 iältään 60–78-vuotiasta henkilöä, 625 Kirkkonummelta ja 566 Lakeudelta. Kliinisessä tutkimuksessa selvitettiin hampaattomuus ja proteesien purentatasapaino. Alaleuan leukakulma, nousevan haaran ja nivellisäkkeen korkeus, hammasharjanteen korkeus ja kiinteiden proteesien esiintyminen arvioitiin panoraamaröntgenkuvista. Tulehdusriskiä kuvaava indeksi arvioitiin röntgenkuvien tulehdusmuutoksista, joina rekisteröitiin syvä karies, hampaan juurenpään tulehdus, tulehdus takahampaiden juurten haarautumassa, syventyneet luutaskut ja kiinnityskudoskato usean hampaan alueella.

Hampaattomuuden vallitsevuus oli 37 %. Se oli tilastollisesti merkitsevästi korkeampi naisilla kuin miehillä ja pohjoisella alueella merkitsevästi korkeampi kuin eteläisellä. Hampaattomuus oli yleisempää vähiten koulutusta saaneilla kuin korkeamman koulutuksen saaneilla. Hampaallisilla oli pienempi alaleuan leukakulma kuin hampaattomilla, ja heillä oli myös korkeampi nouseva haara ja nivellisäke kuin hampaattomilla. Naisilla oli merkitsevästi useammin vakavaa hammasharjanteen madaltumista kuin miehillä. Molemmilla sukupuolilla tyytymättömyys proteeseihin liittyi merkitsevästi huonoon purentatasapainoon. Yli kolmella neljäsosalla tutkituista oli vakava tulehdusriski, eteläisellä alueella enemmän kuin pohjoisella. Hampaallisessa aineistossa naisilla oli enemmän kiinteitä proteeseja kuin miehillä. Kirkkonummen alueella tutkituilla oli enemmän kiinteitä proteeseja kuin Lakeuden alueella.

Hampaattomuus oli hyvin yleistä 60–78-vuotiailla suomalaisilla. Alaleuanluun muoto muuttui hampaiden menetyksen seurauksena. Kiinteiden proteesien määrä oli vähäinen ja ikääntyvillä suomalaisilla oli röntgenkuvissa runsaasti hammasperäisten tulehdusten löydöksiä. Suun terveyden alueelliset erot tulisi ottaa huomioon suu- ja hammasterveyden edistämistyössä, jossa erityisesti tulisi huomioida alhaisen sosioekonomisen aseman ja huonon terveyden omaava vanhempi väestö.

Asiasanat: alveolaarinen luukato, hampaan pesäkeinfektio, hampaaton suu, ikääntyvä, kiinteä proteesi, luun uudelleen muotoutuminen, panoraamaröntgenkuvaus, 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, Tyrnävä 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.

I am deeply grateful to my principal supervisor, Professor Kirsi Sipilä, who patiently introduced the world of research to me and guided me through this process. She has always been there for me to share my worries and has promptly helped me with them. I deeply appreciate her dedication and friendship. I owe my gratitude also to my other supervisor, Professor Kyösti Oikarinen, who has taken part in this project from the very beginning, managed many administrative tasks and showed me the way to scientific writing. I am also grateful to my third supervisor, Docent Sisko Huumonen, for all the co-operation and advice concerning radiographic issues in the early phase, when still a co-author, and later as a supervisor.

I want to express my appreciation to the reviewers of this dissertation, Professor Timo Närhi from the University of Turku and Docent Kimmo Suomalainen from the University of Helsinki. Their valuable and constructive comments have improved this work, and I gratefully acknowledge their contribution.

I also want to express my gratitude to Professor Anna-Lisa Söderholm, who together with Kyösti Oikarinen was the principal researcher at the beginning of this project, and who guided me with the writing of the articles. My warmest thanks go also to my other co-authors, Taina Remes-Lyly DDS, the Chief Dental Officer of the Kirkkonummi Health Centre, and Ritva Näpänkangas DDS, PhD and Professor Aune Raustia from the Institute of Dentistry, University of Oulu.

My warmest thanks are also due to my colleagues and friends since years back, Professor Matti Knuuttila and Professor Satu Lahti, acknowledged researchers, with whom I have had many fruitful discussions about dentistry and science and who also kindly worked in my follow-up group through these years.

My sincere thanks are due to Ahti Niinimaa, PhD, for his valuable work with data management. I also want to thank Anna Vuolteenaho, MA, for careful revision of the language.

I owe my warm thanks to many colleagues and friends for their interest in and encouragement for this project.

My warmest thanks are due to my brother Carl-Erik, who was the first of my family to defend a thesis and who showed me the way and was always interested, thus encouraging me in my project. My warmest thanks belong also to my children Mauri, Anna-Leena and Matti and my daughter-in-laws Ulla and Sari, who have always been there for me during ups and downs and have always supported me. I want to thank my grandchildren Otto, Aapo, Laura, Noora and Lilli for being there and giving so much love, sunshine and empowerment into my life.

Finally, I want to express my gratitude to my beloved husband Erkki, for his patience and help in everyday life. Without his love and support this work would hardly have been accomplished.

This research has been financially supported by grants from the Finnish Dental Association, the Linda Gadd Foundation and the Health Care Foundation of Northern Finland.

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:

I Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2008) Prevalence of edentulousness and related factors among elderly Finns. J Oral Rehabil 35: 827–835.

II Huumonen S, Sipilä K, Haikola B, Tapio M, Söderholm AL, Remes-Lyly T, Oikarinen K & Raustia AM (2010) Influence of edentulousness on gonial angle, ramus and condylar height. J Oral Rehabil 37: 34–38.

III Huumonen S, Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2012) Residual ridge resorption, lower denture stability and subjective complaints among edentulous individuals. J Oral Rehabil 39: 384–390.

IV Haikola B, Huumonen S, Sipilä K, Oikarinen K, Remes-Lyly T & Söderholm AL (2013) Radiological signs indicating infection of dental origin in elderly Finns. Acta Odontol Scand 71: 498–507.

V Näpänkangas R, Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2011) Prevalence of single crowns and fixed partial dentures in elderly citizens in the southern and northern parts of Finland. J Oral Rehabil 38: 328–332.

Contents

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.

Country	Reference	Sample Method	Time period year	Age group n = no. of subjects	Prevalence of edentulousness
Australia	Sanders *et al.* 2004	national survey	1979–2002	over 15 years	change from 21% to 8%
Australia	Crocombe & Slade 2007	national interview	2004–2006	55–74 75 and over n=14,123	14% 36%
Brazil	Colussi & de Freitas 2007	local clinical		60 years and over n=277	48 %
United Kingdom	McGrath & Bedi 2002	national survey		16 and over n=1,855	13%
India	Shah *et al.* 2004	local clinical		60 years and over, n=1,240	15%
Ireland	McGrath *et al.* 1998	local clinical	1995	65 and over n=524	42%
Japan	Shimazaki *et al.* 2003	local institutionalized clinical	1988–89	65 and over n=1,929	47%
Japan	Hanioka *et al.* 2007	national survey	1999	men 60–69 over 70 women 60–69 over 70 n=5,457	8% 26% 8% 30%
Spain	Casado *et al.* 1994	local clinical		56 and over n=491	28%

Country	Reference	Sample Method	Time period year	Age group n = no. of subjects	Prevalence of edentulousness
Spain	Eustaquio-Raga *et al.* 2013	local clinical		65–74 n=531	21%
Turkey	Gur *et al.* 2003	local multi-centre survey		40–86 women n=1,171	39%
USA	Northridge *et al.* 2012	local clinical	2006–2009	65–74	17%
				75 and over n=662	22%
USA	Wu *et al.* 2012	national survey and clinical	2008	50 and over	
				Caucasian	17%
				African Amer.	19%
				Hispanic	14%
				Asian Amer.	14%
				Amer.Native n=118,340	24%
USA	Wu *et al.* 2011	national survey and clinical	2004	60 and over total n=4,355	25%
				white	25%
				black	29%
				Mex.Amer.	18%

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.

Country	Reference	Sample Method	Time period year	Age group n=no. of subjects	Prevalence of edentulousness
Denmark	Avlund *et al.* 2001	local interview	1984 and 1989	75-yr-old men	45%
				women	45%
				80-yr-old men	44%
				women n=326	38%
Finland	Suominen-Taipale *et al.* 2004	national clinical	2000	65–74 yrs n=804	36%
				75 yrs and over n=656	56%
Iceland	Axelsson & Helgadottir 1995	national survey	1990	18 yrs and over	21%
				65 years and over	72%
Iceland	Bourgeois *et al.* 1998	national survey		65–74 yrs	70%

Country	Reference	Sample Method	Time period year	Age group n=no. of subjects	Prevalence of edentulousness
Norway	Henriksen *et al.* 2003	national clinical	1996–1999	67–79 yrs 80 yrs and over n=582	26% 49%
Sweden	Pihlgren *et al.* 2011	local clinical	1990 and	35, 50 and 65 yrs n=715	13%
			2002	35, 50, 65 and 75 yrs n=768	4%
Sweden	Norlen *et al.* 1996	local clinical	1982–1983	men 68 yrs n=483	23%
Sweden	Hugoson *et al.* 2005	local clinical and radiographical	1973	40–70 yrs n=1,104	16%
			2003	40–80 yrs n=987	1%
Sweden	Österberg & Mellström 1986	local clinical	1971–1983	70 yrs n=1,377	from 52% to 34%
three Nordic localities	Österberg *et al.* 1995	local interview		75 yrs Gothenburg S n=308	23%
				Glostrup DK n=411	45%
				Jyväskylä FIN n=310	58%

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.

