RADIOGRAPHIC ORAL FINDINGS AND DEATH RISK IN THE ELDERLY

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Institute of Dentistry

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Abstract

AbstractRadiographic oral and maxillofacial findings were recorded in a cohort of 293 home living elderly, in Helsinki, Finland, derived from a random sample of 8035 subjects, , born in 1904, 1909, and 1912, who participated in the Helsinki Ageing Study. They were 76, 81, and 86 years old at the commencement of the radiographic study. The relationships of potentially infectious findings with increased all-cause mortality over four years were studied. During the four-year follow-up, 18.5% of the subjects died.

Of the 124 edentulous subjects, 17% had condylar findings, 13% radiopaque intraosseous findings, 9% retained roots, 6% maxillary sinus findings, 4% impacted teeth and 3% radiolucent findings. Edentulous women had more arthrotic condylar findings than men.

The mean number of teeth in the 169 dentate subjects was 13.9, 15.5 in men and 13.2 in women. Carious teeth were found in 75%, radiolucent findings in 41%, teeth with vertical infrabony pockets in 51%, furcation lesions in 28%, calculus in 40%, and condylar findings in 25%. Periodontal attachment loss was slight in 18%, moderate in 31%, and advanced in 46%. 21% of the teeth had been endodontically treated. Periapical lesions were found in 17% of these teeth, and in 4% of the other teeth. 75% of the rootfillings were inadequate, exhibiting periapical lesions twice as often as the adequate ones. Men had more carious teeth, periapical lesions and furcation lesions than women, indicating better oral hygiene and/or utilisation of dental services in women.

Compared with the previous studies carried out in Finland, slightly more teeth and less tooth-associated pathology were found in the present subjects. In contemporary Scandinavian studies, only a slightly better oral health status in the elderly has been reported.

During the four-year follow-up, mortality was higher in the subjects with moderate to advanced infrabony pockets, OR 2.2, 1.0-4.7. In the previous studies, similar associations have been found in larger study cohorts including younger subjects. Our results indicate that oral foci may be more dangerous for the elderly than it has been previously thought, as the subjects who died had poorer dental health than those who survived.

Keywords: dental, gerodontology, mortality, old, oral infection, radiography

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Oulu, October 1999

List of original papers

This thesis is based on the following papers, which are referred in the text by their Roman numerals I-V:

I Soikkonen K, Ainamo A, Wolf J, Xie QF, Tilvis R, Valvanne J & Erkinjuntti T (1994) Radiographic findings in the jaws of the clinically edentulous old people in Helsinki, Finland. Acta Odontol Scand 52:229-233.

II 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 52:243-249.

III Soikkonen K (1995) Endodontically treated teeth and periapical findings in the elderly. International Endodontic Journal 28:200-203.

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

V Soikkonen K, Wolf J, Salo T & Tilvis R (1999) Radiographic periodontal attachment loss as an indicator of death risk in the elderly. In press, J Clin Periodontol.

Additional information is also presented.

Contents

1. Introduction

The proportion of the elderly out of the population of all industrialized countries is increasing, and the most quickly expanding cohort consists of the "old elderly", i.e. those aged over 85 years. The number of elderly who have retained their natural teeth is also increasing, resulting in more teeth at risk for dental diseases. (Central Statistical Office of Finland 1989, Nyman 1990, Ainamo & Österberg 1992, Joshi *et al*. 1996). This possible increase in tooth-related disease will translate into an increased need and demand for professional dental services (Bomberg & Ernst 1986, McGuire *et al*. 1991, Joshi *et al*. 1996). As tooth-related diseases increase, so may increase the prevalence of serious diseases caused by them. Oral infections have been associated with several serious pathologic conditions, the most widely studied of them being cardiovascular disease and stroke (Syrjänen *et al*. 1989, Mattila 1993, Nieminen *et al*. 1993, DeStefano 1993, Beck *et al*. 1996, Grau *et al*. 1997). Thus far, the associations with oral infections and the prevalence of serious diseases and increased mortality have been observed in young and middle-aged subjects only.

Independent home-living elderly are a relatively scantly studied population subgroup. More studies have been made on institutionalized elderly, among whom edentulism is more widespread, and who have far poorer oral health status than their community-dwelling counterparts (Mäkilä 1979, Mäkilä & Kerosuo 1979, Ekelund 1984, Slade *et al*. 1990, Wefers 1995, Jokstad 1996, Knabe & Kram 1997).

In this work, I have studied the prevalences and distributions of radiographic oral and maxillofacial pathologic and degenerative findings in a cohort of 293 community-dwelling elderly living in Helsinki, Finland, born in 1904, 1909 and 1914. A particular emphasis was placed on the potentially infectious findings and their relationships with all-cause mortality within a follow-up time of four years.

2. Review of the literature

2.1. The elderly

A cut-off pointof 65 years of age has been generally accepted as the threshold of old age, and people past it are referred in statistical studies as “the elderly”.

With advancing age, degenerative changes in cells and organs lead to progressive loss of organ function and adaptability (Masaro 1986, Viidik 1986). Although there is notable individual variability in the processes of ageing (Evans & Williams 1992), the outcome of ageing is always inevitable. Death is usually caused by a degenerative disease related to ageing or an infection aggravated by ageing and only rarely by old age itself (Ishii *et al.* 1980).

2.2. Gerontology, geriatrics and gerodontology

Gerontology is the study of physiological age-related changes, whereas the speciality of medicine dealing with the study, diagnosis and treatment of diseases associated with advanced age is called geriatrics. The domain of gerodontology is the investigation of age-related diseases and changes in the oral region.

The expected increase in the elderly population and the improved dental health in the younger cohorts, predicting increased numbers of dentate elderly in near future, have increased the interest in gerodontology in the past decade. (Central Statistical Office of Finland 1989, Nyman 1990, Ainamo & Österberg 1992, Henry 1995, Österberg *et al.* 1995, Shay & Ship 1995, Nordström *et al*. 1995, White *et al*. 1995, Steele *et al.* 1996, Joshi *et al*. 1996, Eklund *et al*. 1997, Ettinger 1997).

2.3. Oral health in the elderly

In the past decades the number and percentage of the elderly in the population of all industrialized countries has increased dramatically (Central Statistical Office of Finland 1989, Ainamo & Österberg 1992, Henry 1995, Österberg *et al*. 1995, White *et al*. 1995, Steele *et al*. 1996, Eklund *et al*. 1997, Ettinger 1997). In Finland, the number of persons older than 75 years tripled from about 100,000 to 300,000 in twenty years (1970-1990), and this trend has been forecast to continue until the year 2030 (Nyman 1990). The most prominent increase has taken place in the oldest age cohorts of over 85 years, in which the need of medical care is also greatest. (Central Statistical Office of Finland 1989, Ainamo & Österberg 1992, Henry 1995) The percentage of edentulous subjects has rapidly diminished, and the number of retained natural teeth has increased (Österberg *et al*. 1995, White *et al*. 1995, Steele *et al*. 1996, Joshi *et al*. 1996, Eklund *et al*. 1997, Ettinger 1997). Thus, there will be more teeth at risk for dental caries and periodontal disease than before in the older age groups. The fastest-growing cohort of the elderly, those aged over 85 years, is also the most dependent group. In the USA, only 10% of the 65- to 69-year-olds are functionally dependent, while 57% of the 85-year-olds or older are (Henry 1995). Functionally dependent elderly have formerly usually been inmates of nursing homes. The oral health status of the institutionalized elderly is far poorer than that of the community-dwelling elderly, edentulism is prevalent among them, and advanced caries and periodontitis are common in the dentate persons (Leake & Marinello 1972, Mäkilä 1979, Mäkilä & Kerosuo 1979, Ekelund 1984, Slade *et al*. 1990, Wefers 1995, Jokstad *et al*. 1996, Knabe & Kram 1997). This indicates a serious decline in the ability or will to maintain adequate oral hygiene prior to, or after institutionalization. Indeed, deterioration of functional capacities, such as manual gripping force, has been associated with poor oral health (Österberg *et al*. 1990, Österberg *et al*. 1995). Systemic disease and/or medication may also affect negatively salivary secretion (Närhi 1994), leading to caries increment. Caries may lead to periapical periodontitis, and periodontitis to the formation of infrabony pockets and furcation involvements; the potentially infectious oral foci. Thus, the increase of dentate elderly may increase the prevalence of serious disease caused by oral pathogens, if preventive and maintenance care is not adequately carried out. The need for oral health care among the old population seems to be increasing, indicating a need for better public oral health benefits for the elderly. Also, the importance of the oral health status for general health and the effect of oral infections upon it must be emphasized in both medical and dental education.

2.4. Radiographic methods used for dental screening

The radiographic imaging method most widely used to screen for pathoses in the oral hard tissues is panoramic radiography. It has been used in many radiographic screening studies of adult populations, with or without supplementary intraoral radiographs (Kiminki & Paatero 1962, Lysell 1977, Mäkilä & Suoranta 1978, Mäkilä & Kerosuo 1979, Widström *et al*. 1983, Hugoson *et al*. 1986, Ahlqwist 1989, Lindqvist *et al* 1989, Salonen *et al*. 1991, Packota *et al*. 1991, Nuckles *et al*. 1993, Yamaoka *et al*. 1997).

Periapical full-mouth status, although more accurate than panoramic radiography in the dental area, leaves large areas of the maxillofacial skeleton unimaged and, thus, many lesions undetected that would be visible in panoramic radiographs (Osborne & Hemmings 1992). However, the additional findings requiring treatment that are not visible in a full-mouth intraoral status may be rare according to some studies (White & Weissman 1977, Rushton & Horner 1996, Richardson 1997). The speed and convenience of panoramic radiography for both the patient and the personnel compared to intraoral full-mouth status is by no means a trivial feature when choosing the imaging method. Also, the radiation dose from panoramic radiography is 40-50% less than the dose from an intraoral full-mouth status (Molander *et al*. 1995). Panoramic radiography is therefore the method of choice for screening for pathologic findings in the maxillofacial area. There are, however, some limitations and error sources in both the panoramic and the periapical methods. For the detection of carious lesions, intraoral radiography is better than panoramic (Hurlburt & Wuehrmann 1976, Valachovic *et al*. 1986). Periapical lesions are visualized well in both panoramic and intraoral radiographs (Rohlin *et al*. 1989, Molander *et al*. 1993). Clinically probed attachment loss has been shown to correlate positively with radiographically assessed attachment loss in panoramic radiographs (Soikkonen *et al*. 1990, Machtei *et al*. 1993, Hausmann *et al*. 1994, Walsh *et al*. 1997). The ability of both radiographic methods to detect small periodontal osseous destructions is rather poor, but periapical radiography is slightly more accurate than panoramic. Due to projection factors, radiographs tend to underestimate the degree of osseous destruction (Ainamo & Tammisalo 1967, Soikkonen *et al*. 1990, Åkesson *et al* 1992, Pepelassi & Diamanti-Kipioti 1997). However, radiography and surgical exposure of marginal bone are the most accurate methods for assessing the level of marginal alveolar bone (Suomi *et al*. 1986, Soikkonen *et al*. 1990), and as surgical exposure is quite unsuitable for screening purposes, radiography is the method of choice to detect osseous destruction caused by periodontitis. By using supplementary intraoral radiographs of areas not well visualized in the panoramic image, the sensitivity and specificity of the detection of periodontal lesions can be further enhanced (Bean & Akerman 1984, Rohlin & Åkerblom 1992, Molander *et al*. 1995).

Pathologic or degenerative changes in the mandibular condyles are visualized well in panoramic radiographs, though tomography is a more accurate method in detecting them (Ludlow *et al*. 1995, Dahlström & Lindvall 1996). Findings in the maxillary sinus floor and the anterior parts of the sinus are well visualized on panoramic radiographs, but the posterior and upper regions of the maxillary sinuses are poorly imaged (Mattila 1965, Duker & Fabinger 1978, Ohba *et al*. 1991, McGowan *et al*. 1993, Ohba *et al*. 1994). Panoramic radiography reveals cyst-like findings in maxillary sinuses better than Water's view, which, in turn, exels in detecting overall cloudiness and sclerotic changes (Ohba & Katayama 1976). When compared with computed tomography in detecting antral malignacy, the finding was observed on panoramic radiographs in 90% of the cases (Epstein *et al*. 1996).

2.5. Radiographic oral findings in the elderly

2.5.1. Edentulism

In most industrialized countries, edentulism in all age groups seems to be gradually disappearing (Österberg *et al*. 1995, White *et al*. 1995, Shay & Ship 1995, Nordström *et al*. 1995, Steele *et al*. 1996, Joshi *et al*. 1996, Eklund *et al*. 1997, Ettinger 1997). In the USA, the percentage of edentulous elderly dropped from 55% in the 1960s through 46 % in the 1970s and to 41% in the 1980s. By the 1990s, the percentage of edentulous subjects over 65 years of age had dropped to 38%. Among those over 75 years of age edentulism continued to be more prevalent (47%). (White *et al*. 1995). Among the community-dwelling elderly aged 70 years or more in New England, USA, the percentage of edentulous subjects was 37% in 1988-1991 (Marcus *et al*. 1996). In many other western countries in the 1970s, more than 50% of the elderly were edentulous (MacEntee 1985). In Finland, no increase or decrease in edentulism among the elderly in the 1970s was detected, and the average percentage of edentulous elderly (over 64 years old) subjects was 61% (Tuominen *et al*. 1983). In the 1980s, in Finland the percentage of edentulous elderly (65 years old and older) was 58% (Vehkalahti *et al*. 1991). A decrease in the number of edentulous elderly was observed from 1976 to 1987 in Finland, and the number of remaining teeth in the dentate subjects increased (Nyman 1990). This trend still continues, and the percentage of edentulous elderly (65 years old and older) had decreased to 46% by 1990 (Ainamo & Murtomaa 1991). The percentage of edentulous elderly in Finland has been forecast to drop below 30% in the year 2000 (Tala 1992). In Sweden, too, a decrease in the number of edentulous elderly has been observed during the 1970s and 1980s, and the numbers of remaining teeth have increased (Nordenram & Böhlin 1985, Hugoson *et al*. 1988, Nordström *et al*. 1995). Edentulism is more prevalent among women than men (Mäkilä 1977, Lysell 1977, Mäkilä & Kerosuo 1979, Tuominen *et al*. 1983, Takala *et al*. 1994, Nordström *et al*. 1995, Nyman 1990, Vehkalahti *et al*. 1991), but the difference between the sexes seems to be diminishing (Nyman 1990, White *et al*. 1995). If only one jaw is edentulous, the maxilla is more often edentulous than the mandible (Lysell 1977, Mäkilä 1977, Mäkilä & Kerosuo 1979, Nordström *et al*. 1995, Vehkalahti *et al*. 1991, Takala *et al*. 1994).

2.5.2. Retained natural teeth

The general pattern and sequence of tooth loss in humans at the population level is such that mandibular molars are lost first, being followed, in this order, by maxillary molars, maxillary premolars, mandibular premolars, upper incisors and canines, and finally, lower incisors and canines (Ahlqwist *et al*. 1988, Vehkalahti *et al*. 1991, Nordström *et al*. 1995). The number of remaining teeth decreases with advancing age due to the accumulating caries and periodontitis experience (Phipps & Stevens 1995, Angelillo *et al*. 1996, Hiidenkari *et al*. 1996, Hull *et al*. 1997). About one third of all extractions are due to caries and one third to periodontal disease. Molars and premolars are usually extracted because of caries, and incisors, canines and premolars for periodontal disease. Caries is

the main cause of extractions in subjects aged under 50 years, and periodontitis in those over 50 years of age. Third molars are usually extracted because of impaction or malocclusion, and some premolars and molars for orthodontic reasons. (Phipps & Stevens 1995, Angelillo *et al*. 1996, Hiidenkari *et al*. 1996, Hull *et al*. 1997). In women, more teeth are extracted for prosthetic reasons than in men (Hiidenkari *et al*. 1996). In Norway, the role of caries and its sequelae as an indication for extraction decreased from 69% to 43% during 1968 - 1988 (Klock & Haugejorden 1991). The number of remaining teeth in the dentate elderly in the USA during the period from 1958 to 1985 increased from 7.4 to 17.9 in 65- to 74-year-olds, and from 4.1 to 16.8 in 75- to 79-year-olds (NIDR survey 1987). In Jönköping, Sweden, the number of teeth in dentate 70-year-olds increased in ten years (1973-1983) from 8.5 to 11.8 (Hugoson *et al*. 1986). From 1981 to 1990 in Umeå, Sweden, the mean number of teeth in 70-year-olds did not change significantly, being 15.1 in 1981 and 15.4 in 1990, but more subjects had some natural teeth left (Nordström *et al*. 1995). In Finland, the number of teeth in 65-year-olds and older subjects (including edentulous subjects) increased from 5.1 to 5.5 during 1976 - 1987 (Nyman 1990). In the Mini-Finland study (1978-1980), the mean number of remaining teeth in the dentate elderly was 11 (Vehkalahti *et al*. 1991). In 1985, an average of 12 teeth were found in dentate subjects (Ostrobothnia, Finland) aged 65 years (Tervonen 1988).

