J Clin Periodontol 2006; 33: 376–384 doi: 10.1111/j.1600-051X.2006.00922.x

Journal of Clinical Periodontology

Periodontal disease in the oldest-old living in Kungsholmen, Sweden: findings from the KEOHS project

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Holm-Pedersen P, Russell SL, Avlund K, Viitanen M, Winblad B, Katz RV. Periodontal disease in the oldest-old living in Kungsholmen, Sweden: findings from the KEOHS project. J Clin Periodontol 2006; 33: 376–384. doi: 10.1111/j.1600-051X.2006.00922.x.

Abstract

Aims: The Kungsholmen Elders Oral Health Study evaluated the oral health status of generally healthy, community-dwelling persons aged 80 years and over living in Stockholm, Sweden. This paper reports periodontal disease findings and evaluates the distribution by sociodemographic factors.

Methods: Eligible persons were identified through the Kungsholmen Project, an ongoing, longitudinal, population-based study of older adults. A total of 121 study subjects received a periodontal examination.

Results: The mean pocket probing depth was 2.6 mm and the mean clinical attachment loss was 3.7 mm. Gingival bleeding was common. Over half of all study participants met the criteria used for ''serious periodontitis'' (SP). In the best fit adjusted odds ratio (OR) model, males were 3.1 times more likely than females to have ''SP'' (OR = 3.1, 95% CI 1.2, 8.0), a statistically significant observation. A sub-analysis of the differences in proportion of participants with SP revealed that the difference by sex also increased by age.

Conclusions: These findings document the substantial and ongoing impact of periodontal disease in a sample of generally healthy, community dwelling older adults and underscore the importance of continued periodontal disease prevention and treatment in the oldest-old.

Key words: elderly; gerodontology; older adults; oral health surveys; periodontal disease

Accepted for publication 1 March 2006

Periodontal diseases are among the most prevalent chronic infections in dentate older adults. Although it is well established that the prevalence and severity of periodontal disease increase with chronological age (e.g., USDHHS 1987; Locker & Leake 1993a b; Hirotomi et al. 2002), it is still not clear whether the prevalence and severity of periodontal disease in the oldest-old have shown a decline or an increase in recent years; however, it has been suggested that the greater retention of natural teeth in older adults may contribute to an increase (Douglass et al. 1983; Hugoson et al. 1992; Fox et al. 1994; Joshi et al. 1996). A recent cross-sectional study, for example, compared changes in periodontal status in a Swedish population living in Jönköping over a period of 20 years (1973, 1983, 1993). The proportion of 60- and 70-year-old persons in the groups with healthy periodontium and without signs of alveolar bone loss increased, and the proportion of 60- and 70-year-old persons in the group with moderate bone loss decreased between 1973 and 1983. However, the proportion of 60- and 70-year-old persons in the group with severe bone loss increased between 1973 and 1983, but was unchanged between 1983 and 1993, despite persons in this group exhibiting a further significant increase in tooth retention (Hugoson et al. 1998). Most studies, such as this one, however, have categorized older adults as belonging to a single group, and have not examined subcategories of elderly persons, such as the ''oldest-old'', those over the age of 80.

While the results of cross-sectional studies have found that the majority of dentate older adults have experienced some periodontal disease, the more severe forms of periodontitis appear to affect a substantial minority of the population and generally affect only a

limited number of teeth per individual (e.g., Fox et al. 1994; Steele et al. 1996; Dolan et al. 1997; Locker 1998; Levy et al. 2003). The National Survey of Oral Health in US. Employed Adults and Seniors found that the prevalence of periodontal attachment loss increased progressively by age group, whereas pocket depth and ascending age were only weakly correlated (USDHHS 1987). Comparable data have been reported in other studies (e.g., Brown et al. 1996). Cross-sectional findings of age-related increases in loss of attachment have not been corroborated by longitudinal results, however, and it has been suggested that perhaps the relationship of increasing attachment loss with age group is because of a cohort effect (Ship & Beck 1996).

Despite this increased tooth retention in older adults, relatively few investigations have specifically reported on the periodontal status of non-institutionalized persons aged 80 and over (Beck et al. 1990; Gilbert & Heft 1992; Locker & Leake 1993a; Fox et al. 1994; Levy et al. 2003). As a consequence, information on the periodontal health condition of this segment of the population is limited.