Reference	Sample Method	Time period year	Age group n=no. of subjects	Prevalence of edentulousness
Siirilä & Lindberg 1965	local Eastern Finland clinical	1965	15 and over, men n=1,029 women n=1,071 65–69 years men n=47 women n=57	 12% 30% 32% 54%
Alvesalo & Ainamo 1968	local Hailuoto clinical	1968	20 and over n=399 60 and over n=110	46% 70%

Reference	Sample Method	Time period year	Age group n=no. of subjects	Prevalence of edentulousness
Markkula *et al.* 1973	national interview	1970	15 and over n=975 men n=477 women n=498	23% 18% 28%
Nyman 1983	national interview	1976	45–64 all n=4,960 South.Finland n=1,458 North.Finland n=587 65 and over all n=1,766 South.Finland n=529 North. Finland n=187	38% 26% 53% 64% 59% 71%
Nyman 1990	national interview	1987	55–64 yrs n=1,771 65 and over n=1,739	36% 61%
Vehkalahti *et al.* 1991	national clinical	1980	30 and over n=7,190 men n=3,306 women n=3,884 55–64 n=1,342 men n=601 women n=741 65 and over n=1,578 men n=607 women n=971	 23% 37% 35% 49% 51% 65%
Hiidenkari *et al.* 1996	local Turku clinical	1978	30 and over all n=449 men n=208 women n=241	19% 16% 22%
Ainamo 1983 Ainamo & Murtomaa 1991	national interview	1970 1980 1990	15–64 yrs 1970 n=859 1980 n=921 1990 50–64 1970 n=201 1980 n=208 1990 65 and over 1970 n=116 1980 n=131 1990	 19% 17% 9% 42% 45% 26% 54% 67% 46%
Hämäläinen *et al.* 2003	local Jyväskylä clinical	1990	80 years n=226 men n=65 women n=161	 57% 60%

Reference	Sample Method	Time period year	Age group n=no. of subjects	Prevalence of edentulousness
Pajukoski *et al.*	local Kuopio		70 and over	
1999	clinical		hospitalized n=181	66%
			non-hosp. n=254	42%
Närhi *et al.* 2000	local Helsinki	1990–1995	76 and over all n=103	25%–32%
	radiographic		men	10%–24%
			women	31%–35%
Suominen-Taipale	national	1978–1997	1978	
et al. 1999	survey		45–54 yrs n=226	26%
			55–64 yrs n=294	43%
			1997	
			45–54 yrs n=75	9%
			55–64 yrs n=140	23%
Suominen-Taipale	see Table 2.	2000		
et al. 2004				
Suominen-Taipale	local, two areas	1997	65–74 yrs all n=1,288	41%
et al. 2001	clinical		North Karelia n=686	52%
	interview		Helsinki n=602	28%
Koskinen *et al.* 2012	national	2011	65–74 yrs men	17%
	interview		65–74 yrs women	17%
			75 yrs and over men	29%
			75 yrs and over women	47%

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

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 loose 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, Gotfredsen & 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 multi-factorial, 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).

These deleterious effects on nutrition may lead to cardiovascular diseases, stroke, gastrointestinal disorders, obesity and increased risk of non-insulin dependent diabetes mellitus (Abnet *et al.* 2005, Felton 2009, Holmlund *et al.* 2010, Hung *et al.* 2004, Joshipura *et al.* 1996b, Lowe *et al.* 2003, Okoro *et al.* 2005, Österberg *et al.* 2010, Ritchie *et al.* 2002, 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 precence 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 ≥ 6 mm AL (not on the same tooth) and 1 or more interproximal site(s) with ≥ 5 mm PD. Moderate periodontitis was defined as 2 or more interproximal sites with ≥ 4 mm clinical AL (not on the same tooth) or 2 or more interproximal sites with PD ≥ 5 mm, also not on the same tooth. Mild periodontitis was defined as ≥ 2 interproximal sites with ≥ 3 mm AL and ≥ 2 interproximal sites with ≥ 4 mm PD (not on the same tooth) or 1 site with ≥ 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 intraoral 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).

The above studies have mostly dealt with comparisons of panoramic and periapical radiographic methods in diagnostics of periodontal or periapical infections. For practical reasons, panoramic radiography has been used as the only method in assessing periapical pathology in epidemiological surveys, such as the Finnish Health 2000 Survey (Huumonen *et al.* 2012) and in other studies (Chen *et al.* 2007, Kabak & Abbott 2005, Kayahan *et al.* 2008, Marques *et al.* 1998, Schulte *et al.* 1998) and in assessing marginal bone loss (Oikarinen *et al.* 2009, Tervonen *et al.* 2000) or together with intraoral radiographs and clinical data (Buhlin *et al.* 2005, Buhlin *et al.* 2011, Frisk *et al.* 2003, Frisk & Hakeberg 2005, Hugoson *et al.* 2008, Janket *et al.* 2004, Karhunen *et al.* 2006, Mattila *et al.* 1989, Soikkonen *et al.* 2000, Tezal *et al.* 2009). Panoramic radiography is quick, relatively safe in terms of radiation and adequate in spite of its minor limitations.

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 osteopoenia 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-economical 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.

Factor	Kirkkonummi n (%)	Lakeus n (%)	All n (%)
subjects total	625	566	1,191
men	304 (49)	253 (45)	557 (47)
women	321 (51)	313 (55)	634 (53)
age 60	147 (24)	89 (16)	236 (20)
age 63	135 (22)	93 (16)	228 (19)
age 66	89 (14)	98 (17)	187 (16)
age 69	85 (13)	96 (17)	181 (15)
age 72	82 (13)	85 (15)	167 (14)
age 75	58 (9)	62 (11)	120 (10)
age 78	29 (5)	43 (8)	72 (6)
university degree or senior high school	117 (19)	30 (5)	147 (12)
middle stage school or vocational school	221 (35)	102 (18)	323 (27)
primary school or less than 6 years in school	274 (44)	430 (76)	704 (59)
data on education level missing	13 (2)	4 (1)	17 (2)

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).

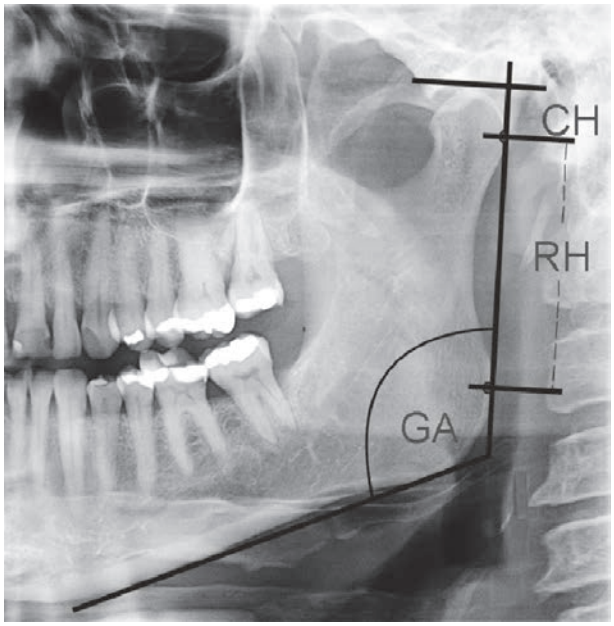

Fig. 1. Illustration of the measurements of gonial angle (GA), ramus height (RH) and condylar height (CH). Reprinted with the kind permission of John Wiley & Sons.

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).

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

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.

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

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.

Variable	Dentate 753 (63%) n (%)	Edentulous 438 (37%) n (%)	p-value*
Age n=1,191			<0.0001
60	186 (79)	50 (21)	
63	173 (76)	55 (24)	
66	120 (64)	67 (36)	
69	103 (57)	78 (43)	
72	88 (53)	79 (47)	
75	56 (47)	64 (53)	
78	27 (37)	45 (63)	
Gender n=1,191			<0.0001
men	392 (70)	165 (30)	
women	361 (57)	273 (43)	
Place of residence n=1,191			<0.0001
Kirkkonummi	489 (78)	136 (22)	
Lakeus	264 (47)	302 (53)	
Level of education n=1,174			<0.0001
high school or university degree	133 (90)	14 (10)	
middle stage school	235 (73)	88 (27)	
primary school or less than 6 years in school or other	372 (53)	332 (47)	
Number of drugs in regular use n=1,186			<0.006
0	207 (67)	101 (33)	
1	163 (68)	75 (32)	
2–4	259 (62)	157 (38)	
5–15	122 (54)	102 (46)	
Smoking n=1,189			<0,064
never	399 (61)	260 (39)	
ceased	107 (64)	59 (36)	
current	247 (68)	117 (32)	
Cardiovascular disease n=1,191			<0.0005
yes	372 (59)	262 (41)	
no	381 (68)	176 (32)	

* 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.

Associating factor	OR (95% CI) n=949, 250 edentulous, 699 dentate
Age	
eldest vs. youngest	1.09 (1.06–1.12)
Gender	
women vs. men	2.06 (1.43–2.94)
Place of residence	
Lakeus vs. Kirkkonummi	2.01 (1.45–2.78)
Level of education	
middle vs. high	5.13 (2.24–11.73)
primary or less vs. high	7.09 (3.18–15.81)
Cardiovascular disease	
yes vs. no	1.51 (1.03–2.21)
Smoking	
ceased vs. never	1.50 (0.90–2.50)
current vs.never	1.73 (1.17–2.55)
Number of drugs used	
1 vs.0	0.78 (0.48–1.27)
2-4 vs. 0	0.84 (0.53–1.33)
5 or more vs.0	0.57 (0.32–1.02)

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.

Associating factor	Light RRR n=191	Severe RRR n=135	Total n	p-value*
Men n=115				
Subjective findings				
Difficulties in wearing dentures	25.0	15.8	63	0.420
Difficulties in eating with dentures	38.6	26.3	63	0.346
Ulceration in denture-bearing area	13.6	21.1	63	0.460
Sore/painful areas	52.3	68.4	63	0.235
Poor chewing ability	56.4	66.7	105	0.347
Not satisfied with dentures	26.7	31.0	115	0.656
Objective findings				
Poor occlusal stability, mandible	7.0	17.2	115	0.104
Women n=211				
Subjective findings				
Difficulties in wearing dentures	12.8	16.4	102	0.609
Difficulties in eating with dentures	23.4	12.7	102	0.159
Ulceration in denture-bearing area	17.0	23.6	102	0.410
Sore/painful areas	83.0	81.8	102	0.878
Poor chewing ability	46.0	67.4	188	0.002
Not satisfied with dentures	11.5	22.1	208	0.041
Objective findings				
Poor occlusal stability, mandible	2.9	15.4	209	0.001

*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%).