The number of remaining teeth is 1-2 teeth higher in men than in women, and the reasons for this are largely unknown, but iatrogenic causes have been suspected (Nyman 1990, Takala *et al*. 1994, Hiidenkari *et al*. 1996).

The prevalence of impacted teeth in radiographic studies of elderly populations has varied from 3% in edentulous jaws (Lysell 1972) to 8% in groups including of both dentate and edentulous subjects (Kiminki & Paatero 1962, Ahlqwist & Gröndahl 1991). In edentulous jaws the prevalence of impacted teeth in general population studies has been from 0.9% (Scandrett *et al*. 1973, Jones *et al*. 1985) to 9% (Tronje *et al*. 1980) (Table 3, I). The teeth found most often to be impacted are the third molars (85-72%), followed by the canines (18-10%), premolars (4-3%) and second molars (2-0%) (Kiminki & Paatero 1962, Ahlqwist & Gröndahl 1991). Impacted teeth are observed more often in the maxilla than in the mandible (Kiminki & Paatero 1962, Tronje *et al*. 1980, Ahlqwist & Gröndahl 1991, Yamaoka *et al*. 1996). Most studies of impacted teeth have been performed on edentulous subjects. The prevalence of impacted teeth, especially the prevalence of impacted third molars, is lower in edentulous jaws than in dentate jaws (Yamaoka *et al*. 1996).

The prevalence of intrabony or submucosal residual roots in radiographic screening studies of the general population, including mostly edentulous subjects, has varied from 75.5% (Glestad *et al*. 1968, Norway) to 9.6% (Dias *et al*. 1988, Malaysia), the average percentage of subjects with retained roots being 27% in different study populations (Glestad *et al*. 1968, Table 3, I). Retained roots are also more common in the maxilla than in the mandible (Barclay & Donaldson 1970, Axelsson 1988, Bremner & Grant 1971, Tronje *et al*. 1980).

2.5.2.1. Carious teeth and roots

In an extensive international statistical study of the dental status of the elderly in 31 countries, the mean number of carious teeth was 1.2, and 27.9% of the subjects exhibited coronal caries, and 33.7% root caries (Ettinger 1993). It is a well-documented fact that men have more carious teeth than women, and women have more filled and missing teeth than men (Banting 1984, Nordenram & Böhlin 1985, Douglass *et al*. 1993, White *et al.* 1995). The reasons of this are naturally iatrogenic (Nyman 1990, Takala *et al*. 1994, Hiidenkari *et al*. 1996). Men also have more carious retained roots than women do. The mean number of carious retained roots per elderly subject has varied within 0.2-2.7 in different studies. (Ranta *et al*. 1987, Nyyssönen *et al*. 1983, Slade & Spencer 1997). The mean number of carious teeth per subject in the dentate elderly in the USA was 0.8-0.7 in men and 0.5-0.7 in women in the 1960s and 1970s (Banting 1984). In the late 1980s in New England, USA, the percentage of dentate subjects aged 70 years or more and having coronal caries was 34% in men and 28% in women. 22% of the subjects had root caries. (Douglass *et al*. 1993). The mean number of carious teeth among the community-dwelling elderly aged 66 and 69 years was 3.3, accounting for 20% of the teeth in 1971 and 1974 in Stockholm, Sweden. In the same area in 1970, 30% of the dentate elderly aged 60 years or more had carious teeth. (Nordenram & Böhlin 1985). In the 1980s in Älvsborg, Sweden, the mean number of carious teeth in the elderly aged over 60 years was 3.4 (Salonen *et al*. 1989). In the Mini-Finland study (1978-1980), 33% of the dentate elderly had carious teeth (Vehkalahti *et al*. 1991). The prevalence of caries in the younger age groups is on the decline, and this trend is expected also to extend to the elderly in the future. (Nordling & Tala 1986, Bailit 1987, Tala 1992). However, as the number of teeth in the elderly increases, and because the prevalence of caries in all age groups has been observed to remain at about the same level (Douglass & Gammon 1985, Hugoson *et al.* 1986, Tervonen & Ainamo 1988, Vehkalahti *et al.* 1991), the number of filled teeth will increase with advancing age and accumulating caries experience (Banting 1984, Douglass & Gammon 1985, Hugoson *et al*. 1986, Hugoson *et al*. 1995, Joshi *et al*. 1996). Older age groups with more teeth have been observed to lead to an increase in caries (Nordenram & Böhlin 1985, Vehkalahti *et al*. 1991, McGuire *et al.* 1993). Instead of primary coronal caries, secondary caries and root caries predominate in the elderly: secondary caries because of the frequently extensive and deteriorating fillings, and root caries because of the exposed root surfaces due to periodontal disease (Banting 1984, Nordström *et al.* 1995).

2.5.2.2. Endodontically treated teeth

With advancing age, both the number of endodontically treated teeth and their proportion out of the remaining teeth increase as a result of accumulating caries experience, attrition, trauma, and loss of teeth (Bergenholz *et al*. 1973a, Hugoson & Koch 1979, Laurell *et al.* 1983, Hugoson *et al.* 1986, Bergström *et al*. 1987, Ödesjö *et al.* 1990, Eriksen 1991). The prevalence of endodontically treated teeth, whether rootfilled or with pulp amputation, has in Scandinavian, German, Dutch, and American general population studies varied

within 0.9 - 3.5 such teeth per subject, corresponding to 4 - 15% of remaining teeth (Eriksen 1991, De Cleen *et al*. 1993, Buckley & Spangberg 1995, Weiger *et al*. 1997). In older subjects, the percentage of endodontically treated teeth increases to over 20% after 60 years of age, being close to 25% at the age of 70 years (Eriksen 1991). In subjects aged 80 years or older, 27% of the teeth have been observed to be endodontically treated (Ödesjö *et al*. 1990). Pulp amputations comprise only 5-6% of the endodontic treatments of adult population in Sweden (Bergenholz *et al*. 1973a, Ödesjö *et al*. 1990). Women have more endodontically treated teeth than men (mean 2.2 and 1.1, respectively) (Lysell 1977), and the proportion of endodontically treated teeth out of the remaining teeth has been observed to be 5% higher in women than in men (Allard & Palmqvist 1986). The prevalence of rootfillings judged radiographically to be of unacceptable quality has been quite high in several radiographic studies. De Cleen (1993) found in Dutch subjects 50.6% of the rootfillings to be inadequate, Buckley & Spanberg (1995) in the USA regarded 58% of the root canal obturations as unsatisfactory, and Weiger *et al*. (1997) in Germany judged 86% of the rootfillings substandard. In Scandinavian studies, the percentage of unacceptable rootfillings has ranged from 84% (Ödesjö *et al*. 1990) to 38.5% (Bergström *et al*. 1987).

In three Scandinavian studies, 9-10% of the root canal fillings projected over the radiographically discernible apex (overfills), 39-50% were 2mm or more short of apex (underfills), 43-70% were judged to be of inadequate density, and 16-36% were deemed as satisfactory (Bergenholz *et al*. 1973b, Eckerbom *et al*. 1989, Ödesjö *et al*. 1990). The success rate of endodontic treatment (whether or not the apical periodontitis lesion heals and/or the symptoms disappear) is related to the quality of root canal obturation. Apical periodontitis lesions have been found in 50-74% of roots with overfills, in 9-25% of roots with underfills and in 29-58% of fillings of inadequate density. Periapical lesions have been found in 7-16% in association with technically adequate rootfillings. (Bergenholz *et al*. 1973b, Petersson *et al*. 1986, Bergström *et al*. 1987, Ödesjö *et al*. 1990). The initial state of the tooth greatly affects the success rate: if there is a radiolucent periapical lesion present at the beginning of endodontic treatment, success rates are 68-84% of the cases, as compared to the overall success rates of 88-91% (Grahnen & Hansson 1961, Kerekes &Tronstadt 1979, Molven & Halse 1988).

2.5.3. Periapical findings

As the number of endodontically treated teeth and their proportion out of the remaining teeth increase with age, so does the prevalence of periapical periodontitis lesions because of the cumulating oral disease experience (Bergenholz *et al*. 1973a, Laurell *et al*. 1983, Hugoson *et al*. 1986, Bergström *et al*. 1987, Eriksen 1991). The number of subjects with many periapical lesions also increases with advancing age (Laurell *et al*. 1983). The mean number of periapical periodontitis lesions per subject has been 0.4 - 1.6% in Scandinavian general population studies, corresponding to 1.5 - 6.3% of the remaining teeth. In the elderly, the proportion of the remaining teeth with periapical lesions has been observed to increase to 9 - 16%, and 66 - 72% of these subjects had periapical lesions. (Lysell 1977, Laurell *et al*. 1983, Allard & Palmqvist 1986, Eriksen 1991). The

prevalence of apical periodontitis lesions is higher in endodontically treated teeth than in the other teeth. In various studies, 29 - 70% of the endodontically treated teeth have exhibited periapical lesions, whereas the prevalence of lesions in non-endodontically treated teeth has been 2.4 - 5.2% (Laurell *et al*. 1983, Petersson *et al*. 1986, Hugoson *et al*. 1986, Bergström *et al*. 1987, Bergenholz *et al*. 1973a, Ödesjö 1990, Eriksen 1991, De Cleen *et al*. 1993, Buckley & Spangberg 1995, Weiger *et al*. 1997). Men have been observed to have slightly more periapical lesions than women, with a mean of 2.1 and 1.4 such teeth respectively (Lysell 1977), though Allard & Palmqvist (1986) found no difference between the sexes.

There are also periapical radiopaque findings: some are infectious in origin: condensing osteitis and its possible remnants as "scars" in bony structure when the original periapical infection has abated. The harmless opaque findings that may exist in the periapical region or project over it in a radiograph include enostoses and cemento-osseous lesions, such as periapical cemental dysplasia. Periapical radiopaque findings indicative of condensing osteitis have been found in 1.4% of the endodontically treated roots (Bergman *et al*. 1979). The prevalence of the findings diagnosed radiographically as enostoses is about 5% in Europeans and about 10% in mongolidic populations (Shafer *et al*. 1974, Austin & Moule 1984, Geist & Katz 1990, Kawai *et al*. 1992).

2.5.4. Periodontal findings

Numerous studies have shown that the prevalence of periodontal disease to increases with advancing age (Black 1917, Marshall-Day & Shourie 1949, Marshall-Day *et al*. l955, Hugoson & Jordan 1982, Halling & Björn 1986, Miller *et al*. 1987, Papapanou *et al*. 1988, Jenkins & Kinane 1989, Brown *et al*. 1989, Wouters *et al*. 1989, Albandar 1990, Beck *et al*. 1990, Todd & Lader 1991, Hugoson *et al*. 1992). In many general population studies, however, the number of elderly subjects, especially those over 75 years of age, has been small, and their number of remaining teeth has been limited. The high prevalence of periodontal disease in the elderly can also be interpreted as a result of cumulative disease experience or cohort differences (Albandar 1990, Papapanou *et al*. 1991, Hugoson *et al*. 1992, Wennström *et al*. 1993, Burt 1994, Fox *et al*. l994, Joshi *et al*. 1996).

In the early radiographic studies of Black (1917), Marshall-Day & Shourie (1949), and Marshall-Day *et al*. (l955) severe periodontal disease was very common in all adult age groups. In some more recent studies carried out in the western countries, a change in the distribution of periodontal disease has been observed: advanced bone loss is now seldom found in subjects below the age of 35, and infrabony pockets or furcation lesions are relatively rare in subjects under 40. (Miller *et al*. 1987, Linden 1988, Papapanou *et al*. 1988, Brown *et al*. 1989, Hugoson *et al*. 1992). Various studies have indicated that advanced periodontal disease affects only a fraction of the population, even in the elderly (Halling & Björn 1986, Miller *et al*. 1987, Okamoto *et al*. 1988, Papapanou *et al*. 1988, Brown *et al*. 1989, Jenkins & Kinane 1989, Beck *et al*. 1990, Hunt *et al*. 1990, Todd & Lader 1991, Diamanti-Kipioti *et al*. 1995). This minority with advanced bone loss, however, increases with advancing age: at 60 years of age, about 30% of subjects have

75% of the advanced bone loss in their age cohort (6 mm or more, Papapanou *et al*. 1988, 7 mm or more, Baelum *et al*. 1986, 1988, >50% attachment lost) (Jenkins & Kinane 1989).

The rising number of dentate elderly with more remaining teeth present, means that there will be more teeth are at risk for periodontal disease. Douglass *et al*. (1983) compared data from two American national health studies from the 1960s and 1970s and found, in association with increasing numbers of teeth present, an increase in the number of elderly subjects with periodontal pockets from 46% to 51% in subjects aged 65-74 years. However, the proportion of subjects free from periodontal disease increased from 10% to 36% in the same group. (Douglass *et al*. 1983). An increase in the number of the dentate elderly in Sweden during 1973-1983 led to a dramatic increase in the proportion of subjects with severe bone loss (in 70-year-olds from 6% to 42%) (Hugoson *et al*. 1992). Fox *et al*. (1994) showed that elderly subjects with both arches dentate had more moderate and severe pocketing than did those with one dentate arch only. In the New England Elderly Dental Study (NEEDS) pocket depth and loss of attachment increased as the number of teeth increased (Joshi *et al*. 1996). Seemingly contradictory results have also been presented, indicating that the more teeth present, the better is the periodontal condition (Palmqvist & Sjödin 1987, Jenkins & Kinane 1989, Burt 1994, Diamanti-Kipioti *et al*. 1995). Only slight attachment loss has been observed in these groups with good oral hygiene (Papapanou *et al*. 1991, Wennström *et al*. 1993, Serino *et al*. 1994, Beck & Koch 1994). The subjects with "successfully ageing dentitions" are also more active utilisers of professional dental services (Joshi *et al*. 1996). Halling & Björn (1986) in a series of 862 Swedish women aged 38-60 years found little or no progression of bone loss in 83% of the subjects, as well as an increase in the number of retained teeth over a follow-up period of 12 years (1968-1980). During this period there was an increase in the availability of dental services in Sweden, and a general dental health insurance system was instituted (Halling & Björn 1986). In several general population studies men have had more periodontal breakdown than women (Douglass *et al*. 1983, Miller *et al*. 1987, Papapanou *et al*. 1988, Wouters *et al*. 1989, Hunt *et al*. 1990, Fox *et al*. 1994, Diamanti-Kipioti *et al*. 1995).

Calculus is an indicator of the oral hygiene level. Calculus has been radiographically observed at an average of 19.2% of the interproximal sites in the Swedish general population. (Wouters *et al* 1993). In clinical examinations, much higher prevalences of calculus have been observed, as in the New England Elderly Study, where 93% of the men and 86% of the women aged 70-96 years had calculus (Fox *et al*. 1994). As plaque retention sites, restoration overhangs and calculus have a local detrimental influence on the alveolar bone level (Hakkarainen & Ainamo 1980, Albandar *et al*. 1987).

Bone loss has been shown to be influenced not only by the patient’s age, but also by tooth type. (Marshall-Day & Shourie 1949, Marshall-Day *et al*. 1955, Albandar *et al*. 1987, Papapanou *et al*. 1988, Brown *et al*. 1989, Papapanou *et al*. 1989, Wouters *et al*. 1989, Albandar 1990, Wennström *et al*. 1993). The patterns of bone loss have shown only little variation in most general population studies. Infrabony pockets and bone loss have been most prevalent in molars, followed by premolars, and least prevalent in incisors and canines, especially lower incisors. This resembles closely the overall pattern of human tooth loss reported in several studies. (Roper *et al*. 1972, Becker *et al*. 1979, McFall 1982, Goldman *et al*. 1986, Miller *et al*. 1987, Palmqvist & Sjödin 1987, Linden 1988,

Papapanou *et al*. 1988, Chauncey *et al*. 1989, Wood *et al*. 1989, Todd & Lader 1991, Chace & Low 1993). However, in some studies almost the opposite pattern of affected teeth has been observed. In the study of Marshall-Day & Shourie (1949) from India, the lower molar region was the most heavily affected area, closely followed by lower incisors and upper incisors, lower bicuspids being most resistant to bone loss. Ainamo and Tammisalo (1970) reported bone loss extending to the apex in 16-19% of the upper molars and 12% of lower central incisors in a series of 100 patients (aged 21 to 64 years) who had all sought dental care for their periodontal problems.