The purpose of this paper is to report periodontal disease findings for generally healthy, community-dwelling persons over the age of 80 years and to evaluate the distribution by sociodemographic factors (age group, sex, marital status, and indicators of social position) and by smoking status. In this study we address some of the issues discussed above in a population-based sample of very old people.

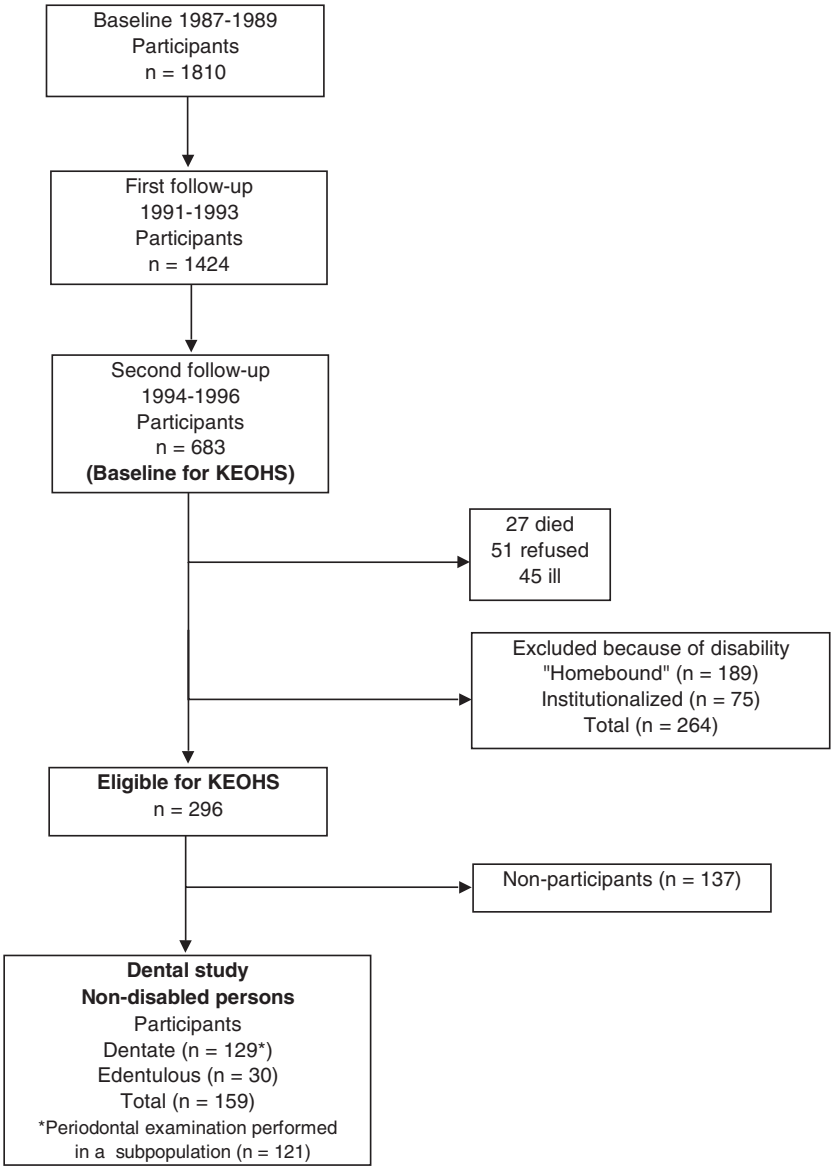

Fig 1. Flow diagram showing the derivation of the sample available for the Kungsholmen Elders Oral Health Study.

Methods

The Kungsholmen Project

The Kungsholmen Project is an ongoing, multicenter, longitudinal population-based investigation of the oldest-old living on Kungsholmen Island in the central part of Stockholm (Fratiglioni et al. 1992). Kungsholmen was selected as a study site because of the large proportion of older adults in its population. In 1987, when the study began, 33% of the population of Kungsholmen were 65 years and older; this percentage is almost twice as high as that of the entire Swedish population (18%). At that time, all Kungsholmen residents born in 1912 or earlier were eligible for participation ($n = 2368$). Of these, 1810 entered the project.