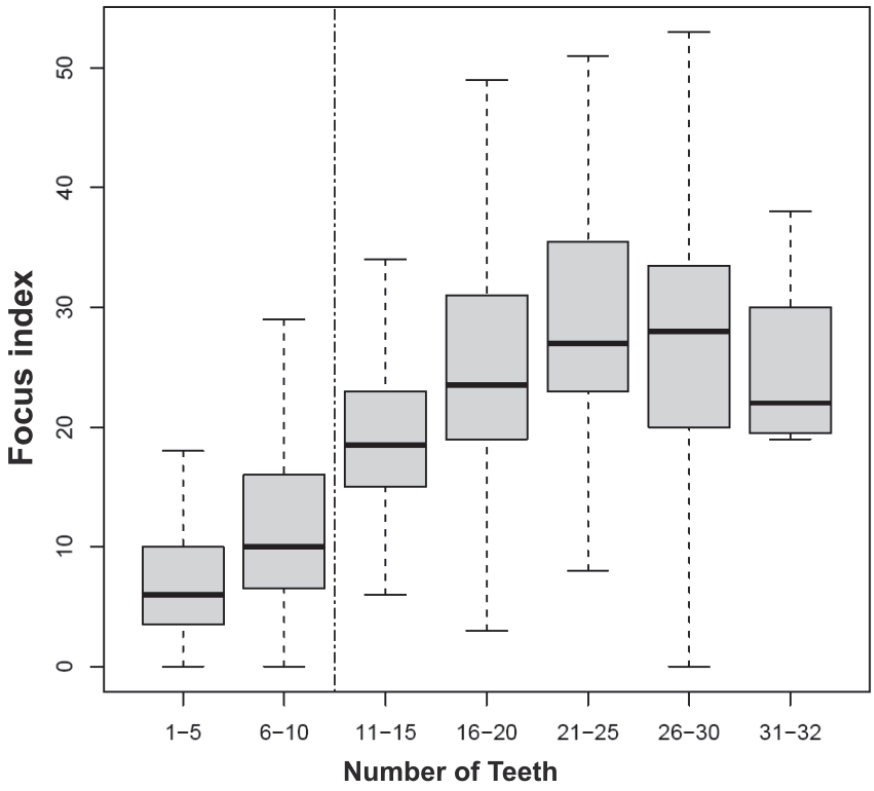

Fig. 2. The median and upper and lower quartiles of the focus index scores according to the number of teeth. Reprinted with the kind permission of Informa Healthcare.

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.

Factor	RR	95% CI
Age group		
over 70	0.94	0.75–1.16
65-70	1.11	0.92–1.34
vs. 60-64	-	-
Region		
Kirkkonummi	1.32	1.10–1.59
vs. Lakeus	-	-
Gender		
women	0.84	0.71–0.99
vs. men	-	-
Education		
high	1.28	1.02–1.62
middle	1.13	0.94–1.36
vs. primary or less	-	-
Use of alcohol		
yes	1.02	0.84–1.23
ceased	0.88	0.56–1.39
vs. no	-	-
Cardiovascular disease		
yes	0.88	0.75–1.04
vs. no	-	-
Rheumatoid arthritis		
yes	0.78	0.55–1.10
vs. no	-	-
Asthma		
yes	0.88	0.66–1.17
vs. no	-	-
Use of drugs reducing salivation		
yes	0.89	0.69–1.15
vs. no	-	-

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.

Region	Dentate men		Dentate women		All dentate	
	n	%	n	%	n	%
Kirkkonummi						
Subjects	245	54	211	46	456	79
Single crowns	56	23	56	27	112	25
FPDs	21	9	36	17	57	13
Lakeus						
Subjects	118	51	113	49	231	49
Single crowns	6	5	11	10	17	4
FPDs	3	3	8	7	11	5
Total						
Subjects	363	53	324	47	687	65
Single crowns	62	17	67	21	129	19
FPDs	24	7	44	14	68	10

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.

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

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, Ylöstalo *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,

Mattila 1993b, Mattila *et al.* 2000, Meurman *et al.* 2003a, Meurman *et al.* 2003b). 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.

References

Abnet CC, Qiao YL, Dawsey SM, Dong ZW, Taylor PR & Mark SD (2005) Tooth loss is associated with increased risk of total death and death from upper gastrointestinal cancer, heart disease, and stroke in a Chinese population-based cohort. Int J Epidemiol 34(2): 467–474.

Adams C, Slack-Smith LM, Larson A & O'Grady MJ (2003) Edentulism and associated factors in people 60 years and over from urban, rural and remote Western Australia. Aust Dent J 48(1): 10–14.

Agerberg G & Viklund L (1989) Functional disturbances in complete denture patients. Int J Prosthodont 2(1): 41–50.

Agueda A, Ramon JM, Manau C, Guerrero A & Echeverria JJ (2008) Periodontal disease as a risk factor for adverse pregnancy outcomes: a prospective cohort study. J Clin Periodontol 35(1): 16–22.

Ahlqwist M, Bengtsson C, Hollender L, Lapidus L & Österberg T (1989) Smoking habits and tooth loss in Swedish women. Community Dent Oral Epidemiol 17(3): 144–147.

Ahlqwist M, Halling A & Hollender L (1986) Rotational panoramic radiography in epidemiological studies of dental health. Comparison between panoramic radiographs and intraoral full mouth surveys. Swed Dent J 10(1-2): 73–84.

Ainamo J (1983) Changes in the frequency of edentulousness and use of removable dentures in the adult population of Finland, 1970-80. Community Dent Oral Epidemiol 11(2): 122–126.

Ainamo A, Soikkonen K, Wolf J, Siukosaari P, Erkinjuntti T, Tilvis R & Valvanne J (1994) Dental radiographic findings in the elderly in Helsinki, Finland. Acta Odontol Scand 52(4): 243–249.

Ainamo J & Murtomaa H (1991) Tooth loss in Finland during the 1970s, 1980s, and 1990s. Suom Hammaslääkärilehti 38(5): 289–293.

Åkesson L (1991) Panoramic radiography in the assessment of the marginal bone level. Swed Dent J Suppl 78: 1–129.

Albandar JM (2002) Global risk factors and risk indicators for periodontal diseases. Periodontol 2000 29: 177–206.

Albandar JM, Brunelle JA & Kingman A (1999) Destructive periodontal disease in adults 30 years of age and older in the United States, 1988-1994. J Periodontol 70(1): 13–29.

Allen PF & McMillan AS (2003a) A longitudinal study of quality of life outcomes in older adults requesting implant prostheses and complete removable dentures. Clin Oral Implants Res 14(2): 173–179.

Allen PF & McMillan AS (2003b) A review of the functional and psychosocial outcomes of edentulousness treated with complete replacement dentures. J Can Dent Assoc 69(10): 662.

Alvesalo L & Ainamo J (1968) Hailuoto dental research project. 3. Incidence of removable dentures. Suom Hammaslääk Toim 64(5): 190–196.

Arbes SJ Jr, Agustsdottir H & Slade GD (2001) Environmental tobacco smoke and periodontal disease in the United States. Am J Public Health 91(2): 253–257.

Armitage GC (2008) Effect of periodontal therapy on general health--is there a missing component in the design of these clinical trials? J Clin Periodontol 35(12): 1011–1012.
Armitage GC, Research, Science and Therapy Committee of the American Academy of Periodontolgy (2003) Diagnosis of periodontal diseases. J Periodontol 74(8): 1237–1247.
Avlund K, Holm-Pedersen P & Schroll M (2001) Functional ability and oral health among older people: a longitudinal study from age 75 to 80. J Am Geriatr Soc 49(7): 954–962.
Avlund K, Schultz-Larsen K, Krustrup U, Christiansen N & Holm-Pedersen P (2009) Effect of inflammation in the periodontium in early old age on mortality at 21-year follow-up. J Am Geriatr Soc 57(7): 1206–1212.
Axelsson G & Helgadottir S (1995) Edentulousness in Iceland in 1990. A national questionnaire survey. Acta Odontol Scand 53(5): 279–282.
Bakke M, Holm B, Jensen BL, Michler L & Moller E (1990) Unilateral, isometric bite force in 8-68-year-old women and men related to occlusal factors. Scand J Dent Res 98(2): 149–158.
Batenburg RH, Stellingsma K, Raghoebar GM & Vissink A (1997) Bone height measurements on panoramic radiographs: the effect of shape and position of edentulous mandibles. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 84(4): 430–435.
Beck J, Garcia R, Heiss G, Vokonas PS & Offenbacher S (1996) Periodontal disease and cardiovascular disease. J Periodontol 67(10 Suppl): 1123–1137.
Beck JD & Offenbacher S (2005) Systemic effects of periodontitis: epidemiology of periodontal disease and cardiovascular disease. J Periodontol 76(11 Suppl): 2089–2100.
Berg E (1993) Acceptance of full dentures. Int Dent J 43(3Suppl1): 299–306.
Bergman B & Carlsson GE (1985) Clinical long-term study of complete denture wearers. J Prosthet Dent 53(1): 56–61.
Bhoyar PS, Godbole SR, Thombare RU & Pakhan AJ (2012) Effect of complete edentulism on masseter muscle thickness and changes after complete denture rehabilitation: an ultrasonographic study. J Investig Clin Dent 3(1): 45–50.
Björn AL & Öwall B (1979) Partial edentulism and its prosthetic treatment. A frequency study within a Swedish population. Swed Dent J 3(1): 15–25.
Bohnenkamp DM (1996) Traumatic stomatitis following an intraoral denture reline: a clinical report. J Prosthet Dent 76(2): 113–114.
Bolender CL, Swoope CC & Smith DE (1969) The Cornell Medical Index as a prognostic aid for complete denture patients. J Prosthet Dent 22(1): 20–29.
Boretti G, Bickel M & Geering AH (1995) A review of masticatory ability and efficiency. J Prosthet Dent 74(4): 400–403.
Bouma J, Schaub RM & van de Poel F (1986) Caries status at the moment of total tooth extraction in a rural and an urban area in the Netherlands. Community Dentistry & Oral Epidemiology 14(6): 345–348.

Bourgeois D, Nihtilä A & Mersel A (1998) Prevalence of caries and edentulousness among 65–74-year-olds in Europe. Bull World Health Organ 76(4): 413–417.

Bras J, van Ooij CP, Abraham-Inpijn L, Kusen GJ & Wilmink JM (1982a) Radiographic interpretation of the mandibular angular cortex: A diagnostic tool in metabolic bone loss. Part I. Normal state. Oral Surg Oral Med Oral Pathol 53(5): 541–545.

Bras J, van Ooij CP, Abraham-Inpijn L, Wilmink JM & Kusen GJ (1982b) Radiographic interpretation of the mandibular angular cortex: a diagnostic tool in metabolic bone loss. Part II. Renal osteodystrophy. Oral Surg Oral Med Oral Pathol 53(6): 647–650.

Brennan RM, Genco RJ, Hovey KM, Trevisan M & Wactawski-Wende J (2007) Clinical Attachment Loss, Systemic Bone Density, and Subgingival Calculus in Postmenopausal Women. J Periodontol 78(11): 2104–2111.

Brown DW (2009) Complete edentulism prior to the age of 65 years is associated with all-cause mortality. J Public Health Dent 69(4): 260–266.

Budtz-Jörgensen E (1981) Oral mucosal lesions associated with the wearing of removable dentures. J Oral Pathol 10(2): 65–80.

Buhlin K, Gustafsson A, Ahnve S, Janszky I, Tabrizi F & Klinge B (2005) Oral health in women with coronary heart disease. J Periodontol 76(4): 544–550.

Buhlin K, Gustafsson A, Håkansson J & Klinge B (2002) Oral health and cardiovascular disease in Sweden. J Clin Periodontol 29(3): 254–259.