2.5.5. Condylar findings

Mechanical stress over an extended period of time can cause adaptive or degenerative remodelling of the joint surfaces in temporomandibular joints, as in all joints in the body (Sokoloff 1980, Muir & Goss 1990a, Muir & Goss 1990b, Sato *et al*. 1996). The main radiographic signs related to this remodelling observed in the condylar head are subchondral sclerosis, flattening of the articular surface and the condylar head, osteophyte formation, and erosions (Muir & Goss 1990a, Muir & Goss 1990b, Gynther *et al*. 1996, Sato *et al*. 1996). Radiographically, these signs are identical to and indistinguishable from those associated with osteoarthrosis (Kopp & Rockler 1979, Altman *et al*. 1986, Gynther *et al*. 1996). The presence of erosions may also indicate arthritis (Könönen & Kilpinen 1990, Gynther *et al*. 1996). These condylar findings have been found to increase with advancing age (Sokoloff 1980, Ishibashi *et al*. 1995, Sakurai & Mizokami 1997). The overall prevalence of radiographic adaptive or degenerative condylar findings per subject in elderly populations has varied from 13 to 26% in panoramic radiography, in conventional plain-film projections and in tomography (Lysell 1977, Mäkilä *et al*. 1980, Sato *et al*. 1996, Soikkonen *et al*. 1996). Aberrant prevalences of condylar findings have also been reported: in 2.5% of the subjects in panoramic radiographs (Keur *et al*. 1987), and 71% of the subjects in condylar zonographs (Sakurai & Mizokami 1997). Most common of the findings has been flattening of the articular surface and the condylar head (9-11% of the subjects), followed by osteophytes (3-12% of the subjects), erosion (3-8% of the subjects) and sclerosis (3-7% of the subjects) (Lysell 1977, Mäkilä *et al*. 1980, Sato *et al*. 1996). These condylar findings have been observed somewhat more often in women than in men, but the difference between the sexes has been slight and not always statistically significant (Mäkilä *et al*. 1980, Sato *et al*. 1996, Soikkonen *et al*. 1996). According to recent studies, edentulism or partial occlusal support does not seem to have an effect on the prevalence of radiographic condylar findings (Sato *et al*. 1996, Soikkonen *et al*. 1996). Although the condylar heads in the elderly may often be grossly deformed and flattened, the subjective TMJ symptoms tend to abate with age (Österberg *et al*. 1992, Koidis *et al*. 1993).

2.5.6. Findings in maxillary sinuses

The maxillary sinus mucosa responds to irritation by swelling from its normal 1-mm thickness to 10-15 mm (Goaz & White 1994). If a duct of a seromucinous gland is blocked, the secretion dilates the gland and the duct forming a cyst lined with epithelium; this is the secretory type of mucous cyst, also called retention cyst (Lindsay 1942, Schuknecht & Lindsay 1949, Paparella 1963, Allard & van der Kwast 1981, Gardner 1984, Goaz & White 1994). If, for example, an odontogenic infection causes local irritation in the sinus wall, it may cause capillary damage and fluid leakage. The inflammatory exudate, (Lindsay 1942, Goaz & White 1994) then pools above the periostium (McGregor 1928, Lindsay 1942, Allard & van der Kwast 1981, Goaz & White 1994), forming a pseudocyst, the non-secretory type of mucous cyst (McGregor 1928, Lindsay 1942, Schuknecht & Lindsay 1949, Goaz & White 1994, Allard & van der Kwast 1981).

The radiographic appearance of retention cysts and pseudocysts is similar, a well-defined "dome-shaped" uniform radiopacity rising from the floor or the walls of a sinus (Allard & van der Kwast 1981, Goaz & White 1994). Retention cysts, however, seldom become large enough to be visible radiographically (Paparella 1963, Gardner 1984). Odontogenic cysts, which may also extend into the maxillary sinus, have a thin radiopaque bony margin, which is absent in mucous cysts (Allard & van der Kwast 1981, Goaz & White 1994).

There are also other, more diffuse mucosal changes with a different radiographic appearance from that of mucous cysts. These "mucosal thickenings" appear as diffuse, often polypous, radiopacity along the margin of the sinus. Polyps are often multiple, pendulous and less regularly shaped than mucous cysts. (Killey & Kay 1970, Kwapis & Whitten 1971)

In radiographic studies of mucous cysts found in the maxillary sinuses of both dentate and edentulous subjects, prevalence figures ranging from 2 to 13% have been reported (Ibsen 1945, Wright 1946, Kivimäki & Ekholm 1961, Myrhaug 1962, Mattila 1965, Lilly *et al*. 1967, Myall *et al*. 1974, Ohba & Manson-Hing 1975, Allard & van der Kwast 1981, MacDonald-Jankowski 1993, McGowan *et al*. 1993, Goaz & White 1994). The diffuse mucosal thickenings are more common, with frequencies up to 50% of radiographic incidental findings (mucous cysts included) in the paranasal sinuses (Wilson & Grogutt 1990), and they are most common in the maxillary sinuses (Cooke & Hadley 1991).

According to Mattila (1965), the prevalence of mucous cysts is not age-dependent, and the prevalences of mucous cysts and mucosal thickenings in the elderly fall within the ranges found in general population studies (Soikkonen & Ainamo 1995). In younger age groups, mucous cysts are most prevalent in the third decade, and more prevalent in men than women (Allard & van der Kwast 1981, McGowan *et al*. 1993, Goaz & White 1994). There also exists some seasonal variation: mucous cysts and mucosal swellings in the maxillary sinuses are more common in winter than in summer (Savolainen *et al*. 1997, Carter *et al*. 1998). Periodontitis or periapical infection may also cause mucosal swelling or sinusitis (Falk *et al*. 1986), and odontogenic sinusitis accounts for 5 - 45 % of all sinusitides (McGowan *et al*. 1993, Abrahams & Glassberg 1996). Mucous cysts and mucosal thickenings are usually asymptomatic, but are occasionally associated with a variety of symptoms, such as facial pain, headache and toothache (Lindsay 1942,

Paparella 1963, Fisher *et al*. 1989, Rhodus 1990, Goaz & White 1994). Mucous cysts tend to rupture and disappear spontaneously (Halstead 1973, Goaz & White 1994), and mucosal thickenings resolve when their cause is removed (Naschiz & Yesrun 1985). In symptomatic cases, however, surgical removal of the cyst may be indicated (Fisher *et al*. 1989).

2.5.7. Other findings

The prevalence of cysts in oral radiographic studies has varied from 1% to 9% of the subjects (Carlsson 1959, Wolf 1969, Lysell 1977, Perrelet *et al*. 1977, Mäkilä 1979, Axelsson 1988). In oral biopsy studies, the most prevalent cysts have been radicular and residual cysts (over 50% of all cysts), followed by follicular cyst (about 20%). Most common nonodontogenic cyst has been the nasopalatine duct cyst (3%). (Kreidler *et al*. 1993, Daley *et al*. 1994). The prevalence of tumours in oral radiographic studies has been low, 0.3-0.6% of the subjects (Wolf 1969, Perrelet *et al*. 1977). The most common tumours in oral biopsy studies have been odontomas (over 50% of odontogenic tumours), the compound odontoma being more common than the complex odontoma (Daley *et al*. 1994, Owens *et al*. 1997). The prevalence of sialoliths was 1.3% of the subjects in a study by Axelsson (1988). Foreign bodies, such as amalgam fragments, broken instrument tips, and bullet fragments have been found in 0.4-9% of the subjects in oral radiographic studies (Carlsson 1959, Wolf 1969, Lysell 1977, Perrelet *et al*. 1977, Jones *et al*. 1985, Axelsson 1988).

2.6. Oral foci and their effect on general health

The detrimental effect of oral infections upon general health and their associations with general diseases have long been observed and suspected, already at the beginning of the 20th century (Äyräpää 1902). Oral foci are local infectious lesions that can cause pathologic changes in distant organs via various mechanisms. In an oral radiographic examination, intrabony foci, such as periapical periodontitis lesions, vertical bone loss defects and furcation lesions can be detected, but such foci that involve soft tissue only are not visible. The bacteria present in oral foci (Tanner *et al*. 1992, Maiden *et al*. 1992, Slots & Rams 1992) can multiply and pass into the bloodstream, causing such conditions as endocarditis, pyelonephritis and brain abscesses (Rams & Slots 1992, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Navazesh & Mulligan 1995, Beck *et al*. 1996, Grau *et al*. 1997, Meurman 1997). Aspiration of oral bacteria, especially in association with periodontal disease, may cause pneumonia in the hospitalized elderly or in medically compromised patients (Greenberg *et al*. 1982, Limeback 1988, Rams & Slots 1992, Christensen *et al*. 1993, Finegold *et al*. 1993). Non-oral respiratory pathogens are also able to colonize the dental plaque, which then acts as a "reservoir" of these bacteria. (Scannapieco *et al*. 1992, Scannapieco & Mylotte 1996, Fourrier *et al*. 1998). Bacterial toxins emitted by locally asymptomatic oral foci can cause fever of unknown origin (Katz *et al*. 1992, Rams & Slots 1992). An overreactive immunologic host response in

association with oral foci can result in "metastatic inflammation" manifesting most often as uveitis or iritis (Torabinejad *et al*. 1983, Kettering & Torabinejad 1984, Bloch-Michel 1985, Brummer & van Wyk 1987, Rams & Slots 1992). Subjects with periapical periodontitis lesions have also been found to have significantly increased prevalence of systemic allergies and elevated levels of IgE (Kettering & Torabinejad 1984, Brummer & van Wyk 1987). Oral infections have been observed to aggravate arthritis and Crohn's disease, while an amelioration of symptoms follows the eradication of oral foci (Halme *et al*. 1993, Meurman 1997).

All infections or inflammations seem to increase suspectibility to myocardial infarction, a finding observed in young and middle-aged subjects only (Nieminen *et al*. 1993, DeStefano *et al*. 1993). Oral infections have been associated with an increased risk not only for myocardial infarction, but also for brain infarction (Syrjänen *et al*. 1989, Valtonen 1991, Mattila 1993, Beck *et al*. 1996, Grau *et al*. 1997).

2.7. Oral foci and their effect on risk of death

Oral infections can be life-threatening due to direct spread of the infection, e.g. from a periapical periodontitis lesion in a lower molar lingually into the floor of the mouth under m. mylohyoideus and into the mediastinum (Äyräpää 1902, Moncada *et al*. 1978, Garatea-Crelgo & Gay-Escoda 1991). Pneumonia is a major cause of death in the institutionalized elderly, and aspiration of oral bacteria of the dental plaque may be one of the causes of severe pneumonia (Greenberg *et al*. 1982, Limeback 1988, Rams & Slots 1992, Christensen *et al*. 1993, Finegold *et al*. 1993). Hematogenous dissemination of oral bacteria can also lead to many potentially fatal conditions (Rams & Slots 1992, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Navazesh & Mulligan 1995, Beck *et al*. 1996, Grau *et al*. 1997). The bacteria, however, need not necessarily spread from the foci to cause hazardous systemic effects: it has been suspected that infections and inflammations increase blood coagulation factors, which, in turn, may lead to heart and brain infarctions. (Syrjänen *et al*. 1989, Valtonen 1991, Mattila 1993, Kweider *et al*. 1993, Beck *et al*. 1996). The exact pathogenic mechanism, however, is still unknown.

DeStefano *et al*. (1993) found an association between clinically diagnosed periodontitis and mortality in 9,760 subjects aged 25-74 years (OR 1.5, 95% confidence interval 1.3 to 1.7). The strongest association was found in young and middle-aged men aged 25-49 years (OR 2.1, 95% confidence interval 1.2 to 3.6). However, Joshipura *et al*. (1996) found no associations between self-reported periodontal disease and sudden death in a questionnaire study of 44,119 male health professionals, of whom 58% were dentists.

In a study cohort of 1,147 men drawn from the population of the Normative Aging Study, Boston, USA, which consisted of 2,280 men aged 21 to 80 years at the baseline and followed up for 18 years, Beck *et al*. (1996) found associations with radiographically assessed alveolar bone loss and coronary heart disease, heart infarction and death from a heart attack. Subjects having mean radiographic periodontal attachment loss of more than 20% of the root length had twice as often fatal heart attacks than those with less than 20% mean attachment loss (age-adjusted odds ratio 2.2, 95% confidence intervals 1.3-3.9, and the odds ratio adjusted for age and known risk factors for cardiovascular disease was 1.9,

95% confidence intervals 1.1-3.4). Clinical probing depth also showed an association with cardiovascular disease, and the percentage of teeth (of all teeth) having more than 3 mm probing depth showed an age-adjusted odds ratio of 3.6, the 95% confidence intervals being 1.5-8.5, which was the highest risk ratio observed in this study (Beck *et al.* 1996).

In a recent study of 804 dentate men (mean age 42 years at the baseline) followed up for over 25 years for mortality, an association between radiographically diagnosed alveolar bone loss and all-cause mortality was observed (OR 1.7, 95% confidence interval 1.2-2.4). Forcing the number of teeth into the model increased slightly the risk of death associated with bone loss (OR 1.9, 95% confidence interval 1.3-2.7). For each 20% increase in the mean alveolar bone loss, the death risk increased by 51% (OR 1.5, 95% confidence interval 1.1-2.0). This was independent of the recognised death risk factors, and comparable to cigarette smoking as a predictor of death risk. Clinical probing depth also showed an association with the death risk (OR 1.7, 95% confidence interval 1.1-2.8). (Garcia *et al*. 1998).

3. Objectives of the study

As the number of the elderly and, most importantly, dentate elderly in the Finnish population is increasing, detailed information of the prevalences and distributions of oral findings in this relatively little studied population subgroup is needed, with a particular emphasis on the potentially infectious findings that may be hazardous to health. In studies including younger subjects, results indicative of relationships between oral infections and cardiovascular diseases and stroke have recently emerged. Increased death risk has also been associated with oral infecions, mainly periodontitis. This topic has not been studied in the elderly.

The papers I, II, III, and IV comprised the descriptive-epidemiologic part of this thesis, and, in paper III, the relationship of the radiographically assessed technical quality of endodontic treatment to the prevalences of periapical lesions was also studied (the numbers in parentheses refer to the original papers). In paper V, the hypothesis tested was that radiographically observable potentially infectious oral radiographic findings increase all-cause mortality.

The following questions and hypotheses formulated on the basis of these questions were addressed:

1. What are the prevalences of radiographic pathologic or degenerative maxillofacial and dental findings in 76-, 81-, and 85-year-old home-living elderly in Helsinki, Finland? Are there differences in the prevalences of the findings between the sexes or age groups? Do the prevalences of the findings differ from those of the earlier or contemporary studies made in Finland, other Nordic countries, or in other Western countries (I, II, and IV)?

   The following hypotheses were based on these questions: Women would have less teeth and be more often edentulous than men, as this has been observed in many studies before. Fewer teeth would mean less tooth-related pathology in women. Because the age range was limited, no major differences between the age groups would be expected. No major differences compared to the studies made in the Nordic or other Western countries would be expected, since Finland also has a rather well developed health care system. But because the subjects had lived their earlier life at times when the health care system was more modest, the present dentate subgroup might represent a "survivor" population that with possibly decreased prevalences of

oral pathologic findings, as those more prone to caries and periodontitis might have lost their teeth long ago.

2. Do the distributions of teeth present and lost and the locations of the periodontal findings follow the patterns observed in most previous studies (IV)?

   As the present dentate subgroup was assumed to be a "survivor" population with high resistance to caries and periodontitis, differences in these respects might be expected compared to general population studies including younger subjects.

3. What is the prevalence of technically inadequate endodontic treatments and how are they related to the presence of periapical lesions? Are there more or less failures of endodontic treatment in the present study group compared to previous studies (III)?

   Earlier studies have shown that there are more periapical lesions in endodontically treated teeth than in other teeth, and that overfills and fillings of inadequate density carry the poorest success rates among endodontic technical failures. But in the present very old subjects, there might be proportionally more teeth present with technically inadequate fillings without periapical lesions than in the previous studies including younger subjects, as symptomatic failures are probably weeded out with time, resulting in an accumulation of successful rootfillings, regardless of their technical quality.

4. Is mortality increased in the subjects who have potentially infectious oral findings? Are there also other findings than those related to periodontitis that increase the death risk?

   Apical periodontitis lesions, in addition to the findings related to periodontitis (infrabony pockets, furcation involvements, horizontal bone loss), can be considered to be potentially infectious oral foci and to be radiographically observable. The hypothesis was that the presece of such findings would increase all-cause mortality Carious teeth, although not infectious foci as such, lead, if untreated, to the development of apical periodontitis. Moreover, they harbour plaque and are an indicator of the oral health care status, and they might thus also be associated with increased mortality.