The first follow-up examination of the Kungsholmen participants was conducted in 1991–1993, during which the sample was expanded to include individuals living in the contiguous area of St. Göran who were born in or before 1902. The second follow-up occurred in 1994–1996, and during that period the Kungsholmen Elders Oral Health Study (KEOHS) was conducted (Fig. 1). The KEOHS is a cross-sectional study, which included a sample from the parent study's second follow-up. In 1994 the study participants were 82 years and older. By the start of the oral health study, 7 years after the implementation of the Kungsholmen Project, approximately 60% of the original population had died.

The KEOHS has been approved by the Ethical Committee of Science at the Karolinska Institute, Stockholm, Sweden (D. no. 94-335).

Oral Health Study

KEOHS data collection was restricted to generally healthy, community-dwelling individuals who were then-current participants in the Kungsholmen Project. Generally healthy persons were defined as individuals whose physical, medical, and mental status allowed them to travel to and participate in a comprehensive

oral health examination conducted in a clinical setting. Lists of potentially eligible KEOHS subjects were prepared by the coordinator of the Kungsholmen Project on a rolling basis after cohort members completed the medical, neuropsychological, and social components of the parent study's second follow-up. Persons who lived in nursing homes, were homebound, or whose frailty precluded their traveling to the examination site were excluded from participation. Further details regarding selection of oral health study participants have been reported elsewhere (Morse et al. 2002a).

As a majority of the study participants lived in this area for most of their lives, it is likely that they had access to public dental care when they grew up, because the public school dental service was established in Kungsholmen as early as in 1918. They would also have been affected by the National Dental Health Insurance in Sweden, which was introduced in 1974 (Holm-Pedersen et al. 2005a).

The oral health study included both an interview and a clinical oral examination. First, a trained and experienced dental assistant interviewed the study participants in a quiet and unhurried environment. The following data were collected as part of the oral interview: (1) basic demographic information, (2) current self-rated general health status, (3) self-rated oral health status, (4) dental health service utilization behaviour, (5) oral health symptoms and complaints, (6) dietary habits, (7) smoking habits, and (8) taste perception. Other demographic and medical information was obtained from the research records of the parent Kungsholmen Project. Subsequent to the interview, study participants underwent a comprehensive extra- and intra-oral examination. Data describing the following conditions and diseases were collected: (1) dental status, (2) coronal caries, (3) root surface caries, (4) periodontal status, (5) oral mucosal lesions, (6) denture status and function, (7) taste detection and recognition thresholds, and (8) salivary secretion. This report summarizes the data derived from the periodontal examination; caries data have been previously presented (Morse et al. 2002a,; Morse et al. 2002b).

Periodontal Examination

The periodontal examinations were carried out by one of two standardized examiners. All teeth, including third molars, were examined. Partially erupted teeth and root tips were excluded from the periodontal examination. An assessment of periodontal disease was made for each tooth using a modification of the previously defined NIDCR criteria for measuring periodontal pocket depth (PPD) and clinical attachment loss (CAL) (USDHHS 1987). Teeth were dried with air before examination, and four sites (mesiobuccal, buccal, distobuccal, and midlingual) were assessed for each examined periodontal parameter. For molar teeth, the buccal and lingual assessments were always made at the mid-point of the crown. Pocket probing depths (PPD) were measured as the distance from the gingival margin to the bottom of the sulcus or pocket with a standard Michigan periodontal probe using a probing force that did not exceed 25 N. Recession was measured as the distance from the gingival margin to the cementoenamel junction (CEJ). If the gingival margin was located coronal to the CEJ, recession was recorded as a negative number. Clinical periodontal attachment (CAL) loss was calculated by adding pocket depth and recession measurements. All measurements were rounded to the lowest whole millimeter. Calculus that obscured the CEJ or interfered with the correct placement of the probe was removed with a curette. If the margin of a restoration was apical to the CEJ, the position of the CEJ was estimated using dental anatomy and adjacent landmarks, and if the examiner could not estimate the location of the CEJ, for example, if a crown obscured the entire CEJ, the site was excluded. Splinted and hemisected teeth were considered on an individual basis and examined whenever possible.