Buhlin K, Mäntyla P, Paju S, Peltola JS, Nieminen MS, Sinisalo J & Pussinen PJ (2011) Periodontitis is associated with angiographically verified coronary artery disease. J Clin Periodontol 38(11): 1007–1014.

Cabrera C, Hakeberg M, Ahlqwist M, Wedel H, Björkelund C, Bengtsson C & Lissner L (2005) Can the relation between tooth loss and chronic disease be explained by socio-economic status? A 24-year follow-up from the population study of women in Gothenburg, Sweden. Eur J Epidemiol 20(3): 229–236.

Caplan DJ, Chasen JB, Krall EA, Cai J, Kang S, Garcia RI, Offenbacher S & Beck JD (2006) Lesions of endodontic origin and risk of coronary heart disease. J Dent Res 85(11): 996–1000.

Carlsson GE (1998) Clinical morbidity and sequelae of treatment with complete dentures. J Prosthet Dent 79(1): 17–23.

Carlsson GE, Otterland A, Wennström A & Odont D (1967) Patient factors in appreciation of complete dentures. J Prosthet Dent 17(4): 322–328.

Casado I, Gil Miguel A, Lopez Jimenez R, Descalzo Fernandez FJ & del Rey Calero J (1994) An epidemiological study of dental health in a population of pensioners. Aten Primaria 13(4): 178–181.

Casey DM & Emrich LJ (1988) Changes in the mandibular angle in the edentulous state. J Prosthet Dent 59(3): 373–380.

Chala S, Abouqal R & Abdallaoui F (2011) Prevalence of apical periodontitis and factors associated with the periradicular status. Acta Odontol Scand 69(6): 355–359.

Chapple IL, Genco R & working group 2 of the joint EFP/AAP workshop (2013) Diabetes and periodontal diseases: consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. J Periodontol 84(4 Suppl): S106–S112.

Chen CY, Hasselgren G, Serman N, Elkind MS, Desvarieux M & Engebretson SP (2007) Prevalence and quality of endodontic treatment in the Northern Manhattan elderly. J Endod 33(3): 230–234.

Clarkson JJ & O'Mullane DM (1983) Edentulousness in the United Kingdom and Ireland. Community Dent Oral Epidemiol 11(5): 317–320.

Colussi CF & de Freitas SF (2007) Edentulousness and associated risk factors in a south Brazilian elderly population. Gerodontology 24(2): 93–97.

Crocombe LA & Slade GD (2007) Decline of the edentulism epidemic in Australia. Aust Dent J 52(2): 154–156.

D'Aiuto F, Orlandi M & Gunsolley JC (2013) Evidence that periodontal treatment improves biomarkers and CVD outcomes. J Clin Periodontol 40 Suppl 14: S85–105.

Dalla Vecchia CF, Susin C, Rosing CK, Oppermann RV & Albandar JM (2005) Overweight and obesity as risk indicators for periodontitis in adults. J Periodontol 76(10): 1721–1728.

Dallanora AF, Grasel CE, Heine CP, Demarco FF, Pereira-Cenci T, Presta AA & Boscato N (2012) Prevalence of temporomandibular disorders in a population of complete denture wearers. Gerodontology 29(2): e865–e869.

Daly RM, Elsner RJ, Allen PF & Burke FM (2003) Associations between self-reported dental status and diet. J Oral Rehabil 30(10): 964–970.

Daniell HW (1983) Postmenopausal tooth loss. Contributions to edentulism by osteoporosis and cigarette smoking. Arch Intern Med 143(9): 1678–1682

de Baat C, Kalk W & van 't Hof M (1993) Factors connected with alveolar bone resorption among institutionalized elderly people. Community Dent Oral Epidemiol 21(5): 317–320.

De Backer H, Van Maele G, De Moor N & Van den Berghe L (2007) The influence of gender and age on fixed prosthetic restoration longevity: an up to 18- to 20-year follow-up in an undergraduate clinic. Int J Prosthodont 20(6): 579–586.

DeStefano F, Anda RF, Kahn HS, Williamson DF & Russell CM (1993) Dental disease and risk of coronary heart disease and mortality. BMJ 306(6879): 688–691.

Dietrich T, Maserejian NN, Joshipura KJ, Krall EA & Garcia RI (2007) Tobacco use and incidence of tooth loss among US male health professionals. J Dent Res 86(4): 373–377.

Divaris K, Ntounis A, Marinis A, Polyzois G & Polychronopoulou A (2012) Loss of natural dentition: multi-level effects among a geriatric population. Gerodontology 29(2): e192–e199.

Dolan TA, Gilbert GH, Duncan RP & Foerster U (2001) Risk indicators of edentulism, partial tooth loss and prosthetic status among black and white middle-aged and older adults. Community Dent Oral Epidemiol 29(5): 329–340.

Drake CW & Beck JD (1993) The oral status of elderly removable partial denture wearers. J Oral Rehabil 20(1): 53–60.

Eitner S, Wichmann M, Heckmann J & Holst S (2006) Pilot study on the psychologic evaluation of prosthesis incompatibility using the SCL-90-R scale and the CES-D scale. Int J Prosthodont 19(5): 482–490; discussion 490.

Eke PI, Dye BA, Wei L, Thornton-Evans GO, Genco RJ & CDC Periodontal Disease Surveillance workgroup (2012) Prevalence of periodontitis in adults in the United States: 2009 and 2010. J Dent Res 91(10): 914–920.

Eklund SA & Burt BA (1994) Risk factors for total tooth loss in the United States; longitudinal analysis of national data. J Public Health Dent 54(1): 5–14.

Engström C, Hollender L & Lindqvist S (1985) Jaw morphology in edentulous individuals: a radiographic cephalometric study. J Oral Rehabil 12(6): 451–460.

Eustaquio-Raga MV, Montiel-Company JM & Almerich-Silla JM (2013) Factors associated with edentulousness in an elderly population in Valencia (Spain). Gac Sanit 27(2): 123–127.

Farrell TH & Dyer MR (1989) The provision of crowns in the General Dental Service 1948-1988. Br Dent J 167(11): 399–403.

Feine JS & Lund JP (2006) Measuring chewing ability in randomized controlled trials with edentulous populations wearing implant prostheses. J Oral Rehabil 33(4): 301–308.

Felton DA (2009) Edentulism and comorbid factors. J Prosthodont 18(2): 88–96.

Finnish Dental Association, Finnish Pharmacists Association (1989) Lääkkeet ja suu – suun kuivuus. Finnish Dental Journal 36(19): 1037–1038.

Fish SF (1979) Change in the gonial angle. J Oral Rehabil 6(3): 219–227.

Fiske J, Davis DM, Frances C & Gelbier S (1998) The emotional effects of tooth loss in edentulous people. Br Dent J 184(2): 90–93.

Fontijn-Tekamp FA, Slagter AP, Van Der Bilt A, Van 'T Hof MA, Witter DJ, Kalk W & Jansen JA (2000) Biting and chewing in overdentures, full dentures, and natural dentitions. J Dent Res 79(7): 1519–1524.

Frisk F & Hakeberg M (2005) A 24-year follow-up of root filled teeth and periapical health amongst middle aged and elderly women in Göteborg, Sweden. Int Endod J 38(4): 246–254.

Frisk F & Hakeberg M (2006) Socio-economic risk indicators for apical periodontitis. Acta Odontol Scand 64(2): 123–128.

Frisk F, Hakeberg M, Ahlqwist M & Bengtsson C (2003) Endodontic variables and coronary heart disease. Acta Odontol Scand 61(5): 257–262.

Fyffe HE (1992) Provision of crowns in Scotland – a ten year longitudinal study. Community Dent Health 9(2): 159–164.

Geerts SO, Legrand V, Charpentier J, Albert A & Rompen EH (2004) Further evidence of the association between periodontal conditions and coronary artery disease. J Periodontol 75(9): 1274–1280.

Genco RJ & Grossi SG (1998) Is estrogen deficiency a risk factor for periodontal disease? Compend Contin Educ Dent Suppl 22: S23–S29.

Gilbert GH, Duncan RP & Shelton BJ (2003) Social determinants of tooth loss. Health Serv Res 38(6 Pt 2): 1843–1862.

Gotfredsen K & Walls AW (2007) What dentition assures oral function? Clin Oral Implants Res 18 Suppl 3: 34–45.

Grodstein F, Colditz GA & Stampfer MJ (1998) Tooth loss and hormone use in postmenopausal women. Compend Contin Educ Dent Suppl 22: S9–S16.

Guckes AD, Smith DE & Swoope CC (1978) Counseling and related factors influencing satisfaction with dentures. J Prosthet Dent 39(3): 259–267.

Gur A, Nas K, Kayhan O, Atay MB, Akyuz G, Sindal D, Aksit R, Oncel S, Dilsen G, Cevik R, Gunduz OH, Ersoy Y, Altay Z, Ozturk C, Akkus S, Senocak O, Kavuncu V, Kirnap M, Tekeoglu I, Erdogan F, Sarac AJ, Demiralp L, Demirkesen A & Adam M (2003) The relation between tooth loss and bone mass in postmenopausal osteoporotic women in Turkey: a multicenter study. J Bone Miner Metab 21(1): 43–47.

Haapanen N, Miilunpalo S, Pasanen M, Oja P & Vuori I (1997) Agreement between questionnaire data and medical records of chronic diseases in middle-aged and elderly Finnish men and women. Am J Epidemiol 145(8): 762–769.

Habets LL, Bezuur JN, Naeiji M & Hansson TL (1988) The Orthopantomogram, an aid in diagnosis of temporomandibular joint problems. II. The vertical symmetry. J Oral Rehabil 15(5): 465–471.

Haffajee AD & Socransky SS (2005) Microbiology of periodontal diseases: introduction. Periodontol 2000 38: 9–12.

Haisman-Welsh RJ & Thomson WM (2012) Changes in periodontitis prevalence over two decades in New Zealand: evidence from the 1988 and 2009 national surveys. N Z Dent J 108(4): 134–138.

Hämäläinen P, Meurman JH, Keskinen M & Heikkinen E (2003) Relationship between dental health and 10-year mortality in a cohort of community-dwelling elderly people. Eur J Oral Sci 111(4): 291–296.

Hanioka T, Ojima M, Tanaka K & Aoyama H (2007) Association of total tooth loss with smoking, drinking alcohol and nutrition in elderly Japanese: analysis of national database. Gerodontology 24(2): 87–92.

Hartikainen M (1994) Oral health and treatment needs of 65-year-old residents of Oulu, Finland. Thesis. Oulu, Finland, University of Oulu.

Hatch JP, Shinkai RS, Sakai S, Rugh JD & Paunovich ED (2001) Determinants of masticatory performance in dentate adults. Arch Oral Biol 46(7): 641–648.