4. Subjects and methods

4.1. Study population and study designs

This investigation is part of a comprehensive medical and dental survey (Helsinki Ageing Study) comprising a random sample of 8035 subjects (Fig. 1, II) born in 1904, 1909, and 1914 and living in Helsinki, Finland, on 1 January, 1989 (Lindroos et al. 1993). For the medical survey the response rate from the invited sample of 795 old people was 82% (n=651) (Valvanne 1992). Between 1989 and 1990, 651 subjects participated in a comprehensive medical examination. Before 31 May 1990 the annual mortality among the participants in the medical survey was 8% (n=51). In 1990-1991, the 600 subjects still alive were invited to the Institute of Dentistry, University of Helsinki, for a comprehensive dental examination. A total of 133 persons were interviewed by phone and mail. No dental data was available for 103 subjects. Altogether 364 subjects, of whom 28% were men and 72% women, were examined in 1990-1991 (Ainamo et al. 1993). The response rate for invited men was 69% and for women 58% (Vehkalahti et al. 1996). Of the 364 subjects, 293 were examined clinically and radiographically at the Institute of Dentistry, whereas 71 subjects were examined only clinically at home or in institutions.

Of the 293 subjects radiographed, 169 (54 men and 115 women) had one or more clinically visible natural teeth, and 124 (32 men and 92 women) were clinically edentulous. Thus, 42% of the radiographed sample were edentulous and 58% dentate. (Table 1, I, Table 1, II)**.** During the four-year follow-up, 54 (18.5%) of the subjects died (15 men and 39 women), 32 (11 men and 21 women) of them being dentate (18.9%) (Tables 1, 2, and 4, V).

4.2. Radiographic methods

Panoramic radiographs were obtained with the PM 2002® radiographic apparatus (Planmeca Oy, Helsinki, Finland). Trimax® T16 intensifying screens and GTU® X-ray films (3M Co. St. Paul, MN. USA) were employed. Intraoral radiographs of poorly

visible areas in the panoramic radiograph were taken with a Siemens Heliodent®70 (Siemens Medical Engineering, Dental Sector, Bensheim, Germany) dental radiographic unit and Kodak® Ultra-speed X-ray film (Eastman Kodak Co., Rochester, MN, USA). In all, 293 panoramic and 116 intraoral radiographs were taken. Films were mounted in frames (Trollhätteplast, Trollhättan, Sweden). The radiographs were studied by one dental radiologist (K.S.) under standardized conditions using Matsson's binoculars (X-Produkter, Malmö, Sweden) with a 2x magnification and a viewing light of adjustable brightness (Institute of Dentistry's own manufacture, Helsinki, Finland).

4.3. Diagnostic criteria and registered findings

Dentate/edentulous: subject was judged as edentulous if there were no clinically visible teeth or roots in the mouth. (I, II).

Mental foramen situated at the top of residual ridge (I).

The total number of teeth, and the numbers of teeth in the upper and lower jaw, impacted teeth, intrabony residual roots and supernumerary teeth were recorded. (I, II).

The numbers of carious teeth and carious residual roots: the diagnosis of caries was based on the radiographic observation of a loss of mineral substance of the tooth, exhibiting itself as a radiolucency of the typical shape. (II, V).

The number of endodontically treated teeth: Teeth with pulp amputations were recorded separately. Unfilled roots in multi-rooted teeth, root canal posts in roots without visible root canal filling, and root perforations by posts were also registered. The root canal filling was judged as adequate if there was no visible radiolucent gap between the filling and root canal walls, and if the canal was filled to at least 2 mm from the radiographically discernible apex. The root canal was judged to be underfilled if the filling tip was more than 2 mm short of the radiographically discernible apex. The root canal filling was judged to be of inadequate density if there was a visible radiolucent gap between the filling and root canal walls. Overfill was recorded if the filling projected over the radiographically discernible apex. (III).

The number of periapical lesions: periapical lesion was registered if there was a clearly discernible local widening of the apical periodontal membrane space and loss of lamina dura at the site. Lateral lesions of a similar kind were also included in this category. Periapical lesions in endodontically treated teeth were also recorded separately. (II, III, V). Cysts were also registered separately. A radiolucent lesion was interpreted as a cyst if it was more than 1 cm in diameter, and had well-defined roundish opaque margins. (I).

Local radiopaque findings: these were diagnosed as small cemento-osseous lesions if there was a radiolucent capsule present but no root canal. Condensing osteitis was diagnosed only if opacity was noted in association with an infectious process. Enostoses included local thickenings in bony structure without apparent cause. (I, II). Sialoliths were diagnosed from occlusal radiographs (submandibular gland) and by sialography in one case (parotid gland) (I).

Radiographically discernible calculus was graded into four categories:

0: No calculus
1: Barely discernible calculus. A few small interproximal spines on a few teeth, usually molars or lower anterior teeth.
2: Moderate calculus. Clearly discernible interproximal spines on most teeth.
3: Substantial calculus. Heavy masses of calculus interproximally and also a continuous mass discernible through the crowns of the teeth.

Infrabony interproximal defects deeper than 3 mm were judged as infrabony pockets. The extent of horizontal bone loss and the depth of infrabony pockets were observed at the site where they were most advanced in relation to the roots of the teeth. They were graded into five categories:

0: No bone loss, bone level within 2-3 mm of the CEJ area.
1: Slight bone loss, bone level at the cervical third of the roots.
2: Moderate bone loss, bone level at the middle third of the roots.
3: Advanced bone loss, bone level at the apical third of the roots.
4: Extreme bone loss, bone level at or beyond the apex.

If bone loss was clearly observed to extend apically from the furcation area of a multi-rooted tooth, a furcation lesion was recorded. Interproximal restoration overhangs were observed from fillings or crowns. The numbers of teeth with restoration overhangs, furcation lesions and infrabony pockets were registered. (II, IV, V).

Changes in temporomandibular joints were diagnosed from the mandibular condyles. The changes recorded were osteoarthrosis (flattening, cortical sclerosis, osteophytes, subchondral cysts and erosion) and other pathologic findings or abnormalities. (I).

Findings of increased opacity in the area of the maxillary sinuses discernible in the panoramic radiograph were recorded and divided into two categories: mucosal cysts, i.e. well-defined opacities with a round outline rising from the floor or walls of the sinus, and mucosal thickenings, representing a more diffuse opacity along the margins of the sinus without a well-defined round outline. (I).

The subjects were followed for four years for mortality to find out the relationships of the potentially infectious findings to the risk of death. The findings included were periapical lesions, infrabony periodontal pockets, furcation lesions, horizontal bone loss, and carious teeth. (V).

4.4. Statistical analyses

Of the StatView TM SE+ Graphics (Abacus Concepts Inc., Berkeley, CA, USA) statistical program package for the MacIntosh® computer (Apple Computer Inc., CA, USA), the unpaired two-tailed t-test was used for numerical data (II) and the Chi-square test for category data (I, III). If the t-test was not valid because of a scarcity of subjects or findings, the Mann-Whitney U-test was used instead (III).

Additionally, ANOVA was used in the periodontal study for the numerical variables to determine the statistical significance of the differences between the age groups and the sexes, and simple regression analysis was used to determine the significance of the associations between the variables. (IV).

Biomedical Data Processing Program (BMDP2L- Survival analysis with covariates) (BMDP Statistical Software, Inc., Los Angeles, CA, USA) was used in calculating the Cox Proportional Hazards Model with age and sex forced into the regression model, to determine the relationships between the potentially infectious findings and the death risk. (V). The relative risk of death associated with the variables was expressed as odds-ratios (risk ratios). The 95% confidence intervals of the odds-ratios were calculated using the formula:

$$\text{Confidence Interval} = e^{b \pm 1.96\ SE.}$$

Here, b is the beta-coefficient and SE its standard error.

The reliability of the radiographic observations was assessed by having the radiologist (K.S.) who had examined all the radiographs, review 41 randomly selected radiographs of 21 dentate and 20 edentulous subjects six months later, to determine the intra-examiner variation. In addition, another radiologist (J.W.) examined 50 randomly selected radiographs to find out the inter-examiner variation. Cohen's Kappa test was used in the statistical analysis of the intra- and inter-examiner variations.

4.5. Approval by the ethics committee

The Ethics Committees of the Helsinki University Central Hospital and the Institute of Dentistry, University of Helsinki, approved the protocol.

5. Results

5.1. Radiographic findings in edentulous subjects (I)

Eleven (9%) of the 124 edentulous subjects had retained roots. Twelve of the roots were located in the maxilla and two in the mandible. Impacted teeth were found in five women (4%): two maxillary third molars, one maxillary cuspid, one mandibular premolar and one mandibular molar. Radiolucent findings were found in four subjects (3%). Radiographically, two of these were diagnosed as residual cysts and one as a nasopalatine duct cyst. One male subject had two radiolucent lesions at the apexes of two submucosal roots, judged as periapical periodontitis. Localized radiopaque findings in the bony structure of the jaws were found in 16 subjects (13%). They were slightly more common in women (14%) than in men (9%). Most of the opacities were diagnosed as enostoses. Two findings were diagnosed as small cemento-osseous lesions and one as condensing osteitis around a periapical lesion in a submucosal root. Three sialoliths were found in three women (2%). One was located in the duct of right parotid gland and two in the duct of the left submandibular gland. Aberrations from the normal condylar shape and structure were found in 21 subjects (17%). Twenty subjects (16%) had condylar changes indicative of osteoarthrosis. These findings were more common in women (19%) than in men (13%) ($p<0.05$). One man had a deformed condyle, probably due to an old fracture. Opaque maxillary sinus findings were found in eight subjects (6%). In four subjects these were judged as mucous cysts, and in the other four as more diffuse mucosal thickenings. Two more opaque maxillary sinus findings judged as small osteomas were found in two subjects (1%). The mental foramen was situated at the top of the residual ridge in 52 subjects (42%). Only 13% of the men had the mental foramen at the top of the ridge, whereas it was topically situated in 52% of the women ($p<0.001$). No significant differences were found between the three age groups in the location of the mental foramen.

5.2. Dental radiographic findings (II)

In the 169 subjects with one or more clinically visible teeth, a total of 2,355 teeth were found, including 1,367 maxillary and 988 mandibular teeth. The mean number of teeth was highest (15.2) in the 76-year-olds, and lowest in the oldest, 86-year old group (11.6), ($p<0.05$). In men, no statistically significant difference in the mean number of teeth between the age groups could be found. Older women with fewer teeth caused the differences between the age groups as a whole. More teeth were missing from the maxilla than from the mandible in both men and women in all age groups, even though 379 more maxillary teeth were found in the study population as a whole. The mean numbers of teeth by sex and age group are shown in Table 2 (IV). There were 60 subjects (36%) with one edentulous jaw. The maxilla was edentulous in 54 (32%), and the mandible in 6 (4%) subjects. One edentulous jaw was found in 39% of the women and 28% of the men, but this difference was not statistically significant. Intrabony retained roots were found in 25 subjects (15%), in all 33 root remains, of which 69% were located in the maxilla and 31% in the mandible. Fourteen subjects (7%) had altogether 19 impacted teeth: 12 wisdom teeth, 4 cuspids, 2 supernumerary teeth, and 1 premolar. Radiographically detectable caries was found in 126 subjects (75%). Of the total number of 2,355 teeth, 507 (22%) were judged as carious. A relatively high proportion of the carious teeth (62%) were found in a rather limited part of the study population (24%). Carious roots were found in 28 subjects (17%), and these roots comprised 14% of all carious teeth. Of all the teeth, only 3% were carious roots. The mean number of carious teeth increased from 2.5 in the 76-year-olds to 4.5 in the 86-year-olds ($p<0.05$). This increase was statistically significant in men ($p<0.01$), but not in women. Carious teeth were also more common in men than in women ($p<0.001$). (II, Table 2).

Teeth with rootfillings or pulp amputations were found in 129 subjects (76%). A total of 507 teeth (21%) out of the 2,355 teeth found had been endodontically treated, of which only 13 (0.5%) teeth had a pulp amputation. The mean number of endodontically treated teeth per subject was 2.9, (3.4 in men, and 2.8 in women). The percentage of endodontically treated teeth out of the total number of teeth in each age group increased from 19% in the 76-year-olds, through 23% in the 80-year-olds, to 26% in the 86-year-olds. Neither the sex- nor the age group differences were statistically significant. Periapical radiolucent lesions indicating periapical periodontitis were found in 70 subjects (41%). Such lesions were found in 7% of all teeth studied, and they were observed more often in endodontically treated teeth, 17% of which exhibited periapical lesions. Only 4% of the other teeth had periapical lesions. The mean number of periapical lesions per subject was 1.0. Periapical radiolucencies were more common in men than in women ($p<0.001$). (II, Table 3). In twelve subjects (7%), periapical lesions judged as radicular cysts were observed. The other cysts observed were three residual cysts in one subject, and one subject had a follicular cyst. In addition, sclerotic periapical findings indicating condensing osteitis were found at 35 teeth (1.5% of the 2,355 teeth), and these findings were also more common in men than in women ($p<0.001$).

Teeth with vertical infrabony pockets (depth 3 mm or more) were found in 88 subjects (51%), and teeth exhibiting furcation lesions (furcation involvements) were found in 47 subjects (28%). The mean number of teeth with vertical infrabony pockets per subject was 1.5, (1.8 in men, and 1.3 in women). The mean number of teeth with vertical pockets

per subject was 0.5, (0.9 in men, and 0.4 in women). The men in the 76-year-old group had more teeth with vertical infrabony pockets than the women in the same group ($p<0.05$) and also more furcation lesions ($p<0.01$). In the whole study group, men had also more furcation lesions ($p<0.05$). (II, Table 4). One large opaque finding diagnosed as a complex odontoma associated with an unerupted lower third molar was found in one man, and one suspected benign-looking parotid tumour was found in one woman by sialography.

5.3. Endodontically treated teeth and periapical findings (III)

Of the 169 dentate subjects, 133 (79%), 45 men and 88 women, had endodontically treated teeth and/or periapical radiolucent lesions. Of the endodontically treated teeth, 17% exhibited periapical lesions, but only 4% of the other teeth ($p<0.0001$). 75% of the rootfillings were judged to be inadequate. Periapical lesions were found more often in teeth with inadequate rootfillings (18%) than in teeth with rootfillings judged as adequate (10%) ($p<0.05$). The lesion prevalences ranged from 10% (adequate rootfillings) to 100% (root perforations by a post or a root canal screw) (III, Fig. 1, Table 2).

Men had more periapical radiolucent lesions in endodontically treated teeth than women ($p<0.0001$), although they did not have significantly more endodontically treated teeth than women ($p<0.3$). Men also had more periapical radiolucent lesions in teeth that were not endodontically treated ($p<0.0003$). Local radiopaque findings in the bony structure were not statistically significantly associated with endodontic treatment or periapical radiolucent lesions. Local radiopaque findings were more common in men ($p<0.005$). No other statistically significant differences were found between the sexes, nor between the three age groups, although the percentage of endodontically treated teeth out of all teeth increased from 19% in the 76-year-olds to 26% in the 86-year-olds.

5.4. Radiographic periodontal findings (IV)

Horizontal or vertical alveolar bone loss measured at the site where it was most advanced was common among the study population. Only eight subjects (5%) were considered to have no radiographically observable bone loss. This periodontal breakdown was judged as slight in 30 subjects (18%), moderate in 53 subjects (31%), and advanced or extreme in 78 subjects (46%). 88 subjects (52%) had infrabony pockets, 55% of the men and 50% of the women. Furcation lesions were found in 47 subjects (28%), 35% of the men and 24% of the women. 82 subjects (49%) had horizontal bone loss only. Men had, on average, 15.5 remaining teeth, while women had 13.2 teeth ($p<0.05$). Of all the 2,355 teeth studied, 11% were affected by periodontal breakdown, but only 4% exhibited advanced or extreme bone loss. Infrabony pockets were most prevalent in molars (17-29%), of which 22% had furcation lesions. Least prevalent infrabony pockets were in incisors (1-7%). The prevalences of the periodontal findings recorded (calculus, horizontal bone loss, infrabony pockets, furcation lesions, and interproximal restoration overhangs) are shown in the Figures 2, 3, 4, 5, 6, 7, 8, and in Table 3 (IV). The

percentage of teeth with infrabony pockets increased slightly from the 76-year-olds (10%) to the 86-year-olds (16%). No statistically significant differences could be demonstrated with ANOVA either between the sexes, or between the three age groups. The prevalence of calculus had no association with the other variables studied. The only statistically significant associations were between the numbers of interproximal overhangs and infrabony pockets ($R=0.3$, $p<0.001$), between the numbers of interproximal overhangs and furcation lesions ($R=0.3$, $p<0.0001$) and between the numbers of infrabony pockets and furcation lesions ($R=0.4$, $p<0.0001$).