The presence or absence of gingival bleeding upon probing was assessed following probing of all sites of a sextant. Furcation involvements on multirooted teeth were measured with a Nabor's probe using the following criteria: degree 1, horizontal loss of supporting tissues not exceeding one-third the width of the tooth; degree 2, horizontal loss of supporting tissues exceeding one-third the width of the tooth, but not encompassing the total width of the furcation area; degree 3, horizontal ''through and through'' destruction of supporting tissues in the furcation (Nyman & Lindhe 1984). Tooth mobility was assessed according to the following criteria: 0 = no mobility; 1 = movement up to 1 mm in any horizontal direction; 2 = movement greater than 1 mm in any horizontal direction; 3 = vertical movement (Nyman & Lindhe 1984).

Examiners were standardized to the diagnostic criteria and calibrated before the beginning of the study and during the data collection period. Given the age of KEOHS study subjects and the length of the examinations, repeat examinations were performed only in a limited number of study participants at each calibration session; consequently, estimates of examiner reliability are not available. The two examiners were experienced periodontists.

When defining periodontitis, previous studies have used different combinations of CAL and PPD to establish a periodontitis case definition (e.g., Beck et al. 1990; Machtei et al. 1992). The rationale behind PPD and CAL combinations is that PPD is considered to indicate the presence of current disease, whereas CAL represents a cumulative measure of periodontal tissue destruction over the life-course. For this study, we chose to dichotomize study participants based upon Beck's definition of SP, which identifies a case as a study participant who exhibits four or more sites with a CAL of 5 mm or more with at least one of those sites having a pocket depth of 4 mm or more (Beck et al. 1990).

Sociodemographic variables examined as associated factors and/or confounding variables included age, sex, marital status, housing situation, education, social class indicators and smoking. Age was trichotomized as 90+, 85–89, or 80–84 years. Sex was categorized as female or male, and marital status was dichotomized as either unmarried (never married, widowed or divorced) or married. Years of education were categorized as 2–7, 8–10, or 11+ years. In addition, housing status was evaluated by determining whether participants were living independently or in assisted living situations, and whether they lived alone. The measurement of social class was based on data about former occupation, working tasks, and position obtained using a standard questionnaire. Occupation was based on the main occupation held during the person's working life, and the classification scheme grouped occupations on the basis of their relation to the process of production and their position in the labour market. Housewives were classified

Table 1. Demographic characteristics of study participants by age and sex in the oldest-old, Stockholm, Sweden

Sex/Age group	Percent married	Education (%)			Social class (%)		
		⩽7 years	8–10 years	⩾11 years	high	middle	low
Females (years)							
80–84	20.0	45.0	35.0	20.0	0.0	41.2	58.8
85–89	20.0	25.7	40.0	31.4	3.1	25.0	71.9
90+	0.0	33.3	46.7	13.3	12.5	37.5	50.0
Total female	16.2	33.8	41.2	25.0	3.5	31.6	64.9
Males (years)							
80–84	66.7	16.7	25.0	58.3	36.4	45.5	18.2
85–89	66.7	25.0	25.0	50.0	45.5	18.2	36.4
90+	57.1	28.6	14.3	57.1	33.3	50.0	16.7
Total male	64.5	22.6	22.6	54.8	39.3	35.7	25.0
Total study	31.3	30.3	35.4	34.3	15.3	32.9	51.8