Heath MR (1982) The effect of maximum biting force and bone loss upon masticatory function and dietary selection of the elderly. Int Dent J 32(4): 345–356.

Heimonen A, Janket SJ, Kaaja R, Ackerson LK, Muthukrishnan P & Meurman JH (2009) Oral inflammatory burden and preterm birth. J Periodontol 80(6): 884–891.

Helkimo E, Carlsson GE & Helkimo M (1977) Bite force and state of dentition. Acta Odontol Scand 35(6): 297–303.

Helkimo E, Carlsson GE & Helkimo M (1978) Chewing efficiency and state of dentition. A methodologic study. Acta Odontol Scand 36(1): 33–41.

Henriksen B, Axell T & Laake K (2003) Geographic differences in tooth loss and denture-wearing among the elderly in Norway. Community Dent Oral Epidemiol 31(6): 403–411.

Heydecke G, Tedesco LA, Kowalski C & Inglehart MR (2004) Complete dentures and oral health-related quality of life – do coping styles matter? Community Dent Oral Epidemiol 32(4): 297–306.

Hiidenkari T, Parvinen T & Helenius H (1996) Missing teeth and lost teeth of adults aged 30 years and over in south-western Finland. Community Dent Health 13(4): 215–222.

Hoad-Reddick G, Grant AA & Griffiths CS (1987) The dental health of an elderly population in North-west England: results of a survey undertaken in the Halton Health Authority. J Dent 15(4): 139–146.

Holmlund A, Holm G & Lind L (2006) Severity of periodontal disease and number of remaining teeth are related to the prevalence of myocardial infarction and hypertension in a study based on 4,254 subjects. J Periodontol 77(7): 1173–1178.

Holmlund A, Holm G & Lind L (2010) Number of teeth as a predictor of cardiovascular mortality in a cohort of 7,674 subjects followed for 12 years. J Periodontol 81(6): 870–876.

Holm-Pedersen P, Schultz-Larsen K, Christiansen N & Avlund K (2008) Tooth loss and subsequent disability and mortality in old age. J Am Geriatr Soc 56(3): 429–435.

Howell TH, Ridker PM, Ajani UA, Hennekens CH & Christen WG (2001) Periodontal disease and risk of subsequent cardiovascular disease in U.S. male physicians. J Am Coll Cardiol 37(2): 445–450.

Hugoson A, Koch G, Gothberg C, Helkimo AN, Lundin SA, Norderyd O, Sjödin B & Sondell K (2005) Oral health of individuals aged 3-80 years in Jönköping, Sweden during 30 years (1973-2003). II. Review of clinical and radiographic findings. Swed Dent J 29(4): 139–155.

Hugoson A, Sjödin B & Norderyd O (2008) Trends over 30 years, 1973-2003, in the prevalence and severity of periodontal disease. J Clin Periodontol 35(5): 405–414.

Hujoel PP, Drangsholt M, Spiekerman C & Derouen TA (2001) Examining the link between coronary heart disease and the elimination of chronic dental infections. J Am Dent Assoc 132(7): 883–889.

Hujoel PP, Drangsholt M, Spiekerman C & DeRouen TA (2002) Pre-existing cardiovascular disease and periodontitis: a follow-up study. J Dent Res 81(3): 186–191.

Hung HC, Joshipura KJ, Colditz G, Manson JE, Rimm EB, Speizer FE & Willett WC (2004) The association between tooth loss and coronary heart disease in men and women. J Public Health Dent 64(4): 209–215.

Hung HC, Willett W, Merchant A, Rosner BA, Ascherio A & Joshipura KJ (2003) Oral health and peripheral arterial disease. Circulation 107(8): 1152–1157.

Huumonen S, Vehkalahti MM & Nordblad A (2012) Radiographic assessments on prevalence and technical quality of endodontically-treated teeth in the Finnish population, aged 30 years and older. Acta Odontol Scand 70(3): 234–240.

ICMJE 2013 http://www.icmje.org/icmje-recommendations.pdf

Inagaki K, Kurosu Y, Kamiya T, Kondo F, Yoshinari N, Noguchi T, Krall EA & Garcia RI (2001) Low metacarpal bone density, tooth loss, and periodontal disease in Japanese women. J Dent Res 80(9): 1818–1822.

Ingervall B & Thilander B (1974) Relation between facial morphology and activity of the masticatory muscles. J Oral Rehabil 1(2): 131–147.

Jainkittivong A, Aneksuk V & Langlais RP (2002) Oral mucosal conditions in elderly dental patients. Oral Dis 8(4): 218–223.

Janket SJ, Jones JA, Meurman JH, Baird AE & Van Dyke TE (2008) Oral infection, hyperglycemia, and endothelial dysfunction. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105(2): 173–179.

Janket SJ, Qvarnström M, Meurman JH, Baird AE, Nuutinen P & Jones JA (2004) Asymptotic dental score and prevalent coronary heart disease. Circulation 109(9): 1095–1100.

Joshipura KJ, Douglass CW & Willett WC (1998) Possible explanations for the tooth loss and cardiovascular disease relationship. Ann Periodontol 3(1): 175–183.

Joshipura KJ, Hung HC, Rimm EB, Willett WC & Ascherio A (2003) Periodontal disease, tooth loss, and incidence of ischemic stroke. Stroke 34(1): 47–52.

Joshipura KJ, Willett WC & Douglass CW (1996a) The impact of edentulousness on food and nutrient intake. J Am Dent Assoc 127(4): 459–467.

Joshipura KJ, Rimm EB, Douglass CW, Trichopoulos D, Ascherio A & Willett WC (1996b) Poor oral health and coronary heart disease. J Dent Res 75(9): 1631–1636.

Joshipura KJ & Ritchie C (2005) Can the relation between tooth loss and chronic disease be explained by socio-economic status? Eur J Epidemiol 20(3): 203–204.

Kabak Y & Abbott PV (2005) Prevalence of apical periodontitis and the quality of endodontic treatment in an adult Belarusian population. Int Endod J 38(4): 238–245.

Kalk W & de Baat C (1989) Some factors connected with alveolar bone resorption. J Dent 17(4): 162–165.

Kalsbeek H, Truin GJ, Burgersdijk R & van 't Hof M (1991) Tooth loss and dental caries in Dutch adults. Community Dent Oral Epidemiol 19(4): 201–204.

Kamer AR, Dasanayake AP, Craig RG, Glodzik-Sobanska L, Bry M & de Leon MJ (2008) Alzheimer's disease and peripheral infections: the possible contribution from periodontal infections, model and hypothesis. J Alzheimers Dis 13(4): 437–449.

Kandelman D, Petersen PE & Ueda H (2008) Oral health, general health, and quality of life in older people. Spec Care Dentist 28(6): 224–236.

Karhunen V, Forss H, Goebeler S, Huhtala H, Ilveskoski E, Kajander O, Mikkelsson J, Penttilä A, Perola M, Ranta H, Meurman JH & Karhunen PJ (2006) Radiographic assessment of dental health in middle-aged men following sudden cardiac death. J Dent Res 85(1): 89–93.

Karikoski A, Murtomaa H & Ilanne-Parikka P (2002) Assessment of periodontal treatment needs among adults with diabetes in Finland. Int Dent J 52(2): 75–80.

Karpinski L, Plaksej R, Derzhko R, Orda A & Witkowska M (2009) Serum levels of interleukin-6, interleukin-10 and C-reactive protein in patients with myocardial infarction treated with primary angioplasty during a 6-month follow-up. Pol Arch Med Wewn 119(3): 115–121.

Kasai K, Richards LC, Kanazawa E & Iwasawa T (1997) Cephalometric analysis of masseter muscle and dentoskeletal morphology in dentate and edentulous humans. J Nihon Univ Sch Dent 39(2): 78–85.

Kasai K, Richards LC, Kanazawa E, Ozaki T & Iwasawa T (1994) Relationship between attachment of the superficial masseter muscle and craniofacial morphology in dentate and edentulous humans. J Dent Res 73(6): 1142–1149.

Kayahan MB, Malkondu O, Canpolat C, Kaptan F, Bayirli G & Kazazoglu E (2008) Periapical health related to the type of coronal restorations and quality of root canal fillings in a Turkish subpopulation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105(1): e58–e62.

Käyser AF (1990) How much reduction of the dental arch is functionally acceptable for the ageing patient? Int Dent J 40(3): 183–188.

Kirkevang LL, Örstavik D, Horsted-Bindslev P & Wenzel A (2000) Periapical status and quality of root fillings and coronal restorations in a Danish population. Int Endod J 33(6): 509–515.

Kirkevang LL & Wenzel A (2003) Risk indicators for apical periodontitis. Community Dent Oral Epidemiol 31(1): 59–67.

Könönen E & Muller HP (2014) Microbiology of aggressive periodontitis. Periodontol 2000 65(1): 46–78.

Koskinen S, Lundqvist A & Ristiluoma N (eds) (2012) Health, functional capacity and welfare in Finland in 2011. Helsinki, National Institute for Health and Welfare.

Krall EA, Dawson-Hughes B, Hannan MT & Kiel DP (1998) Postmenopausal estrogen replacement and tooth retention. Compend Contin Educ Dent Suppl (22): S17–S22.

Kribbs PJ, Chesnut CH,3rd, Ott SM & Kilcoyne RF (1989) Relationships between mandibular and skeletal bone in an osteoporotic population. J Prosthet Dent 62(6): 703–707.

Krustrup U & Petersen PE (2006) Periodontal conditions in 35–44 and 65–74-year-old adults in Denmark. Acta Odontol Scand 64(2): 65–73.

Lafon A, Pereira B, Dufour T, Rigouby V, Giroud M, Bejot Y & Tubert-Jeannin S (2014) Periodontal disease and stroke: a meta-analysis of cohort studies. Eur J Neurol 21(9):1155–1161.

Lahti S, Suominen-Taipale L & Hausen H (2008) Oral health impacts among adults in Finland: competing effects of age, number of teeth, and removable dentures. Eur J Oral Sci 116(3): 260–266.

Lechner SK, Champion H & Tong TK (1995) Complete denture problem solving: a survey. Aust Dent J 40(6): 377–380.

Lee JS, Weyant RJ, Corby P, Kritchevsky SB, Harris TB, Rooks R, Rubin SM & Newman AB (2004) Edentulism and nutritional status in a biracial sample of well-functioning, community-dwelling elderly: the health, aging, and body composition study. Am J Clin Nutr 79(2): 295–302.

Li X, Tronstad L & Olsen I (1999) Brain abscesses caused by oral infection. Endod Dent Traumatol 15(3): 95–101.

Linden G, Patterson C, Evans A & Kee F (2007) Obesity and periodontitis in 60–70-year-old men. J Clin Periodontol 34(6): 461–466.