5.5. Radiographic potentially infectious findings and the risk of death (V)

The incidence of death did not differ in the edentulous and dentate subjects (V, Table 4). Sex and age were not significantly associated with death (V, Table 5). Among the dentate subjects who had periodontal infrabony pockets extending to the middle third of the roots or deeper, mortality was increased during the four-year follow-up (OR 2.2, 95% confidence intervals 1.0-4.7). Mortality was also slightly increased in the subjects who had 5-14 infrabony pockets, moderate to advanced horizontal bone loss and apical periodontitis lesions, and in relation to the pooled sum of all the potentially infectious findings studied, but the 95% significance level was not attained. The number of carious teeth and the number of furcation lesions showed an inverse relationship to the risk of death, but it was statistically not significant. (V, Fig's 1 and 2, Table 5).

5.6. Reliability of the observations (I-V)

To assess the reliability of the radiographic observations, 41 randomly selected radiographs, of 21 dentate and 20 edentulous subjects, were re-examined six months later to determine the intra-examiner variation (K.S.). The mean percentage of agreement 96% (SD 5%)**.** To assess inter-examiner variation, another radiologist (J.W.) examined the radiographs of 50 randomly selected subjects six months later. The mean percentage of agreement was 87% (SD 9%). The Kappa values ranged from 0.96 to 0.19 in the intra-examiner variation, and from 0.95 to 0.24 in the inter-examiner variation (Dunn & Everitt 1995) (Tables 1 and 2)**.**

Table 1. Intra-examiner variation. 41 subjects' (21 dentate, 20 edentulous) radiographs re-examined.

Finding	Number of different observations	Percentual agreement of observations	Kappa
Maxilla edentulous	0	100	0.83
Mandible edentulous	0	100	0.60
Degree of maxillary atrophy	8	80	0.65
Degree of mandibular atrophy	3	93	0.70
Mental foramen at the top of the residual ridge	2	95	0.80
Number of upper teeth	0	100	0.59
Number of lower teeth	1	98	0.56
Impacted teeth	0	100	0.19
Supernumerary teeth	0	100	E
Intrabony root remains	0	100	E
Radiolucent periapical lesions	2	95	0.96
Cysts	0	100	0.38
Tumours	1	98	E
Condensing osteitis	0	100	0.28
Cemento-osseous lesions	0	100	0.09
Enostoses	0	100	0.62
Carious roots	0	100	0.38
Carious teeth	4	90	0.56
Number of endodontically treated teeth	2	95	0.61
Underfill	1	98	0.73
Inadequate density	5	8	0.79
Overfill	2	95	0.27
Periapical lesion in endodontically treated tooth	2	95	0.73
Pulp amputations	0	100	E
Amount of calculus	2	95	0.46
Number of restoration overhangs	3	93	0.71
Degree of horizontal bone loss	1	98	0.58
Number of vertical pockets	6	88	0.85
Depth of the deepest pocket	1	98	0.70
Furcation lesions	1	98	0.67
Condylar findings	7	82	0.83
Maxillary sinus findings	2	95	0.58
Bony structure	1	98	E

Mean intra-examiner variation 96%, SD 5%. Kappa values: under 0.4, poor agreement from 0.4 to 0.75, fair to good agreement 0.75 and over, excellent agreement. (Fleiss and Cohen 1969, 1973). E = Kappa value could not be calculated.

Table 2. Inter-examiner variation. 50 subjects (27 dentate, 23 edentulous) radiographs re-examined.

Finding	Number of different observations	Percentual agreement of observations	Kappa
Maxilla edentulous	5	90	0.80
Mandible edentulous	0	100	0.50
Degree of maxillary atrophy	3	94	0.68
Degree of mandibular atrophy	4	92	0.58
Mental foramen at the top of the residual ridge	3	94	0.71
Number of upper teeth	6	88	0.55
Number of lower teeth	3	94	0.50
Impacted teeth	0	100	E
Supernumerary teeth	1	98	0.24
Intrabony root remains	6	88	0.47
Radiolucent periapical lesions	12	78	0.84
Cysts	2	96	0.24
Tumours	1	98	E
Condensing osteitis	7	86	0.73
Cemento-osseous lesions	1	98	E
Enostoses	5	90	0.53
Carious roots	6	88	0.95
Carious teeth	14	72	0.45
Number of endodontically treated teeth	4	92	0.54
Underfill	9	82	0.59
Inadequate density not assessed			
Overfill	4	92	0.87
Periapical lesion in endodontically treated tooth	4	92	0.59
Pulp amputations	5	90	0.24
Amount of calculus	10	80	0.90
Number of restoration overhangs	10	90	0.70
Degree of horizontal bone loss	6	88	0.43
Number of vertical pockets	13	74	0.78
Depth of the deepest pocket	8	84	0.64
Furcation lesions	5	90	0.34
Condylar findings	14	72	0.58
Maxillary sinus findings	20	60	0.26
Bony structure	13	74	0.70

Mean inter-examiner variation 87%, SD 9%. Kappa values: under 0.4, poor agreement from 0.4 to 0.75, fair to good agreement 0.75 and over, excellent agreement. (Fleiss and Cohen 1969, 1973). E = Kappa value could not be calculated.

6. Discussion

6.1. Study population and study designs

The 293 subjects that comprised the present oral radiography study group, were derived from the Helsinki Aging Study, in which a random sample of 8,035 subjects was studied by interwiews and by comprehensive medical examinations and laboratory tests. Some of the medical examinations were quite unpleasant to the subjects, such as gastroscopy. The subjects were also very old, being born in 1904, 1909 and 1914. These factors may have resulted in the high number of drop-outs before the commencement of the dental part of the study in 1990, after the medical examinations (Fig. 1, II). Thus, the subjects in the present study group may represent the the portion of the original sample that was the hardiest and in the best state of health. The fact that Finnish men tend to die almost ten years earlier than Finnish women (Valkonen *et al.* 1990) emphasizes even more the "survivor" nature of this cohort. Those that did not attend the dental study were more often older, had more often deteriorated mobility, or showed symptoms of dementia. In addition, non-participation in the dental study was more common among the edentulous subjects, which may have led to exessive prevalence figures for teeth present in the series as a whole. (Vehkalahti *et al.* 1996). This also leads to exessive prevalence figures of tooth-associated pathology, in the whole study population. To prevent this error, the findings of the edentulous and the dentate groups have been given separately.

The radiographed sample of 293 subjects, of whom 169 had at least one tooth present, while 124 were edentulous, is quite large for a radiographic study of elderly subjects of such advanced age. For an epidemiological study, however, the sample is limited. Other studies of larger samples more suitable for epidemiological purposes but including younger subjects have, however, attained results comparable with ours. These include the studies by DeStefano *et al.* (1993) on a sample of 9,760 subjects aged 25-74 years, by Beck *et al.* (1996) on a sample of 1,147 men aged 18-80 years and by Garcia *et al.* (1998), on a sample of 804 dentate men (mean age 42 years).

6.2. Radiographic methods

Panoramic radiography supplemented with intraoral radiographs when necessary (of areas poorly visible in the panoramic radiograph) was employed as the imaging method in this study. This method was chosen as it gives a good or at least adequate view of the dental area as well as the adjacent maxillofacial structures, such as the temporomandibular joints and the maxillary sinuses. The speed and convenience of panoramic radiography was another important reason for choosing this method. The radiation dose per patient in panoramic radiography is also 40-50% lower than that from an intraoral full-mouth status (Molander *et al*. 1995). If, in addition to an intraoral full-mouth status, the maxillary sinuses and the temporomandibular joints were imaged with conventional projections to obtain information comparable with a panoramic radiograph, the patient doses would, of course, rise even higher. The lens of the eye, the hypophysis and some bone marrow would then be exposed to radiation, which also occurs to some extent when the panoramic method is used. In these very old subjects, however, the harmful effects of the radiation to which they were exposed in this study can be considered negligible: genetic effects are bound to be nonexistent, as the subjects, at least the women, are unlikely to reproduce, and the development of malignant tumours takes a long time (decades, with the exception of leukemia) from the original exposure, which may well exceed the life expectancy of most of the present subjects.

6.3. Radiographic oral findings in the elderly

6.3.1. Edentulism

The general trend among all age groups in the industrialized countries is towards a decreasing proportion of edentulous subjects (Österberg *et al.* 1995, White *et al*. 1995, Shay & Ship 1995, Nordström *et al*. 1995, Steele *et al*. 1996, Joshi *et al*. 1996, Eklund *et al*. 1997, Ettinger 1997). The trend of diminishing edentulism among the elderly in the USA, from 55% in the sixties, to 38% in the nineties (White *et al*. 1995) has also been observed in Finland, from 61% in the seventies to 46% in the nineties in the age group of 64-65 years or more (Tuominen *et al*. 1983, Ainamo & Murtomaa 1991). The percentage of the edentulous in the present study cohort was 42%, which is even lower, while the subjects are older. But as mentioned before, the dentate are likely to be over-represented in this sample.

Edentulism has been observed to be more prevalent among women than men in many studies (Mäkilä 1977, Lysell 1977, Mäkilä & Kerosuo 1979, Tuominen *et al*. 1983, Takala *et al*. 1994, Nordström *et al*. 1995, Nyman 1990, Vehkalahti *et al*. 1991), and this was also the case in the present study, where 32 men (representing 26% of the edentulous) and 92 women (representing 74% of the edentulous) were clinically edentulous. However, the difference between the sexes may be gradually diminishing, due to increase in the proportion of dentate women (Nyman 1990, White *et al*. 1995). The maxilla is more often the edentulous jaw, if only one jaw is edentulous (Lysell 1977, Mäkilä 1977, Mäkilä &

Kerosuo 1979, Nordström *et al*. 1995, Vehkalahti *et al*. 1991, Takala *et al*. 1994). This was also seen in the present series, where the maxilla was edentulous in 54 (32% of the dentate) and the mandible in 6 (4% of the dentate) subjects.

6.3.2. Retained natural teeth

Concomitantly with the decrease in the number of edentulous elderly from 1976 to 1987 in Finland the number of remaining teeth in the dentate subjects increased (Nyman 1990). In Sweden, too, the decrease in the number of edentulous elderly during the seventies and eighties has been concomitant with an increase in the number of remaining teeth (Nordenram & Böhlin 1985, Hugoson *et al*. 1988, Nordström *et al*. 1995). The increase in the mean number of remaining teeth was from 7.4 to 17.9 among dentate 65-74-year-olds and from 4.1 to 16.8 in 75-79-year-olds in the USA during 1958 - 1985 (NIDR survey 1987). In Sweden, the number of teeth in dentate 70-year-olds increased during 1973-1983 from 8.5 to 11.8 (Hugoson *et al*. 1986). After that, no significant change in the mean number of teeth in the elderly has been observed in Sweden, but more subjects had some natural teeth present, which means that the teeth are "distributed more equally" (Nordström *et al*. 1995). In Finland an increase in the number of teeth in 65-year-old and older subjects (edentulous subjects included) was from 5.1 to 5.5 during 1976 - 1987 (Nyman 1990). In the Mini-Finland study (1978-1980), the mean number of remaining teeth in the dentate elderly was 11 (Vehkalahti *et al*. 1991). In 1985 an average of 12 teeth were found in the dentate subjects aged 65 years in Ostrobothnia, Finland (Tervonen 1988). The mean number of teeth in the present 169 subjects with one or more clinically visible teeth was 13.9, which shows some improvement compared to the previous Finnish studies, especially when the advanced age of the subjects in the present study is taken into account (Table 2, IV).

The number of remaining teeth has been found to be higher by 1-2 teeth in men than in women, which difference has been considered iatrogenic, as women make more dental visits than men (Nyman 1990, Takala *et al*. 1994, Hiidenkari *et al*. 1996). On an average, men had two more teeth than women in the present series, too (Table 2, IV), the difference being statistically significant.

More maxillary than mandibular teeth had been lost by both men and women in all age groups in the present study group, which is in accordance with the previous studies, on the patterns and sequence of tooth loss in humans: mandibular molars are lost first, being followed by maxillary molars, maxillary premolars, mandibular premolars, upper incisors and canines, and finally, lower incisors and canines (Ahlqwist *et al*. 1988, Vehkalahti *et al*. 1991, Nordström *et al* 1995). This corresponds well to the observed numbers of remaining teeth in the present subjects (Fig. 8, IV). The number of remaining teeth decreases with advancing age due to cumulating caries and periodontitis experience (Phipps & Stevens 1995, Angelillo *et al*. 1996, Hiidenkari *et al*. 1996, Hull *et al*. 1997), and the older the subjects were, the fewer teeth they had in the present study, too (Table 2, IV). We do not know the exact reasons for tooth loss in the present subjects, as most of the teeth had been lost a long time ago. From previous studies we know, however, that about one third of all extractions are due to caries, one third to for periodontal disease,

and the last third are extracted because of impaction, trauma-associated pathology, or orthodontic and prosthetic reasons. Caries is the main cause of extraction in subjects under 50 years, and periodontitis in those aged over 50. Molars and premolars are usually extracted because of caries, and incisors, canines and premolars because of periodontal disease. Third molars are usually extracted because of impaction or malocclusion, and some premolars and molars for orthodontic reasons. (Phipps & Stevens 1995, Angelillo *et al*. 1996, Hiidenkari *et al*. 1996, Hull *et al*. 1997). In women, more teeth are extracted for prosthetic reasons than in men, which is one of the iatrogenic factors causing old women to have fewer remaining teeth than old men (Hiidenkari *et al*. 1996). The role of caries and its sequelae as extraction indications seems to be diminishing, as in Norway, for example, extractions due to them decreased from 69% to 43% during 1968 - 1988 (Klock & Haugejorden 1991).

Impacted teeth are more prevalent in the maxilla than in the mandible (Kiminki & Paatero 1962, Tronje *et al*. 1980, Ahlqwist & Gröndahl 1991, Yamaoka *et al*. 1996), which was also observed in the present study. Most studies of impacted teeth have been performed on edentulous subjects. However, in edentulous jaws the prevalence of impacted teeth, especially the prevalence of impacted third molars is lower than in dentate jaws (Yamaoka *et al*. 1996). This finding was also confirmed by the present study: the prevalence of impacted teeth was slightly higher in the dentate subjects (7%) than in the edentulous (4%), and the dentate subjects had 12 impacted third molars, the edentulous ones having only two. The reason why more impacted teeth are found in the maxilla may lie in the fear of perforating the adjacent maxillary sinus during the surgical extraction of impacted upper third molars, or the fact that impacted maxillary canines and supernumerary teeth are more common than mandibular ones. That there are fewer impacted teeth in edentulous jaws than in dentate jaws may be due to their removal prior to prosthetic treatment, or that they have erupted due to alveolar atrophy and consequently been extracted.

The prevalence of intrabony or submucosal retained roots in radiographic general population screening studies of mostly edentulous subjects has varied from 75% (Glestad *et al*. 1968, Norway) to 9% (Dias *et al*. 1988, Malaysia), the percentage of subjects with retained roots being 27% on average in different study populations (Glestad *et al*. 1968, Table 3, I). Our prevalence figures for retained roots fall within this range, being well below "the international average", which may be interpreted as an indicator of good dental care, with the utilization of dental radiography. Of the present 124 edentulous subjects, 9% had retained roots, of which 86% were located in the maxilla, and 14% in the mandible. Intrabony retained roots were found in 15% of the 169 dentate subjects, and 69% of them were located in the maxilla, and 31% in the mandible. Retained roots being more common in the maxilla than in the mandible, has also been reported previously (Barclay & Donaldson 1970, Axelsson 1988, Bremner & Grant 1971, Tronje *et al*. 1980). The fact that retained intrabony roots are more common in the maxilla than in the mandible, is most probably due to the relative thinness of the upper molar root tips, and the upper molars and first premolars usually having one more root than their mandibular counterparts, and the proximity of the maxillary sinus, which may discourage fractured root tip removal.

6.3.2.1. Carious teeth and roots

First, we must bear in mind the limitations of caries diagnosis based on panoramic radiographs, as some caries lesions are bound to be misdiagnosed radiolucent fillings, and some lesions may be missed altogether. On the other hand, radiography reveals interproximal caries and caries under fillings that may be missed in a clinical examination.

Radiographically detectable caries was found in 75% of the 169 dentate subjects. The mean number of carious teeth was 3.0 (SD. 3.3), 4.4 (SD. 4.0) in men and 2.4 (SD. 2.7) in women (Table 2, II). 22% of all teeth were diagnosed as carious. Men also had more carious retained roots than women. On average, there were 0.9 (SD. 1.8) carious roots in men and 0.2 (SD. 0.8) in women. The mean number of carious roots per elderly subject has varied within 0.2-2.7 in different studies. (Ranta *et al*. 1987, Nyyssönen *et al.* 1983, Slade & Spencer 1997). The prevalence of carious roots in the present subjects can be considered rather low, indicating good utilization of professional dental care. Of all teeth, only 3% were carious roots.

It is a well-documented fact that men have more carious teeth than women, while women have more filled and missing teeth than men (Banting 1984, Nordenram & Böhlin 1985, Douglass *et al*. 1993, White *et al*. 1995). The reasons for this are, of course, iatrogenic, such as the lower number of retained teeth and the more prevalent edentulism in women (Nyman 1990, Takala *et al*. 1994, Hiidenkari *et al*. 1996). In the present 169 dentate subjects, the mean number of carious teeth increased from 2.5 in the 76-year-olds to 4.5 in the 86-year-olds. This increase was statistically significant in men, but not in women, which indicates better oral hygiene and/or better utilization of professional dental care by women.

An average of 1.2 carious teeth per subject were observed in an extensive international statistical study of the dental status of the elderly in 31 countries (Ettinger 1993). The mean number of carious teeth per subject in the dentate elderly in the USA has been 0.8-0.7 in men and 0.5-0.7 in women in the 1960s and 1970s (Banting 1984), so our caries figures are poorer, but when compared to the other Scandinavian studies we fare better. In Stockholm, Sweden, the mean number of carious teeth in the community-dwelling elderly aged 66 and 69 years was 3.3 in 1971 and 1974, comprising 20% of all teeth. In the same area in 1970, 30% of the dentate elderly aged 60 years or more had carious teeth. (Nordenram & Böhlin 1985). In the eighties in Älvsborg, Sweden, the mean number of carious teeth in the elderly aged over 60 years was 3.4 (Salonen *et al*. 1989). In the Mini-Finland study (1978-1980), 33% of the dentate elderly had carious teeth (Vehkalahti *et al.* 1991). The prevalence of caries in the younger age groups has been in decline over the last decades, and this trend is continuing in the elderly of the future. (Nordling & Tala 1986, Bailit 1987, Tala 1992). However, as the number of teeth in the elderly increases, and as the prevalence of caries in all age groups has been observed to remain at about the same level (Douglass & Gammon 1985, Hugoson *et al*. 1986, Tervonen & Ainamo 1988, Vehkalahti *et al*. 1991), the number of filled teeth will increase with advancing age and cumulating caries experience (Banting 1984, Douglass & Gammon 1985, Hugoson *et al.* 1986, Hugoson *et al*. 1995, Joshi *et al*. 1996). In the older age groups having more teeth at risk, this has been observed to lead to increase in caries (Nordenram & Böhlin 1985, Vehkalahti *et al*. 1991, McGuire *et al*. 1993).

Secondary caries and root caries are more prevalent in the elderly than in younger age groups: secondary caries because of often numerous, extensive and deteriorating fillings, and root caries because of exposed root surfaces due to advanced periodontal disease (Banting 1984, Nordström *et al.* 1995). In the late eighties, in New England, USA, the percentage of dentate subjects aged 70 years or more and having coronal caries was 34% in men and 28% in women. 22% of the subjects had root caries. (Douglass *et al.* 1993). In the international statistical study of Ettinger (1993), 28% of the subjects exhibited coronal caries, and 34% root caries. Regular dental care is thus necessary to keep the prevalence of caries in the elderly at the same level as in the younger age groups. This leads to an increase in the need for treatment and preventive care. As the dental care utilization patterns learned earlier in life tend to continue in old age, the demand for such services will also increase (Bomberg & Ernst 1986). There is also a need to identify the risk groups and to allocate the dental services accordingly. This is reflected in the uneven distribution of carious teeth in the present series: 62% of the carious teeth were found in 24% of the study population. This may indicate differences between the subjects in their oral health care habits and professional dental care utilization, as well as possible deterioration of the general health status, manifesting as disabilities in daily life, including oral hygiene.

The importance of treating carious teeth lies not only in the patient discomfort caused by toothache or possible tooth loss, but also in the potentially hazardous effects of caries sequelae: apical periodontitis lesions. These are among the oral infectious foci that may cause serious and even fatal systemic manifestations and aggravate some diseases (Syrjänen *et al.* 1989, Valtonen 1991, Rams & Slots 1992, Mattila 1993, Nieminen *et al.* 1993, DeStefano *et al.* 1993, Navazesh & Mulligan 1995, Beck *et al.* 1996, Grau *et al.* 1997, Garcia *et al.* 1998). Carious teeth also harbour plaque, and the oral bacteria from dental plaque or the respiratory pathogens colonizing it may cause aspiration pneumonia, a major cause of death in the frail elderly (Greenberg *et al.* 1982, Limeback 1988, Rams & Slots 1992, Christensen *et al.* 1993, Finegold *et al.* 1993, Scannapieco *et al.* 1992, Scannapieco & Mylotte 1996, Fourrier *et al.* 1998).

6.3.2.2. Endodontically treated teeth

The prevalence of endodontically treated teeth, whether rootfilled or with pulp amputation, has been 0.9 to 3.5 such teeth per subject, corresponding to 4 - 15% of remaining teeth in Scandinavian, German, Dutch, and American general population studies including younger subjects (Eriksen 1991, De Cleen *et al.* 1993, Buckley & Spangberg 1995, Weiger *et al.* 1997). The mean number of endodontically treated teeth per subject in the present dentate study group was 2.9, (3.4 in men, and 2.8 in women), representing 21% of the remaining teeth. In the older population groups the proportion of endodontically treated teeth has been found to exceed 20% after 60 years of age, approaching 25% at the age of 70 years (Eriksen 1991). In subjects aged 80 years or older, 27% of the teeth have been observed to be endodontically treated (Ödesjö *et al.* 1990). This resembles closely the findings of the present study: the percentage of endodontically treated teeth increased from 19% in the 76-year-olds, to 23% in the 80-

year-olds, reaching 26% in the 86-year-olds. This gradual increase both in the number of endodontically treated teeth and in their proportion out of the remaining teeth is caused by cumulating caries experience, attrition, trauma and loss of teeth (Bergenholz *et al.* 1973a, Hugoson & Koch 1979, Laurell *et al.* 1983, Hugoson *et al*. 1986, Bergström *et al.* 1987, Ödesjö *et al*. 1990, Eriksen 1991). Endodontically treated teeth might also be retained longer, as they do not cause symptoms when affected by advanced caries.

Pulp amputations comprise only 5-6% of the endodontic treatments of adults in Sweden (Bergenholz *et al*. 1973a, Ödesjö *et al*. 1990). In the present dentate population only 0.5% of the teeth were amputated, representing 3% of the endodontic treatments observed.

Women have usually had more endodontically treated teeth than men (mean 2.2 - 1.1, respectively) (Lysell 1977), and the proportion of endodontically treated teeth out of the remaining teeth has been found to be 5% higher in women than in men (Allard & Palmqvist 1986). This is contrary to what was observed in the present study group, where men had an average of 3.4 endodontically treated teeth and women 2.8. This may be due to chance, or the fact that these men were very old and had a relatively high number of remaining teeth, or that the men may just have visited the dentist "at a later stage" than women, because of toothache or other symptoms, resulting in more endodontically treated teeth.

The prevalence of rootfillings judged radiographically to be of unacceptable quality has been quite high in several studies. De Cleen (1993) found 50% of the rootfillings to be inadequate in Dutch subjects, Buckley & Spanberg (1995) in the USA regarded 58% of the root canal obturations unsatisfactory, and Weiger *et al*. (1997) in Germany, judged 86% of the rootfillings substandard. In Scandinavian studies, the percentage of unacceptable rootfillings has ranged from 84% (Ödesjö *et al*. 1990) to 38.5% (Bergström *et al*. 1987). 75% of the rootfillings in the present dentate subjects were judged to be inadequate, which is within the range of the previous Scandinavian studies, although relatively high.

In three Scandinavian studies, 9-10% of the root canal fillings have projected over the radiographically discernible apex (overfills), 39-50% have been 2mm or more short of apex (underfills) and 43-70% have been judged to be of inadequate density (Bergenholz *et al*. 1973b, Eckerbom *et al*. 1989, Ödesjö *et al.* 1990). In our series of the 507 endodontically treated teeth, 100 (20%) were underfilled, 2 mm or more short of the radiographically discernible apex, 45 (9%) were of inadequate density, 91 (18%) exhibited both underfill and inadequate density, 16 (3%) were overfilled, 67 (13%) multi-rooted teeth had one or more unfilled roots (including the few pulp amputations, as these cannot be reliably discerned from each other), and in 60 (12%) teeth a root canal screw or a post was present but unaccompanied by a radiographically visible rootfilling. The percentages of overfills and the inadequate densities were lower in our material than in the previous Scandinavian studies, while the percentage of underfills was of similar magnitude, if unfilled roots and root canal screws or posts without a rootfilling are included in this category. The subjects in the present study were, however, very much older than the subjects in the previous endodontic studies on an average. It is therefore likely that the teeth in which the symptoms had not abated had been re-treated or extracted in the present subjects, resulting in a cumulative over-representation of

successful endodontic treatments with advancing age. This may also have resulted in a selective elimination of those technical failures that carry the poorest success rates: overfills and inadequate densities.

The success rate of endodontic treatment (whether or not the apical periodontitis lesion heals and/or the symptoms disappear) is related to the quality of the root canal obturation and the eradication of the pathogens present. Apical periodontitis lesions have been found in 50-74% of roots with overfills, 9-25% of roots with underfills, 29-58% of fillings of inadequate density, and 7-16% of technically adequate rootfillings. (Bergenholz *et al*. 1973b, Petersson *et al*. 1986, Bergström *et al*. 1987, Ödesjö *et al*. 1990).

6.3.3. Periapical findings

As the number of endodontically treated teeth and their proportion out of the remaining teeth increase with age, so does the prevalence of apical periodontitis lesions because of the cumulating oral disease experience (Bergenholz *et al*. 1973, Laurell *et al*. 1983, Hugoson *et al*. 1986, Bergström *et al*. 1987, Eriksen 1991). The number of subjects with many periapical lesions also increases with advancing age (Laurell *et al*. 1983). The mean number of apical periodontitis lesions per subject has been 0.4 - 1.6% in Scandinavian general population studies, corresponding to 1.5 - 6.3 of the remaining teeth. In the elderly, the proportion of the remaining teeth with periapical lesions has been observed to increase to 9 - 16%, and 66 - 72% of the subjects have had periapical lesions. (Lysell 1977, Laurell *et al*. 1983, Allard & Palmqvist 1986, Eriksen 1991).

Periapical radiolucent lesions indicating apical periodontitis were found in 70 of the 169 dentate subjects (41%). Additionally, one clinically edentulous male subject had two radiolucent lesions at the apexes of two submucosal roots, both judged as apical periodontitis. The mean number of periapical lesions per subject was 1.0, and periapical radiolucent lesions were found in 7% of all teeth studied. In twelve dentate subjects (7%) periapical lesions judged as radicular cysts by their shape and size were observed. These figures, although high, are slightly lower than those in the previous Scandinavian studies of the elderly, and can be interpreted as an indicator of their utilization of professional dental care with widespread use of dental radiography, the only method by which these lesions can be detected in normal dental practice.

Men have been observed to have slightly more periapical lesions than women, with means of 2.1 and 1.4 for such teeth, respectively (Lysell 1977), though Allard & Palmqvist (1986) found no difference between the sexes. In the present dentate study group, periapical radiolucencies were more common in men than in women, with an average of 1.8 and 0.9 such teeth, respectively. (II, Table 3).

The prevalence of apical periodontitis lesions is higher in endodontically treated teeth than in the other teeth. In various studies, 29 - 70% of endodontically treated teeth have exhibited periapical lesions, whereas the lesion prevalence in non-endodontically treated teeth has been 2.4 - 5.2% (Laurell *et al*. 1983, Petersson *et al*. 1986, Hugoson *et al*. 1986, Bergström *et al*. 1987, Bergenholz *et al*. 1973a&b, Ödesjö 1990, Eriksen 1991, De Cleen *et al*. 1993, Buckley & Spangberg 1995, Weiger *et al*. 1997). In the present study, too, periapical radiolucencies were observed more often in endodontically treated teeth, 17%

of which exhibited periapical lesions. Only 4% of the other teeth had periapical lesions. The present low prevalence of periapical radiolucencies in endodontically treated teeth compared to the previous studies, can be best explained by the cumulative over-representation of successful endodontic treatments, as the failures are most probably selectively eliminated over advancing age. Moreover, the prevalence of periapical radiolucencies in non-endodontically treated teeth falls within the range of the earlier Scandinavian studies, being on the high side, which gives even more credibility to this explanation.

Although men did not have significantly more endodontically treated teeth, they had significantly more periapical radiolucent lesions in endodontically treated teeth than women. Men also had more periapical radiolucent lesions in teeth that were not endodontically treated. That men had more periapical lesions in non-endodontically treated teeth and more carious teeth and carious roots than women, indicates poorer oral hygiene and less frequent visits to the dentist, perhaps only when unbearable symptoms have appeared. It is therefore likely that the state of men's teeth at the initial stage of treatment has been more unfavourable in view of successful endodontic therapy than that in women. The initial state of the tooth affects the success rate of endodontic treatment: if there is a radiolucent periapical lesion present at the beginning of endodontic treatment, the success rates are 68-84%, as compared to the overall success rates of 88-91% (Grahnen &Hansson 1961, Kerekes &Tronstadt 1979, Molven & Halse 1988). This may explain the higher prevalence of periapical lesions in the endodontically treated teeth of men.

Periapical radiopaque findings also exist: some of them are of infectious origin, involving condensing osteitis and its remnants as "scars" remaining in the bony structure after the original infection has abated. Harmless opaque findings sometimes seen in the periapical region or projecting on it in radiographs include enostoses and various cemento-osseous lesions such as periapical cemental dysplasia. Condensing osteitis has been found in 1.4% around endodontically treated roots (Bergman *et al.* 1979). This can be considered to be in accordance with the present study, where condensing osteitis was observed around 1.5% of all teeth. The prevalence of findings diagnosed radiographically as enostoses is about 5% in Europeans, and about 10% in mongolidic populations (Shafer *et al*. 1974, Austin & Moule 1984, Geist & Katz 1990, Kawai *et al.* 1992). In the present dentate subjects, condensing osteitis was found in 18% of the subjects, 12 women (10%) and 19 men (35%), while one woman had a finding judged as a small cemento-osseous lesion, and findings judged as enostoses were found in 9% of the subjects, 9 women (8%), and 6 men (11%). In the edentulous subjects, one man had condensing osteitis around an apical periodontitis lesion in a submucosal root, two women had findings interpreted as small cemento-osseous lesions, and findings judged as enostoses were found in 10% of the subjects, 11 women (12%) and 2 men (6%).

The prevalence of enostoses in the present population seems, at the first glance, to be rather high for Europeans. However, in the edentulous subjects and in the edentulous regions of the dentate subject's jaws, remnants of condensing osteitis cannot be reliably differentiated from enostoses, which may have resulted in higher prevalence figures than might be found in Finnish subjects with full dentition. But a possible racial influence cannot fully be ruled out, since the prevalence of enostoses in the edentulous and the dentate groups is of the same magnitude.

Periapical periodontitis lesions have long been considered one of the most important oral intraosseous foci of infection. They can be dangerous or fatal even to young subjects by direct or hematogenous spread of infection to vital areas and organs (Äyräpää 1902, Moncada *et al*. 1978, Syrjänen *et al*. 1989, Valtonen 1991, Garatea-Grego & Gay-Escoda 1991, Rams and Slots 1992, Mattila 1993, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Navazesh and Mulligan 1995, Beck *et al*. 1996, Grau *et al*. 1997). Therefore, these lesions should be adequately diagnosed and treated also in the elderly.

6.3.4. Periodontal findings

Ageing itself does not cause periodontal attachment loss (Papapanou *et al*. 1991, Wennström *et al*. 1993, Burt 1994). However, the lifetime periodontitis experience is cumulative. The increase in the prevalence of periodontal disease with advancing age is a well-documented fact observed in a multitude of studies (Black 1917, Marshall-Day & Shourie 1949, Marshall-Day *et al*. l955, Hugoson & Jordan 1982, Halling & Björn 1986, Miller *et al*. 1987, Papapanou *et al*. 1988, Jenkins & Kinane 1989, Brown *et al*. 1989, Wouters *et al*. 1989, Albandar 1990, Beck *et al*. 1990, Todd & Lader 1991, Hugoson *et al*. 1992). Bone loss has been found to increase with advancing age in both cross-sectional (Fox *et al*. l994) and longitudinal studies (Papapanou *et al*. 1989, Hugoson *et al*. 1992). In one longitudinal study, however, a slightly slower progression of bone loss was described at old than at young age (Albandar 1990). Nevertheless, in most general population studies the number of the "old elderly", those aged 75 years or more, has been small, and their number of remaining teeth limited. The observed high prevalence of periodontal disease in the elderly might thus also be explained by cumulative disease experience or by cohort differences (Albandar 1990, Papapanou *et al*. 1991, Hugoson *et al*. 1992, Wennström *et al*. 1993, Burt 1994, Fox *et al*. l994, Joshi *et al*. 1996). In previous general population studies, men have usually had more periodontal breakdown than women (Miller *et al*. 1987, Papapanou *et al*. 1988, Wouters *et al*. 1989, Hunt *et al*. 1990, Fox *et al*. 1994, Diamanti-Kipioti *et al*. 1995). In the present 169 dentate subjects, the differences in the prevalence of periodontitis-associated radiographic findings (vertical infrabony pockets, horizontal bone loss, furcation involvements) between the three age groups or between the sexes were small, and can be explained by men having more teeth, particularly molars, than women. The results can be interpreted as indicating the relative homogeneity of the present study group and similar levels of periodontitis progression in men and women in all the three age groups.