Linden GJ, Herzberg MC & Working group 4 of joint EFP/AAP workshop (2013) Periodontitis and systemic diseases: a record of discussions of working group 4 of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. J Clin Periodontol 40 Suppl 14: S20–S23.

Linden GJ, Linden K, Yarnell J, Evans A, Kee F & Patterson CC (2012) All-cause mortality and periodontitis in 60-70-year-old men: a prospective cohort study. J Clin Periodontol 39(10): 940–946.

Locker D (1988) Measuring oral health: a conceptual framework. Community Dent Health 5: 3–18.

Locker D (2002b) Changes in chewing ability with ageing: a 7-year study of older adults. J Oral Rehabil 29(11): 1021–1029.

Locker D (2004) Oral health and quality of life. Oral Health Prev Dent 2 Suppl 1: 247–253.

Locker D, Matear D & Lawrence H (2002a) General health status and changes in chewing ability in older Canadians over seven years. J Public Health Dent 62(2): 70–77.

Löfquist L, Bergendal B & Hugoson A (2000) Fixed prosthodontics in adults in Jönköping, Sweden in 1983 and 1993. An epidemiological study of prevalence and choice of material. Swed Dent J 24(3): 93–103.

Lowe G, Woodward M, Rumley A, Morrison C, Tunstall-Pedoe H & Stephen K (2003) Total tooth loss and prevalent cardiovascular disease in men and women: possible roles of citrus fruit consumption, vitamin C, and inflammatory and thrombotic variables. J Clin Epidemiol 56(7): 694–700.

MacEntee MI, Glick N & Stolar E (1998) Age, gender, dentures and oral mucosal disorders. Oral Dis 4(1): 32–-36.

Mack F, Mojon P, Budtz-Jorgensen E, Kocher T, Splieth C, Schwahn C, Bernhardt O, Gesch D, Kordass B, John U & Biffar R (2004) Caries and periodontal disease of the elderly in Pomerania, Germany: results of the Study of Health in Pomerania. Gerodontology 21(1): 27–36.

Markkula J, Ainamo J & Murtomaa H (1973) Dental knowledge and behavior in Finland. I. An interview on edentulousness and occurrence of removable dentures. Proc Finn Dent Soc 69(6): 266–272.

Marques MD, Moreira B & Eriksen HM (1998) Prevalence of apical periodontitis and results of endodontic treatment in an adult, Portuguese population. Int Endod J 31(3): 161–165.

Mattila K, Altonen M & Haavikko K (1977) Determination of the gonial angle from the orthopantomogram. Angle Orthod 47(2): 107–110.

Mattila KJ (1993b) Dental infections as a risk factor for acute myocardial infarction. Eur Heart J 14 Suppl K: 51–53.

Mattila KJ, Asikainen S, Wolf J, Jousimies-Somer H, Valtonen V & Nieminen M (2000) Age, dental infections, and coronary heart disease. J Dent Res 79(2): 756–760.

Mattila KJ, Nieminen MS, Valtonen VV, Rasi VP, Kesäniemi YA, Syrjälä SL, Jungell PS, Isoluoma M, Hietaniemi K & Jokinen MJ (1989) Association between dental health and acute myocardial infarction. BMJ 298(6676): 779–781.

Mattila KJ, Valle MS, Nieminen MS, Valtonen VV & Hietaniemi KL (1993a) Dental infections and coronary atherosclerosis. Atherosclerosis 103(2): 205–211.

Mattila KJ, Valtonen VV, Nieminen M & Huttunen JK (1995) Dental infection and the risk of new coronary events: prospective study of patients with documented coronary artery disease. Clin Infect Dis 20(3): 588–592.

McGrath C & Bedi R (2002) Severe tooth loss among UK adults – who goes for oral rehabilitation? J Oral Rehabil 29(3): 240–244.

McGrath C, Gilhorpe MS & Bedi R (1998) Compounding inequalities in the oral health of older women living outside Dublin. J Ir Dent Assoc 44(4): 106–109.

Mese H & Matsuo R (2007) Salivary secretion, taste and hyposalivation. J Oral Rehabil 34(10): 711–723.

Meurman JH, Janket SJ, Qvarnström M & Nuutinen P (2003b) Dental infections and serum inflammatory markers in patients with and without severe heart disease. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 96(6): 695–700.

Meurman JH, Pajukoski H, Snellman S, Zeiler S & Sulkava R (1997) Oral infections in home-living elderly patients admitted to an acute geriatric ward. J Dent Res 76(6): 1271–1276.

Meurman JH, Qvarnstrom M, Janket SJ & Nuutinen P (2003a) Oral health and health behavior in patients referred for open-heart surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 95(3): 300–307.

Michael CG, Javid NS, Colaizzi FA & Gibbs CH (1990) Biting strength and chewing forces in complete denture wearers. J Prosthet Dent 63(5): 549–553.

Migliorati CA (2008) Periodontal diseases and cancer. Lancet Oncol 9(6): 510–512.

Mohammad AR, Hooper DA, Vermilyea SG, Mariotti A & Preshaw PM (2003) An investigation of the relationship between systemic bone density and clinical periodontal status in post-menopausal Asian-American women. Int Dent J 53(3): 121–125.

Molander B (1996) Panoramic radiography in dental diagnostics. Swed Dent J Suppl 119: 1–26.

Molander B, Ahlqwist M & Gröndahl HG (1995) Panoramic and restrictive intraoral radiography in comprehensive oral radiographic diagnosis. Eur J Oral Sci 103(4): 191–198.

Molander B, Ahlqwist M, Gröndahl HG & Hollender L (1991) Agreement between panoramic and intra-oral radiography in the assessment of marginal bone height. Dentomaxillofac Radiol 20(3): 155–160.

Molander B, Ahlqwist M, Gröndahl HG & Hollender L (1993) Comparison of panoramic and intraoral radiography for the diagnosis of caries and periapical pathology. Dentomaxillofac Radiol 22(1): 28–32.

Morris AJ, Steele J & White DA (2001) The oral cleanliness and periodontal health of UK adults in 1998. Br Dent J 191(4): 186–192.

Muller F, Wahl G & Fuhr K (1994) Age-related satisfaction with complete dentures, desire for improvement and attitudes to implant treatment. Gerodontology 11(1): 7–12.

Närhi TO, Ettinger RL & Lam EW (1997) Radiographic findings, ridge resorption, and subjective complaints of complete denture patients. Int J Prosthodont 10(2): 183–189.
Närhi TO, Leinonen K, Wolf J & Ainamo A (2000) Longitudinal radiological study of the oral health parameters in an elderly Finnish population. Acta Odontol Scand 58(3): 119–124.
Negrato CA, Tarzia O, Jovanovic L & Chinellato LE (2013) Periodontal disease and diabetes mellitus. J Appl Oral Sci 21(1): 1–12.
Nevalainen MJ, Närhi TO & Ainamo A (2004) A 5-year follow-up study on the prosthetic rehabilitation of the elderly in Helsinki, Finland. J Oral Rehabil 31(7): 647–652.
Nevalainen MJ, Närhi TO, Siukosaari P, Schmidt-Kaunisaho K & Ainamo A (1996) Prosthetic rehabilitation in the elderly inhabitants of Helsinki, Finland. J Oral Rehabil 23(11): 722–728.
Newton JP, Abel EW, Robertson EM & Yemm R (1987) Changes in human masseter and medial pterygoid muscles with age: a study by computed tomography. Gerodontics 3(4): 151–154.
Newton JP, McManus FC & Menhenick S (2004) Jaw muscles in older overdenture patients. Gerodontology 21(1): 37–42.
Newton JP, Yemm R, Abel RW & Menhinick S (1993) Changes in human jaw muscles with age and dental state. Gerodontology 10(1): 16–22.
Nieuwenhuizen WF, Weenen H, Rigby P & Hetherington MM (2010) Older adults and patients in need of nutritional support: review of current treatment options and factors influencing nutritional intake. Clin Nutr 29(2): 160–169.
Nissinen A, Kivelä SL, Tuomilehto J & Pietinen P (1987) Health behaviour of an elderly population in eastern Finland in 1982. Z Gerontol 20(3): 129–135.
Nitschke I & Muller F (2004) The impact of oral health on the quality of life in the elderly. Oral Health Prev Dent 2 Suppl 1: 271–275.
Norderyd O, Henriksen BM & Jansson H (2012) Periodontal disease in Norwegian old-age pensioners. Gerodontology 29(1): 4–8.
Norlen P, Johansson I & Birkhed D (1996) Impact of medical and life-style factors on number of teeth in 68-year-old men in southern Sweden. Acta Odontol Scand 54(1): 66–74.
Northridge ME, Ue FV, Borrell LN, De La Cruz LD, Chakraborty B, Bodnar S, Marshall S & Lamster IB (2012) Tooth loss and dental caries in community-dwelling older adults in northern Manhattan. Gerodontology 29(2): e464–e473.
Nuttall NM, Slade GD, Sanders AE, Steele JG, Allen PF & Lahti S (2006) An empirically derived population-response model of the short form of the Oral Health Impact Profile. Community Dent Oral Epidemiol 34(1): 18–24.
Nyman K (ed) (1983) Adult dental care in Finland 1968-1981. Helsinki, Social Insurance Institution, Finland.
Nyman K (ed) (1990) Dental status and dental care in Finland 1987. A nationwide evaluative survey of dental care and its development. Helsinki, Social Insurance Institution, Finland.

Offenbacher S & Beck JD (2005) A perspective on the potential cardioprotective benefits of periodontal therapy. Am Heart J 149(6): 950–954.

Offenbacher S, Katz V, Fertik G, Collins J, Boyd D, Maynor G, McKaig R & Beck J (1996) Periodontal infection as a possible risk factor for preterm low birth weight. J Periodontol 67(10 Suppl): 1103–1113.

Official Statistics of Finland 2010, Statistics Finland, Helsinki Finland

Ohm E & Silness J (1999) Size of the mandibular jaw angle related to age, tooth retention and gender. J Oral Rehabil 26(11): 883–891.

Öhman SC, Dahlen G, Moller A & Öhman A (1986) Angular cheilitis: a clinical and microbial study. J Oral Pathol 15(4): 213–217.

Öhman SC, Österberg T, Dahlen G & Landahl S (1995) The prevalence of Staphylococcus aureus, Enterobacteriaceae species, and Candida species and their relation to oral mucosal lesions in a group of 79-year-olds in Göteborg. Acta Odontol Scand 53(1): 49–54.

Oikarinen K, Zubaid M, Thalib L, Soikkonen K, Rashed W & Lie T (2009) Infectious dental diseases in patients with coronary artery disease: an orthopantomographic case-control study. J Can Dent Assoc 75(1): 35.

Oikarinen R, Syrjälä AM, Komulainen K, Knuuttila M, Ruoppi P, Hartikainen S, Sulkava R & Ylöstalo P (2013) Body mass index and periodontal infection in a sample of non-smoking older individuals. Oral Dis. 2014 Apr;20(3):e25–e30. doi: 10.1111/odi.12108. Epub 2013 Apr 11.

Okoro CA, Balluz LS, Eke PI, Ajani UA, Strine TW, Town M, Mensah GA & Mokdad AH (2005) Tooth loss and heart disease: findings from the Behavioral Risk Factor Surveillance System. Am J Prev Med 29(5 Suppl 1): 50–56.

Okoro CA, Strine TW, Eke PI, Dhingra SS & Balluz LS (2012) The association between depression and anxiety and use of oral health services and tooth loss. Community Dent Oral Epidemiol 40(2): 134–144.

Örstavik D, Kerekes K & Eriksen HM (1986) The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 2(1): 20–34.

Österberg T, Carlsson GE & Sundh V (2000) Trends and prognoses of dental status in the Swedish population: analysis based on interviews in 1975 to 1997 by Statistics Sweden. Acta Odontol Scand 58(4): 177–182.

Österberg T, Carlsson GE, Sundh V & Mellström D (2008) Number of teeth - a predictor of mortality in 70-year-old subjects. Community Dent Oral Epidemiol 36(3): 258–268.

Österberg T, Carlsson GE, Tsuga K, Sundh V & Steen B (1996) Associations between self-assessed masticatory ability and some general health factors in a Swedish population. Gerodontology 13(2): 110–117.

Österberg T, Dey DK, Sundh V, Carlsson GE, Jansson JO & Mellström D (2010) Edentulism associated with obesity: a study of four national surveys of 16 416 Swedes aged 55–84 years. Acta Odontol Scand 68(6): 360–367.

Österberg T, Era P, Gause-Nilsson I & Steen B (1995) Dental state and functional capacity in 75-year-olds in three Nordic localities. J Oral Rehabil 22(8): 653–660.

Österberg T & Mellström D (1986) Tobacco smoking: a major risk factor for loss of teeth in three 70-year-old cohorts. Community Dent Oral Epidemiol 14(6): 367–370.

Pajukoski H, Meurman JH, Snellman-Gröhn S & Sulkava R (1999) Oral health in hospitalized and nonhospitalized community-dwelling elderly patients. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 88(4): 437–443.

Palmqvist S, Söderfeldt B, Vigild M & Kihl J (2000) Dental conditions in middle-aged and older people in Denmark and Sweden: a comparative study of the influence of socioeconomic and attitudinal factors. Acta Odontol Scand 58(3): 113–118.

Passoja A, Knuuttila M, Hiltunen L, Karttunen R, Niemelä O, Raunio T, Vainio O, Hedberg P & Tervonen T (2011) Serum interleukin-6 may modulate periodontal inflammation in type 1 diabetic subjects. J Clin Periodontol 38(8): 687–693.

Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S & Ndiaye C (2005) The global burden of oral diseases and risks to oral health. Bull World Health Organ 83(9): 661–669.

Pihlgren K, Forsberg H, Sjödin L, Lundgren P & Wänman A (2011) Changes in tooth mortality between 1990 and 2002 among adults in Västerbotten County, Sweden: influence of socioeconomic factors, general health, smoking, and dental care habits on tooth mortality. Swed Dent J 35(2): 77–88.

Pihlstrom BL, Michalowicz BS & Johnson NW (2005) Periodontal diseases. Lancet 366(9499): 1809–1820.

Pine CM, Pitts NB, Steele JG, Nunn JN & Treasure E (2001) Dental restorations in adults in the UK in 1998 and implications for the future. Br Dent J 190(1): 4–8.

Popkin BM, Siega-Riz AM & Haines PS (1996) A comparison of dietary trends among racial and socioeconomic groups in the United States. N Engl J Med 335(10): 716–720.

Pussinen PJ, Jousilahti P, Alfthan G, Palosuo T, Asikainen S & Salomaa V (2003) Antibodies to periodontal pathogens are associated with coronary heart disease. Arterioscler Thromb Vasc Biol 23(7): 1250–1254.

Pussinen PJ, Tuomisto K, Jousilahti P, Havulinna AS, Sundvall J & Salomaa V (2007) Endotoxemia, immune response to periodontal pathogens, and systemic inflammation associate with incident cardiovascular disease events. Arterioscler Thromb Vasc Biol 27(6): 1433–1439.

Pyysalo MJ, Pyysalo LM, Pessi T, Karhunen PJ & Öhman JE (2013) The connection between ruptured cerebral aneurysms and odontogenic bacteria. J Neurol Neurosurg Psychiatry 84(11): 1214–1218.

Raghavendran K, Mylotte JM & Scannapieco FA (2007) Nursing home-associated pneumonia, hospital-acquired pneumonia and ventilator-associated pneumonia: the contribution of dental biofilms and periodontal inflammation. Periodontol 2000 44: 164–177.

Ragnarsson E, Eliasson ST & Gudnason V (2004) Loss of teeth and coronary heart disease. Int J Prosthodont 17(4): 441–446.

Ragnarsson E, Eliasson ST & Olafsson SH (1992) Tobacco smoking, a factor in tooth loss in Reykjavik, Iceland. Scand J Dent Res 100(6): 322–326.

Ranta K, Tuominen R & Paunio I (1987) Rehabilitation with fixed prostheses among Finnish adults. Community Dent Health 4(2): 137–142.

Raustia AM, Pirttiniemi P, Salonen MA & Pyhtinen J (1998) Effect of edentulousness on mandibular size and condyle-fossa position. J Oral Rehabil 25(3): 174–179.

Raustia AM & Salonen MA (1997) Gonial angles and condylar and ramus height of the mandible in complete denture wearers – a panoramic radiograph study. J Oral Rehabil 24(7): 512–516.

Raustia AM, Salonen MA & Pyhtinen J (1996) Evaluation of masticatory muscles of edentulous patients by computed tomography and electromyography. J Oral Rehabil 23(1): 11–16.

Reeve PE, Watson CJ & Stafford GD (1984) The role of personality in the management of complete denture patients. Br Dent J 156(10): 356–362.

Reports from the Ministry of Social Affairs and Health 2011:7, 2011, Ministry of Social Affairs and Health, Helsinki Finland.

Ridao-Sacie C, Segura-Egea JJ, Fernandez-Palacin A, Bullon-Fernandez P & Rios-Santos JV (2007) Radiological assessment of periapical status using the periapical index: comparison of periapical radiography and digital panoramic radiography. Int Endod J 40(6): 433–440.

Ritchie CS, Joshipura K, Hung HC & Douglass CW (2002) Nutrition as a mediator in the relation between oral and systemic disease: associations between specific measures of adult oral health and nutrition outcomes. Crit Rev Oral Biol Med 13(3): 291–300.

Rodriguez-Archilla A, Urquia M, Cutando A & Asencio R (1996) Denture stomatitis: quantification of interleukin-2 production by mononuclear blood cells cultured with Candida albicans. J Prosthet Dent 75(4): 426–431.

Rohlin M, Kullendorff B, Ahlqwist M, Henrikson CO, Hollender L & Stenström B (1989) Comparison between panoramic and periapical radiography in the diagnosis of periapical bone lesions. Dentomaxillofac Radiol 18(4): 151–155.

Rönning O, Barnes SA, Pearson MH & Pledger DM (1994) Juvenile chronic arthritis: a cephalometric analysis of the facial skeleton. Eur J Orthod 16(1): 53–62.

Sanders AE, Slade GD, Carter KD & Stewart JF (2004) Trends in prevalence of complete tooth loss among Australians, 1979 – 2002. Aust N Z J Public Health 28(6): 549–554.

Saxlin T, Ylöstalo P, Suominen-Taipale L, Männisto S & Knuuttila M (2011) Association between periodontal infection and obesity: results of the Health 2000 Survey. J Clin Periodontol 38(3): 236–242.

Sbaraglia M, Turnbull RS & Locker D (2002) Risk indicators for periodontal disease in a remote Canadian community – a dental practice-based study. J Public Health Dent 62(1): 51–56.

Scannapieco FA & Mylotte JM (1996) Relationships between periodontal disease and bacterial pneumonia. J Periodontol 67(10 Suppl): 1114–1122.

Schulte A, Pieper K, Charalabidou O, Stoll R & Stachniss V (1998) Prevalence and quality of root canal fillings in a German adult population. A survey of orthopantomograms taken in 1983 and 1992. Clin Oral Investig 2(2): 67–72.

Scott BJ, Leung KC, McMillan AS, Davis DM & Fiske J (2001) A transcultural perspective on the emotional effect of tooth loss in complete denture wearers. Int J Prosthodont 14(5): 461–465.

Segura-Egea JJ, Castellanos-Cosano L, Machuca G, Lopez-Lopez J, Martin-Gonzalez J, Velasco-Ortega E, Sanchez-Dominguez B & Lopez-Frias FJ (2012) Diabetes mellitus, periapical inflammation and endodontic treatment outcome. Med Oral Patol Oral Cir Bucal 17(2): e356–e361.

Shah N, Parkash H & Sunderam KR (2004) Edentulousness, denture wear and denture needs of Indian elderly – a community-based study. J Oral Rehabil 31(5): 467–476.

Shaw JH (1987) Causes and control of dental caries. N Engl J Med 317(16): 996–1004.

Sheiham A, Steele JG, Marcenes W, Lowe C, Finch S, Bates CJ, Prentice A & Walls AW (2001) The relationship among dental status, nutrient intake, and nutritional status in older people. J Dent Res 80(2): 408–413.

Shimazaki Y, Soh I, Koga T, Miyazaki H & Takehara T (2003) Risk factors for tooth loss in the institutionalised elderly; a six-year cohort study. Community Dent Health 20(2): 123–127.

Siirilä H & Lindberg A (1965) Suomalaisen maalaiskunnan väestön hampaiston ja hoitotarpeen tutkimus vuonna 1963. Osa I. Hampaistotutkimus. Organon Dentale 17: 140–175.

Silness J & Berge M (1990) Changes over time in the clientele and restoration pattern in a dental school prosthodontic department. Int Dent J 40(2): 109–116.

Sipilä K, Näpänkangas R, Könönen M, Alanen P & Suominen AL (2013) The role of dental loss and denture status on clinical signs of temporomandibular disorders. J Oral Rehabil 40(1): 15–23.

Smith JM & Sheiham A (1980) Dental treatment needs and demands of an elderly population in England. Community Dent Oral Epidemiol 8(7): 360–364.

Soikkonen K, Wolf J, Närhi T & Ainamo A (1998) Radiographic periodontal findings in an elderly Finnish population. J Clin Periodontol 25(6): 439–445.