Different teeth are affected by bone loss according to their location in the mouth and are lost in a certain sequence. (Marshall-Day & Shourie 1949, Marshall-Day *et al*. 1955, Albandar *et al*. 1987, Papapanou *et al*. 1988, Brown *et al*. 1989, Papapanou *et al*. 1989, Wouters *et al*. 1989, Albandar 1990, Wennström *et al*. 1993). The patterns of bone loss have shown only a little variation in most general population studies. Infrabony pockets and bone loss have been most prevalent in molars, followed by premolars, and least prevalent in incisors and canines, especially lower incisors. This follows closely the overall pattern of tooth loss reported in several studies. (Roper *et al*. 1972, Becker *et al*. 1979, McFall 1982, Goldman *et al*. 1986, Miller *et al*. 1987, Palmqvist & Sjödin 1987,

Linden 1988, Papapanou *et al*. 1988, Chauncey *et al*. 1989, Wood *et al*. 1989, Todd & Lader 1991, Chace & Low 1993). A similar pattern of infrabony pockets and missing teeth was also found in the present study: molars had the highest and premolars the second highest prevalence of infrabony pockets, followed by canines and incisors (Fig. 8, IV).

However, in a few studies almost an opposite pattern of affected teeth has been observed. In the study by Marshall-Day & Shourie (1949) from India, the lower molar region was the most heavily affected area, closely followed by lower incisors and upper incisors, lower bicuspids being most resistant to bone loss. Ainamo and Tammisalo (1970) reported bone loss extending to the apex in 16-19% of upper molars and in 12% of lower central incisors in their series of 100 patients (aged 21 to 64 years), who had all sought dental care for their periodontal problems. The subjects in these studies may have suffered from a more rapidly advancing form of periodontitis; otherwise their results are difficult to explain.

Severe periodontal disease was very common in all adult age groups at the beginning of the century and up to the forties and fifties (Black 1917, Marshall-Day & Shourie 1949, Marshall-Day *et al*. l955). More recent studies in the western countries have shown a change in the distribution of periodontal disease at the population level: advanced bone loss is now virtually nonexistent below the age of 35, and infrabony pockets or furcation lesions are rarely found in subjects aged under 40. (Miller *et al*. 1987, Linden 1988, Papapanou *et al*. 1988, Brown *et al*. 1989, Hugoson *et al*. 1992). Moreover, advanced periodontal disease is distributed unevenly among the population, even in old age groups (Halling & Björn 1986, Miller *et al*. 1987, Okamoto *et al*. 1988, Papapanou *et al*. 1988, Brown *et al*. 1989, Jenkins & Kinane 1989, Beck *et al*. 1990, Hunt *et al*. 1990, Todd & Lader 1991, Diamanti-Kipioti *et al*. 1995). This minority experiencing advanced bone loss, however, increases with advancing age, so that at 60 years of age about 30% of subjects have 75% of the advanced bone loss in their age cohort (6 mm or more, Papapanou *et al*. 1988, 7 mm or more, Baelum *et al*. 1986 & 1988, >50% attachment lost) (Jenkins & Kinane 1989). Horizontal or vertical alveolar bone loss measured at the site where it was most advanced was also common among the present dentate study population. Only eight subjects (5%) were considered not to have any radiographically observable bone loss. This periodontal breakdown was judged as slight in 30 subjects (18%), moderate in 53 subjects (31%), and advanced or extreme in 78 subjects (46%). 88 subjects (52%) had infrabony pockets, 55% of the men and 50% of the women. However, the advanced bone loss was usually localized at a few sites in the mouth: of all the 2,355 teeth studied, 11% were affected by periodontal breakdown, but only 4% exhibited advanced or extreme bone loss (Fig. 8, IV). This shows clearly the effect of how the use of different indicators of periodontal disease severity affects the study results. High prevalences of advanced bone loss are obtained by recording the site where the bone loss is most advanced or by using a few indicator teeth of which the most diseased site is taken as the treatment need indicator (e.g. CPITN-index), whereas low prevalences are obtained by recording periodontal breakdown at as many sites as possible.

Of the present subjects, 40% had calculus sufficient to be visible radiographically, which may reflect their dental care utilization and oral hygiene habits. Although these were considered fairly adequate in view of their caries and periodontitis lesion prevalences, they might, on the basis of this finding, be considered as somewhat negligent

in this respect after all. Calculus has radiographically been observed in the Swedish general population on average at 19% of the interproximal sites. (Wouters *et al* 1993). As only rather substantial amounts of calculus are radiographically visible, clinical examinations reveal much higher prevalences of calculus, as in the New England Elderly Study, where 93% of the men and 86% of the women aged 70-96 years had calculus (Fox *et al*. 1994). As plaque retention sites, restoration overhangs and calculus have a local detrimental influence on alveolar bone level (Hakkarainen & Ainamo 1980, Albandar *et al*. 1987). However, in a previous study, calculus, age, gingivitis, gingival recession, debris and the depth of periodontal pockets did not correlate in any way in a patient series with an age range from 70 to 94 years (Roper *et al*. 1972). The presence of calculus did not correlate with the radiographic signs of periodontitis in the present study, either, but the presence of interproximal restoration overhangs was associated with the number of infrabony pockets and furcation lesions.

An increase in the number of dentate elderly with more remaining teeth present, leads to more teeth at risk for periodontal disease. In the USA in the sixties and seventies, an increase in the number of remaining teeth in the elderly aged 65-74 years led to an increase of subjects with periodontal pockets from 46% to 51%. However, the proportion of subjects free from periodontal disease also increased from 10% to 36% in the same group. (Douglass *et al*. 1983). An increase in the number of the dentate elderly in the county of Jönköping, Sweden, during 1973-1983 led to a dramatic increase in the proportion of subjects having severe bone loss, in 70-year-olds from 6% to 42% (Hugoson *et al*. 1992). Fox *et al*. (1994) showed that elderly subjects with both arches dentate had more of both moderate and severe pocketing than those with one dentate arch only. In the New England Elder Dental Study, USA, pocket depth and loss of attachment increased as the number of teeth increased (Joshi *et al*. 1996). In the present study, teeth with vertical infrabony pockets were found in 51% of the subjects and teeth exhibiting furcation lesions (furcation involvements) were found in 28% of the subjects. These figures are in accordance with the recent western and Scandinavian findings on home-living elderly. Results indicating that the more teeth present the better, in fact, is the periodontal condition have also been presented (Palmqvist & Sjödin 1987, Jenkins & Kinane 1989, Burt 1994, Diamanti-Kipioti *et al*. 1995). Only slight attachment loss has been observed in these groups practicing good oral hygiene (Papapanou *et al*. 1991, Wennström *et al*. 1993, Serino *et al*. 1994, Beck & Koch 1994). These subjects with so called "successfully ageing dentitions" also utilize dental services more than their less successful counterparts (Joshi *et al*. 1996). Halling & Björn (1986) in a material of 862 women aged 38-60 years living in Gothenburg, Sweden, found little or no progression of bone loss in 83% of the subjects, as well as an increase in the number of retained teeth over a follow-up period of 12 years (1968-1980). During this period there was an increase in the availability of dental services in Sweden, and general dental health insurance system was instituted (Halling & Björn 1986). That in about the same period subjects with severe bone loss increased in the county of Jönköping, Sweden, might indicate that the city-living women of Gothenburg, Sweden, had a better periodontal status to start with. These results may indicate that an increase in the professional health care services may be necessary to maintain the periodontal health state in the elderly at an acceptable

level. As advanced periodontal disease seems to affect relatively limited risk groups of the population, and to be usually limited to a few sites in the mouth, there exists also a need to aim the dental services accordingly.

Periodontitis is a major cause of tooth loss and dental invalidity in the elderly, which alone is a sufficient reason for its prevention and treatment. But during the past decade, reports indicating its possible associations with life-threatening conditions have been emerging. Periodontitis has been associated with an increased risk of cerebrovascular ischemia, heart attacks and an increased risk of death. In essence, periodontal pockets, furcation lesions and the whole infected periodontal soft tissue surface can be counted as oral infectious foci (Syrjänen *et al*. 1989, Valtonen 1991, Rams & Slots 1992, Mattila 1993, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Navazesh & Mulligan 1995, Beck *et al*. 1996, Grau *et al*. 1997, Garcia *et al*. 1998). Subsequently, proper periodontal treatment and good oral hygiene are also essential in the elderly.

6.3.5. Condylar findings

The adaptive or degenerative changes in the temporomandibular joints are caused by mechanical stress from mastication and parafunctions of the masticatory apparatus such as bruxism over an extended period of time. This results in remodelling of the joint surfaces manifesting as osseous changes in the condylar head and the eminentia. Such changes may affect any joint in the body, not only the temporomandibular joints. (Sokoloff 1980, Muir & Goss 1990a, Muir & Goss 1990b, Sato *et al*. 1996). The findings related to this remodelling that are visible in radiographs of the temporomandibular joints are subchondral sclerosis, flattening of the articular surfaces both in the eminentia and in the condylar head, osteophyte formation and erosions (Muir & Goss 1990a, Muir & Goss 1990b, Gynther *et al*. 1996, Sato *et al*. 1996). Radiographically these signs are identical to and indistinguishable from those associated with osteoarthrosis (Kopp & Rockler 1979, Altman *et al*. 1986, Gynther *et al*. 1996). The presence of erosion may also indicate to arthritis in progress (Könönen & Kilpinen 1990, Gynther *et al*. 1996).

Condylar radiographic findings increase with advancing age (Sokoloff 1980, Ishibashi *et al*. 1995, Sakurai & Mizokami 1997). Although the condylar heads in the elderly may often be grossly deformed and flattened, as was often the case in the present study, the subjective TMJ symptoms tend to abate with age (Österberg *et al*. 1992, Koidis *et al*. 1993), which emphasises the adaptive nature of this process, which frequently may appear as highly pathologic in radiographs.

The prevalences of adaptive or degenerative radiographic condylar findings in elderly populations have varied from 13 to 26% per subject in several previous studies made with panoramic radiography, conventional plain-film projections or tomography (Lysell 1977, Mäkilä *et al*. 1980, Sato *et al*. 1996, Soikkonen *et al*. 1996). Aberrant prevalences of condylar findings have also been reported: 2.5% of the subjects in panoramic radiographs (Keur *et al*. 1987), and 71% of the subjects in condylar zonographs (Sakurai & Mizokami 1997). The most common finding has been flattening of the articular surface and the

condylar head (9-11% of the subjects), followed by osteophytes (3-12% of the subjects), erosion (3-8% of the subjects), and sclerosis (3-7% of the subjects) (Lysell 1977, Mäkilä *et al*. 1980, Sato *et al*. 1996).

In the present study, deviations from the normal condylar shape and structure were found in 21 of the 124 edentulous subjects (17%). Twenty subjects (16%) had condylar changes related to osteoarthrosis. One edentulous man had a deformed condyle, probably due to an old fracture. Forty-two of the dentate 169 subjects (25%) had condylar changes related to osteoarthrosis (Soikkonen *et al.* 1996). These prevalences fall within the range of radiographic condylar findings previously reported in elderly populations.

These condylar findings have usually been more prevalent in women than in men, but the difference between the sexes has ever been slight and not always statistically significant (Mäkilä *et al*. 1980, Sato *et al*. 1996, Soikkonen *et al*. 1996). In the present edentulous subjects, condylar findings were more common in women (19%) than in men (13%), but in the dentate subjects the difference between the sexes was statistically insignificant, which results are also in accordance with the previous studies. No statistically significant differences between the age groups were found among either the edentulous or th dentate subjects (Soikkonen *et al*. 1996).

According to the recent studies, edentulism or partial occlusal support does not seem to have an effect upon the prevalence of radiographic condylar findings (Sato *et al*. 1996, Soikkonen *et al*. 1996).

6.3.6. Findings in maxillary sinuses

The main maxillary sinus findings recorded in the present study were mucous cysts and mucosal thickenings. Two kinds of mucous cysts with similar radiographic appearance occur in the maxillary sinus: a well-defined "dome-shaped" uniform radiopacity rising from the floor or wall of the sinus (Allard & van der Kwast 1981, Goaz & White 1994). Mucous retention cysts are caused by an occlusion in the duct of a seromucinous gland (Lindsay 1942, Schuknecht & Lindsay 1949, Paparella 1963, Allard & van der Kwast 1981, Gardner 1984, Goaz & White 1994), while pseudocysts are caused by inflammatory exudate pooling above the periostium (McGregor 1928, Lindsay 1942, Schuknecht & Lindsay 1949, Allard & van der Kwast 1981, Goaz & White 1994). True retention cysts, however, seldom become large enough to be visible radiographically (Paparella 1963, Gardner 1984). Mucosal thickenings, on the other hand, appear as diffuse, often polypous and irregular radiopacities along the margins of the sinus. (Killey & Kay 1970, Kwapis & Whitten 1971)

Previous radiographic studies of mucous cysts of the maxillary sinuses in both dentate and edentulous subjects have reported prevalence figures ranging from 2 to 13% (Ibsen 1945, Wright 1946, Kivimäki & Ekholm 1961, Myrhaug 1962, Mattila 1965, Lilly *et al.* 1967, Myall *et al*. 1974, Ohba & Manson-Hing 1975, Allard & van der Kwast 1981, MacDonald-Jankowski 1993, McGowan *et al*. 1993, Goaz & White 1994). Mucosal thickenings are more common, as figures up to 50% of incidental radiographic findings (mucous cysts included) in the paranasal sinuses have been reported (Wilson & Grogutt 1990). Mucosal thickenings are most common in the maxillary sinuses (Cooke & Hadley

1991). In previous studies on edentulous subjects only, the prevalences of mucous cysts and mucosal thickenings together have ranged from 2 to 20% (Tronje *et al*. 1980, Keur *et al*. 1987). Such maxillary sinus findings were found in eight of the 124 edentulous subjects (6%), and the prevalences are lower than those reported previously. In four subjects the findings were interpreted as mucous cysts, and in the other four as mucosal thickenings. Two maxillary sinus findings of bone-like opacity, judged radiographically as small osteomas or dislodged ankylosed root remains, were found in two of the 124 edentulous subjects (1%). Maxillary sinus findings were found in twenty-nine of the dentate 169 subjects (17%), which is slightly higher prevalence compared to the previous studies using mixed samples of both dentate and edentulous subjects. In ten of the present dentate subjects the findings were judged as mucous cysts and in nineteen subjects as more diffuse mucosal thickenings (Soikkonen & Ainamo 1995). According to Mattila (1965), age plays no part in the occurrence of mucous cysts and, indeed, the prevalences of mucous cysts and mucosal thickenings in the elderly fall within the ranges found in previous general population studies including younger age groups (Soikkonen & Ainamo 1995). Mucous cysts have usually been most prevalent in the third decade, and more prevalent in men than in women (Allard & van der Kwast 1981, McGowan *et al*. 1993, Goaz & White 1994). In the present study, no statistically significant differences in the prevalences of mucous cysts or mucosal swellings were found between the sexes or age groups, indicating diminishing differences between the sexes over age in this respect, too.

However, the maxillary sinus findings were more common in the dentate than edentulous subjects (Soikkonen & Ainamo 1995), and 71% of the mucous cysts and 83% of the mucosal thickenings were found in dentate subjects. Odontogenic infections in the upper jaw, such as periodontitis or apical periodontitis lesions, may encroach upon the maxillary sinus and cause mucosal swelling or sinusitis (Falk *et al*. 1986). Odontogenic sinusitis accounts for 5 - 45 % of all sinusitides (McGowan *et al*. 1993, Abrahams & Glassberg 1996). It involves a local spread of an odontogenic infection and, as it is well known, sinusitis may cause systemic manifestations (fever, cough, local pain, etc.). No obvious sinusitides were found in the present subject's panoramic radiographs. However, 70% of the diffuse mucosal thickenings were found in subjects with at least one maxillary tooth left. This indicates a possible odontogenic causative factor in about 40% of the present cases of mucosal thickenings, as by this figure their prevalence in the subjects with a dentate maxilla exceeded that of the subjects with an an edentulous upper jaw. Further confirmation for this explanation is obtained from the prevalence of mucous cysts, which was 5% regardless of the dentition of the upper jaw, indicating that odontogenic factors play an insignificant role in their formation (Soikkonen & Ainamo 1995).