Soikkonen K, Wolf J, Salo T & Tilvis R (2000) Radiographic periodontal attachment loss as an indicator of death risk in the elderly. J Clin Periodontol 27(2):87–92

Statistical Yearbook of Finland 2009, Statistics Finland, Helsinki Finland

Syrjälä AM, Ylöstalo P & Knuuttila M (2010) Periodontal condition of the elderly in Finland. Acta Odontol Scand 68(5): 278–283.

Syrjälä AM, Ylöstalo P, Ruoppi P, Komulainen K, Hartikainen S, Sulkava R & Knuuttila M (2012) Dementia and oral health among subjects aged 75 years or older. Gerodontology 29(1): 36–42.

Syrjänen J, Peltola J, Valtonen V, Iivanainen M, Kaste M & Huttunen JK (1989) Dental infections in association with cerebral infarction in young and middle-aged men. J Intern Med 225(3): 179–184.

Tallgren A (2003) The continuing reduction of the residual alveolar ridges in complete denture wearers: a mixed-longitudinal study covering 25 years. J Prosthet Dent 89(5): 427–435.

Tallgren A, Lang BR & Miller RL (1991) Longitudinal study of soft-tissue profile changes in patients receiving immediate complete dentures. Int J Prosthodont 4(1): 9–16.

Tenovuo J (1992) Oral defense factors in the elderly. Endod Dent Traumatol 8(3): 93–98.

Terho EO, Husman K & Vohlonen I (1987) Prevalence and incidence of chronic bronchitis and farmer's lung with respect to age, sex, atopy, and smoking. Eur J Respir Dis Suppl 152: 19–28.

Tervonen T (1988) Dental treatment needs of adults in Ostrobothnia, Finland. Thesis Oulu, Finland, University of Oulu.

Tervonen T, Karjalainen K, Knuuttila M & Huumonen S (2000) Alveolar bone loss in type 1 diabetic subjects. J Clin Periodontol 27(8): 567–571.

Tezal M, Grossi SG & Genco RJ (2005) Is periodontitis associated with oral neoplasms? J Periodontol 76(3): 406–410.

Tezal M, Sullivan MA, Hyland A, Marshall JR, Stoler D, Reid ME, Loree TR, Rigual NR, Merzianu M, Hauck L, Lillis C, Wactawski-Wende J & Scannapieco FA (2009) Chronic periodontitis and the incidence of head and neck squamous cell carcinoma. Cancer Epidemiol Biomarkers Prev 18(9): 2406–2412.

Tezal M, Sullivan MA, Reid ME, Marshall JR, Hyland A, Loree T, Lillis C, Hauck L, Wactawski-Wende J & Scannapieco FA (2007) Chronic periodontitis and the risk of tongue cancer. Arch Otolaryngol Head Neck Surg 133(5): 450–454.

Tezal M, Wactawski-Wende J, Grossi SG, Ho AW, Dunford R & Genco RJ (2000) The relationship between bone mineral density and periodontitis in postmenopausal women. J Periodontol 71(9): 1492–1498.

The National Health and Nutrition Examination Survey (NHANES). http://www.nidcr.nih.gov.pc124152.oulu.fi:8080/DataStatistics/FindDataByTopic/GumDisease/PeriodontaldiseaseAdults20to64.htm

Tonetti MS, Claffey N & European Workshop in Periodontology group C (2005) Advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research. Group C consensus report of the 5th European Workshop in Periodontology. J Clin Periodontol 32 Suppl 6: 210–213.

Tonetti MS, Van Dyke TE & Working group 1 of the joint EFP/AAP workshop (2013) Periodontitis and atherosclerotic cardiovascular disease: consensus report of the Joint EFP/AAP Workshop on Periodontitis and Systemic Diseases. J Clin Periodontol 40 Suppl 14: S24–S29.

Treasure E, Kelly M, Nuttall N, Nunn J, Bradnock G & White D (2001) Factors associated with oral health: a multivariate analysis of results from the 1998 Adult Dental Health survey. Br Dent J 190(2): 60–68.

Tsakos G, Herrick K, Sheiham A & Watt RG (2010) Edentulism and fruit and vegetable intake in low-income adults. J Dent Res 89(5): 462–467.

Tuominen R, Reunanen A, Paunio M, Paunio I & Aromaa A (2003) Oral health indicators poorly predict coronary heart disease deaths. J Dent Res 82(9): 713–718.

Tuominen R, Vehkalahti M, Ranta K, Rajala M & Paunio I (1983) Development of edentulousness in Finland during the 1970's. Community Dent Oral Epidemiol 11(4): 259–263.

Vehkalahti M, Paunio IK, Nyyssönen V & Aromaa A (eds) (1991) Oral health in the adult Finnish population and associated factors. Helsinki Finland, Social Insurance Institution Finland.

Vehkalahti M, Siukosaari P, Ainamo A & Tilvis R (1996) Factors related to the non-attendance in a clinical oral health study on the home-dwelling old elderly. Gerodontology 13(1): 17–24.

Velly AM, Franco EL, Schlecht N, Pintos J, Kowalski LP, Oliveira BV & Curado MP (1998) Relationship between dental factors and risk of upper aerodigestive tract cancer. Oral Oncol 34(4): 284–291.

Walls AW & Steele JG (2004) The relationship between oral health and nutrition in older people. Mech Ageing Dev 125(12): 853–857.

Walls AW, Steele JG, Sheiham A, Marcenes W & Moynihan PJ (2000) Oral health and nutrition in older people. J Public Health Dent 60(4): 304–307.

Watts A, Crimmins EM & Gatz M (2008) Inflammation as a potential mediator for the association between periodontal disease and Alzheimer's disease. Neuropsychiatr Dis Treat 4(5): 865–876.

Wayler AH & Chauncey HH (1983) Impact of complete dentures and impaired natural dentition on masticatory performance and food choice in healthy aging men. J Prosthet Dent 49(3): 427–433.

Willershausen B, Kasaj A, Willershausen I, Zahorka D, Briseno B, Blettner M, Genth-Zotz S & Munzel T (2009) Association between chronic dental infection and acute myocardial infarction. J Endod 35(5): 626–630.

Williams RC (1990) Periodontal disease. N Engl J Med 322(6): 373–382.

Wu B, Liang J, Plassman BL, Remle C & Luo X (2012) Edentulism trends among middle-aged and older adults in the United States: comparison of five racial/ethnic groups. Community Dent Oral Epidemiol 40(2): 145–153.

Wu B, Liang J, Plassman BL, Remle RC & Bai L (2011) Oral health among white, black, and Mexican-American elders: an examination of edentulism and dental caries. J Public Health Dent 71(4): 308–317.

Xie Q, Ainamo A & Tilvis R (1997) Association of residual ridge resorption with systemic factors in home-living elderly subjects. Acta Odontol Scand 55(5): 299–305.

Xie QF & Ainamo A (2004) Correlation of gonial angle size with cortical thickness, height of the mandibular residual body, and duration of edentulism. J Prosthet Dent 91(5): 477–482.

Yanikoglu N & Yilmaz B (2008) Radiological evaluation of changes in the gonial angle after teeth extraction and wearing of dentures: a 3-year longitudinal study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 105(6): e55–e60.

Yeh CK, Johnson DA, Dodds MW, Sakai S, Rugh JD & Hatch JP (2000) Association of salivary flow rates with maximal bite force. J Dent Res 79(8): 1560–1565.

Ylöstalo PV, Järvelin MR, Laitinen J & Knuuttila ML (2006) Gingivitis, dental caries and tooth loss: risk factors for cardiovascular diseases or indicators of elevated health risks. J Clin Periodontol 33(2): 92–101.

Yoshihara A, Seida Y, Hanada N, Nakashima K & Miyazaki H (2005) The relationship between bone mineral density and the number of remaining teeth in community-dwelling older adults. J Oral Rehabil 32(10): 735–740.

Zarb GA (1982) Oral motor patterns and their relation to oral prostheses. J Prosthet Dent 47(5): 472–478.

Zitzmann NU, Hagmann E & Weiger R (2007) What is the prevalence of various types of prosthetic dental restorations in Europe? Clin Oral Implants Res 18 Suppl 3: 20–33.

Zitzmann NU, Staehelin K, Walls AW, Menghini G, Weiger R & Zemp Stutz E (2008) Changes in oral health over a 10-yr period in Switzerland. Eur J Oral Sci 116(1): 52–59.

Original articles

I Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2008) Prevalence of edentulousness and related factors among elderly Finns. J Oral Rehabil 35: 827–835.

II Huumonen S, Sipilä K, Haikola B, Tapio M, Söderholm AL, Remes-Lyly T, Oikarinen K & Raustia AM (2010) Influence of edentulousness on gonial angle, ramus and condylar height. J Oral Rehabil 37: 34–38.

III Huumonen S, Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2012) Residual ridge resorption, lower denture stability and subjective complaints among edentulous individuals. J Oral Rehabil 39: 384–390.

IV Haikola B, Huumonen S, Sipilä K, Oikarinen K, Remes-Lyly T & Söderholm AL (2013) Radiological signs indicating infection of dental origin in elderly Finns. Acta Odontol Scand 71: 498–507.

V Näpänkangas R, Haikola B, Oikarinen K, Söderholm AL, Remes-Lyly T & Sipilä K (2011) Prevalence of single crowns and fixed partial dentures in elderly citizens in the southern and northern parts of Finland. J Oral Rehabil 38: 328–332.

Reprinted with permissions from John Wiley & Sons Ltd and Informa Healthcare.

Original publications are not included in the electronic version of the dissertation.

Book orders:
Granum: Virtual book store
http://granum.uta.fi/granum/

UNIVERSITY OF OULU P.O. Box 8000 FI-90014 UNIVERSITY OF OULU FINLAND

ACTA UNIVERSITATIS OULUENSIS

SERIES EDITORS

A
SCIENTIAE RERUM NATURALIUM
Professor Esa Hohtola

B
HUMANIORA
University Lecturer Santeri Palviainen

C
TECHNICA
Postdoctoral research fellow Sanna Taskila

D
MEDICA
Professor Olli Vuolteenaho

E
SCIENTIAE RERUM SOCIALIUM
University Lecturer Veli-Matti Ulvinen

F
SCRIPTA ACADEMICA
Director Sinikka Eskelinen

G
OECONOMICA
Professor Jari Juga

EDITOR IN CHIEF
Professor Olli Vuolteenaho

PUBLICATIONS EDITOR
Publications Editor Kirsti Nurkkala

ISBN 978-952-62-0613-4 (Paperback)
ISBN 978-952-62-0614-1 (PDF)
ISSN 0355-3221 (Print)
ISSN 1796-2234 (Online)

UNIVERSITY of OULU
OULUN YLIOPISTO