6.3.7. Other findings

The prevalence of cysts in oral radiographic studies has varied from 1% to 9% of the subjects (Carlsson 1959, Wolf 1969, Lysell 1977, Perrelet *et al*. 1977, Mäkilä 1979, Axelsson 1988). In oral biopsy studies, the most prevalent cysts have been radicular and

residual cysts (over 50% of all cysts), followed by the follicular (dentigerous) cyst (about 20%). The most common non-odontogenic cyst has been the nasopalatine duct cyst (3%). (Kreidler *et al*. 1993, Daley *et al*. 1994).

Radiolucent findings diagnosed as cysts were found in three of the 124 edentulous subjects (2.4%). Radiographically two of these were diagnosed as residual cysts and one as a nasopalatine duct cyst. Cysts other than radicular cysts that were observed in the 169 dentate subjects included three residual cysts in one subject and a follicular cyst in one subject. In the present dentate subjects, radicular cysts comprised 75%, residual cysts 19% and follicular cysts 6% of the cysts observed in this group. The number of cysts was so low that chance obviously distorts somewhat the prevalences compared to the previous studies.

Three sialoliths were found in three edentulous women (2.4% of the edentulous subjects, 1% of the whole series). One was located in the duct of the right parotid gland, and two in the duct of the left submandibular gland. The prevalence of sialoliths was 1.3% of the subjects studied by Axelsson (1988), and our figure is of the same magnitude.

The prevalence of tumours in oral radiographic studies has been low, 0.3-0.6% of the subjects (Wolf 1969, Perrelet *et al*. 1977). The most common tumours in oral biopsy studies have been odontomas representing over 50% of odontogenic tumours, compound odontoma being more common than complex odontoma (Daley *et al*. 1994, Owens *et al.* 1997). In the present study, tumours were also comparatively rare (0.7% of the whole series). One large opaque finding judged to be a complex odontoma associated with an unerupted lower third molar was found in one dentate man, and one suspected benign-looking parotid tumour was found in one dentate woman by sialography.

Foreign bodies, such as amalgam fragments, broken instrument tips and bullet fragments have been found in oral radiographic studies in 0.4-9% of the subjects (Carlsson 1959, Wolf 1969, Lysell 1977, Perrelet *et al.* 1977, Jones *et al*. 1985, Axelsson 1988). In the present study, foreign bodies were found in 6 dentate (4%) and in 3 edentulous subjects (2.4%), which prevalences fall within the range of the previous studies. In addition, one edentulous woman had four dental implants in the lower anterior area. The foreign bodies included amalgam fragments in three subjects, particles of retrograde fillings in the apical areas of resected teeth in two subjects, and possible war-time remnants in four men (located near the zygomatic arch, behind the condyle, at the tip of the lower jaw and at the lower border of the mandible).

6.4. Oral foci and their effect on general health and the death risk

A local infectious lesion that may cause pathologic changes elsewhere in the body, even in organs situated far from the original site of infection, is called an infectious focus. In oral radiographs, intrabony foci, such as periapical periodontitis lesions, vertical bone loss defects and furcation lesions, can be detected, but no foci that involve soft tissue only. The noxious effect of oral infections upon the general health status and their associations with general diseases have been observed and suspected since the beginning of this century (Äyräpää 1902). There are several known mechanisms whereby an infectious focus can cause damage at distant sites, but some unknown ones may still

exist. A periapical periodontitis lesion in a lower molar can perforate the mandibular lingual cortical bone, with pus oozing into the floor of the mouth under m. mylohyoideus and into the mediastinum, resulting in Ludwig's angina, a life-threatening condition even nowadays (Äyräpää 1902, Moncada *et al*. 1978, Garatea-Grego & Gay-Escoda 1991). Dental plaque may be aspirated, and oral bacteria (especially anaerobic periodontopathogens) can in this way cause pneumonia. This is a special hazard to institutionalized or hospitalized elderly in a poor state of health or to immunosuppressed patients (Greenberg *et al*. 1982, Limeback 1988, Rams & Slots 1992, Christensen *et al*. 1993, Finegold *et al*. 1993). Non-oral respiratory pathogens are also able to colonize dental plaque, which then acts as a reservoir of these bacteria, seeding them to the lungs. (Scannapieco *et al*. 1992, Scannapieco and Mylotte 1996, Fourrier *et al*. 1998). Bacteria themselves may pass into the bloodstream from oral foci, and they have been found to cause very serious infections, such as endocarditis, pyelonephritis and brain abscessses (Rams & Slots 1992, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Navazesh & Mulligan 1995, Beck *et al*. 1996, Grau *et al*. 1997, Meurman 1997). The bacteria themselves need not even leave the foci to be detrimental for general health. Their toxins circulating in blood may cause fever, often termed in the medical practice as "fever of unknown origin", for the causative focus itself may be completely asymptomatic (Katz *et al*. 1992, Rams & Slots 1992). A similar phenomenon is "metastatic inflammation" manifesting most often in the eye as uveitis or iritis. It is caused by an overreactive immunologic host response against the bacteria present in the foci, bacterial parts, or bacterial toxins (Torabinejad *et al*. 1983, Kettering & Torabinejad 1984, Bloch-Michel 1985, Brummer & van Wyk 1987, Rams & Slots 1992). Elevated levels of IgE and an increased prevalence of systemic allergies have also been associated with the presence of periapical periodontitis lesions (Kettering & Torabinejad 1984, Brummer & van Wyk 1987). The presence of oral foci has been associated with an increased frequency of exacerbations in Crohn's disease (Halme *et al*. 1993). Furthermore, eradication of oral foci has been observed to ameliorate the symptoms of severe arthritis in some cases (Meurman 1997).

Oral infections, as well as other infections and inflammations have been associated with increased risk of myocardial infarction and brain infarction in young and middle-aged subjects (Syrjänen *et al*. 1989, Valtonen 1991, Mattila 1993, Nieminen *et al*. 1993, DeStefano *et al*. 1993, Beck *et al*. 1996, Grau *et al*. 1997). The exact pathogenic mechanism whereby the focal infections inflict their hazardous systemic effects on those conditions is still obscure. However, it has been suggested that infections and inflammations increase the blood leukocyte count, circulating fibrinogen and other blood coagulation factors, which, in turn, may lead to heart and brain infarctions. (Syrjänen *et al*. 1989, Valtonen 1991, Mattila 1993, Kweider *et al*. 1993, Beck *et al*. 1996, Meurman 1997). Bacterial lipopolysaccharide endotoxins and host-produced inflammatory cytokines may also play a role in the formation of atheromas and thus lead to infarctions (Loesche 1994, Herzberg & Meyer 1996, Beck *et al*. 1996, Meurman 1997). Myocardial infarction is a common cause of death, and an association between death from coronary heart disease and oral infections has been observed: Beck *et al*. (1996), in a study cohort of 1,147 men, aged 21 to 80 years at the baseline and followed up for 18 years, found mean radiographic periodontal attachment loss of more than 20% of the root length to be associated with a twofold increase in fatal heart attacks. The age-adjusted odds ratio was 2.2, the 95% confidence interval 1.3-3.9, and odds ratio adjusted for age, and known risk

factors for cardiovascular disease was 1.9, with a 95%, confidence interval of 1.1-3.4. Clinical probing depth was also associated with cardiovascular disease, as the percentage of all teeth having more than 3 mm probing depth showed an age-adjusted odds ratio of 3.6, the 95% confidence interval being 1.5-8.5, the highest risk ratio that has been observed between oral infections and cardiovascular disease (Beck *et al*. 1996).

DeStefano *et al*. (1993), also found an association between clinically diagnosed periodontal pockets and death risk (OR 1.5, confidence interval 1.3-1.7) in a sample of 9,760 subjects aged 25-74 years. This association was most pronounced in young and middle-aged men aged 25-49 years (OR 2.1, confidence interval 1.2-3.6). The number of carious teeth had no association with the risk of death. In addition, they found edentulism to be associated with increased death risk in young and middle-aged men (OR 2.6, confidence interval 1.3-5.1). The mortality rates in the edentulous and dentate groups in the present study did not differ (Table 4, V). This may reflect the homogeneity and relatively good state of health of the present study group as a whole. The effect of edentulism may, on the other hand, be most pronounced in younger subjects, or that some other factors, possibly ones related to life-style and socioeconomic status and leading to edentulism at young age, may also precipitate early death.

Garcia *et al*. (1998) found, in a sample of 804 dentate men (mean age 42 years), followed for over 25 years, that radiographically diagnosed mean alveolar bone loss and clinically diagnosed periodontal pockets had a statistically significant association with the death risk (OR 1.9, confidence interval 1.3-2.7 and OR 1.7, confidence interval 1.1-2.8, respectively). The number of remaining teeth had little effect on the death risk.

The mean alveolar bone loss in the previous studies can be compared with the extent of horizontal bone loss in the present study, OR 1.8, confidence interval 0.9-3.8, and the difference did not quite reach the 95% significance level, probably because of the limited sample size. In the present study, the number of carious teeth and the number of furcation lesions showed an inverse relationship to the risk of death, but it was not statistically significant. (V, Fig's 1 and 2, Table 5). In the present dentate study group, increased all-cause mortality was associated with periodontal infrabony extending to the middle third of the roots or deeper, age-and sex-adjusted OR 2.2, 95% confidence intervals 1.0-4.7, figures comparable with those observed in previous studies. Mortality was also slightly increased in the subjects who had 5-14 infrabony pockets, moderate to advanced horizontal bone loss, or apical periodontitis lesions, and along with the pooled sum of all the potentially infectious findings, but the 95% significance level was not attained, again most probably due to the limited sample size.

Of the present 293 radiographed subjects, 54 (18.4%) died within the four year follow-up, and 32 of them (59.3%) were dentate. The sample is thus very small for an epidemiological study of death risk, and one must be careful in making conclusions on the basis of the findings. However, it would be tempting to interpret the results of these previous studies and the present one as indicating a causal relationship between the observed oral findings and the increased death risk. But Joshipura *et al*. (1996) found no association between self-reported periodontal disease and coronary disease and sudden death in a sample of 44,119 male health professionals. The fact that no associations were found in this study may reflect the unreliability of the method used (self-reporting, a questionnaire study), or a possible influence of the selected study cohort. A causal relationship between oral infectious foci and death has been observed in cases where an

oral infection has directly spread into vital areas (Äyräpää 1902, Moncada *et al*. 1978, Garatea-Grelgo & Gay-Escoda 1991). Also, the poor oral hygiene and the resulting dental plaque accumulation in the hospitalized and institutionalized elderly in a poor general condition have been associated with aspiration pneumonia, and pneumonia is one of the most common causes of death in these groups (Greenberg *et al.* 1982, Limeback 1988, Rams & Slots 1992, Christensen *et al*. 1993, Finegold *et al*. 1993). Furthermore, there is another possible explanation for the association between the observed oral foci and clinical periodontal findings and the increased death risk in the elderly: the presence of clinically probed deepened periodontal pockets and radiographically observed infrabony pockets, horizontal bone loss and periapical periodontitis lesions may be indicators of deteriorated physical condition, manual dexterity or capacity to carry out adequate oral hygiene. Possible non-utilisation of professional dental services may also play a role in the development of oral foci in these elderly. The many diseases that the elderly suffer from and various medications they use may often cause hyposalivation, which negatively affects oral health (Närhi 1994, Pajukoski *et al*. 1997). Psychological factors caused by negative life-events may aggravate existing periodontitis. The effect of negative life-events on periodontitis may be due to less active oral hygiene, decreased salivary flow (caused by medication or the psychologic disturbance itself) or possible immunologic factors. Although tobacco smoking, a well-known risk factor for periodontitis (and cardiovascular disease), increased in association with negative life-events in one study, the association between negative life-events and periodontitis remained significant even after smoking was taken into account in the statistics. (Croucher *et al*. 1997). In elderly men, anxiety has been associated with fatal myocardial infarction (OR 3.2, 95% confidence interval 1.3-8.1) and sudden death (OR 5.7, 95% confidence interval 1.3-26.1) (Kawachi *et al.* 1994). Anger has also been associated with an increased risk of cardiovascular disease in elderly men (OR 3.2 for heart attack, 95% confidence interval 0.9-5.6) (Kawachi *et al*. 1996).

Deteriorated physical, cognitive and sensory functional capabilities go hand in hand with a poor functional dental status and an increased risk of death (Österberg *et al*. 1990). Deteriorated physical condition which manifests as various disabilities in daily life has, indeed, been found to be prognostic of death in an extensive follow-up study of community-dwelling elderly, of whom 531 died within one year (Guralnik *et al*. 1991). The deterioration of the dental status and the consequent loss of teeth has been found to be an indicator of deteriorating physical condition in a sample 1,029 75-year-olds from Finland, Denmark and Sweden (Österberg *et al.* 1995). Poor functional dental status was also associated with an impaired quality of life and increased death risk also in a population of 1,137 70- to 75-year-olds in Brescia, Italy (Appollonio *et al.* 1997).

Because of the complex interrelationships between the various risk factors and indicators of the increased mortality, it has not been possible to demonstrate absolutely certain causal relationships between oral infectious foci and death. However, the results of the studies so far undertaken strongly suggest that such causal connections may exist.

6.5. Reliability of the observations

The mean percentage of agreement in the intra-examiner variation (K.S.) was 96% (SD. 5%), while the mean percentage of agreement in the inter-examiner variation was 87% (SD. 9%). The Kappa-values ranged from 0.96 to 0.19 in the intra-examiner variation, and from 0.95 to 0.24 in the interexaminer variation (Dunn & Everitt 1995). (Tables 1 and 2). Kappa values under 0.4 represent poor agreement, those from 0.4 to 0.75 fair to good agreement, and values 0.75 and over represent excellent agreement (Landis & Koch 1977). As can be seen from Tables 1 and 2, percentual agreement can be 100%, but the Kappa value can still represent poor agreement: this is due to relative scarcity of some of the rarer findings in the re-examined radiographs, which the Kappa test takes into account. For the potentially infectious foci studied, the periapical periodontitis lesions, the number of teeth with infrabony pockets, the number of teeth with furcation involvements, the extent of horizontal bone loss and the extent of infrabony pockets, the intra-examiner Kappa values ranged from 0.58 to 0.96, which means that the results can be considered reliable in this respect (Table 6, V).

7. Conclusions

On the basis of this study, the following conclusions can be made:

1. The hypotheses of the descriptive part (I, II, III, IV) of this thesis were supported in part, but no major differences between the present assumably "hardy survivor" study group and comparable previous studies were found:
   - The dentate and healthier elderly may have been over-represented in the present study cohort.
   - Edentulism was less prevalent among the present subjects than in the previous Finnish studies, approaching the level of the other Scandinavian countries and the USA.
   - Compared with the previous studies in Finland, slightly more teeth and less tooth-associated pathology were seen in the present subjects. However, the cumulative disease experience with age had resulted in very many pathologic or degenerative findings. But in the contemporary Scandinavian studies, only slightly better oral health status in the elderly has been observed.
   - Men had more teeth, carious teeth, carious roots, periapical lesions, condensing osteitis and furcation lesions than women, indicating better oral hygiene and/or utilisation of dental services by women.
   - Periapical lesions were found in 17% of the rootfilled teeth, and 4% of the other teeth. 75% of the rootfillings were considered inadequate, exhibiting periapical lesions twice as often as the adequate ones. However, fewer periapical lesions were found in the present series in association with inadequate rootfillings than in the previous studies including younger subjects. This indicates selective removal of symptomatic failures.
   - Periodontal attachment loss was common, and only 5% of the dentate subjects were free from it. Advanced bone loss was observed in 46% of the subjects, and half of the dentate ones had infrabony pockets. However, advanced bone loss was usually restricted to a few sites, as only 4% of the teeth were affected by it. The pattern of teeth lost and the localisation of infrabony pockets followed the general patterns observed in several previous studies.
2. Slightly fewer periapical findings were found in the present study group in association with radiographically inadequate rootfillings than in the previous studies. This, together with the relative scarcity of endodontic technical failures that have the

poorest success rates, supports the hypothesis of cumulative over-representation of successful endodontic treatments over time regardless of their radiographically assessed technical quality.

3. The hypothesis that the presence of potentially infectious radiographic oral foci would increase all-cause mortality was also partially supported, as, during the four-year follow-up, mortality significantly increased in the subjects with moderate to advanced infrabony pockets, OR 2.2, 1.0-4.7. Mortality was also increased in association with periapical periodontitis (OR 2.0), moderate to advanced horizontal bone loss (OR 1.8) and the sum of the potentially infectious findings (OR 1.5), but the 95% significance level was not attained, probably because of the limited sample size. In some previous studies, similar associations between periodontitis and death risk have been found in larger study cohorts including younger subjects. Our results indicate that oral foci may be more dangerous in the elderly than it has been previously thought, or that their presence might indicate the general deterioration of health and manual dexterity prior to death observed in previous studies.

8. References

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