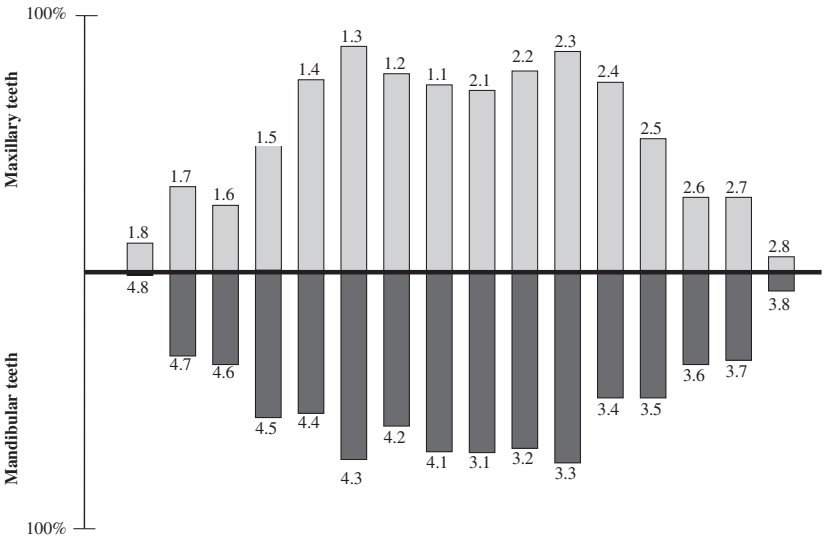

Fig 2. Percentage of subjects with specific tooth remaining in the oldest-old, Stockholm, Sweden.

according to their husband's occupation, and for widows the main occupation of the deceased spouse was recorded. Social class 1 included those in leading positions, professionals, for example, professionals with university degrees, and owners of business enterprises with employees. Social class 2 comprised ''white-collar workers'' on low or medium level, and social class 3 included ''blue-collar workers'' (Swedish National Central Bureau of Statistics 1989; Thorslund & Lundberg 1994).

Statistical Considerations

All interview responses and periodontal disease measurements were recorded directly on a precoded form, which was edited for errors immediately following the examination of each subject. Data were entered and verified by a second entry, and edited for missing, out of range and illogical values. Statistical analysis was performed using the SPSS statistical program. For the descriptive analysis, study participants were stratified by age and by sex. In the case of continuous outcome variables, we used Student's *t*-test and ANOVA to evaluate differences in probability distributions when the distribution of the outcome variables assessed was normally distributed, and Mann–Whitney *U* and Kruskal–Wallis tests to assess differences in non-normal probability. We used the χ^2 test to examine differences for categorical data, and generated odds ratios using the Mantel–Haenzel statistic. Fisher's exact test was used when a table has a cell with an expected frequency of less than five. In addition, logistic regression modelling, using backward selection, was performed to examine association between the various independent variables (including age, sex, marital status, education, social class and smoking) and the presence of SP. All models were controlled for a number of retained teeth. The critical level for statistical significance was $p<0.05$. In order to ''rule in'' possible relationships, tests were not corrected for multiple comparisons.

Results

Of the total of 296 project participants who were identified as potentially eligible for the KEOHS, 54% ($n=159$) participated in the oral health study. Reasons for non-participation included refusal ($n=71$), illness ($n=44$), inability to contact the identified individual ($n=5$), death prior to being contacted ($n=6$), failure to keep scheduled appointments ($n=4$), and other miscellaneous reasons ($n=7$). Of the 159 oral study participants, 81.1% were dentate ($n=129$) and eligible for the periodontal examination. Of these eligible subjects, 93.4% ($n=121$) completed the periodontal examination and comprised the study sample for this report. The other eight subjects refused periodontal examination after having completed both the interview and the caries examination, in most cases because they grew too tired to continue. Figure 1 shows the derivation of the sample available for the oral health study.

Selected demographic characteristics of the participants are shown in Table 1. The mean age of the 121 subjects who underwent periodontal examination was 86.5 ± 3.0 years (range 82–95 years), and approximately 67% (81 persons) were female. Forty-one per cent of the subjects ($n=50$) were widowed, 31.3% ($n=37$) were married, 21% ($n=26$) had never been married, 5% ($n=6$) were divorced, and 2% ($n=2$) were missing data on marital status. Males were more likely to be presently married than were females (64.5% *versus* 16.2%, χ^2, $p\leqslant 0.001$). The majority of subjects (91%, $n=110$) lived in an apartment and most lived either alone (63.6%) or with their spouses (28.9%). Subjects were divided approximately equally among the three education categories: 30.3% had attended school between 2 and 7 years, 35.4% between 8 and 10 years, and 34.3% had completed high school and/or attended college. Females were much less likely to report 11+

Table 2. Periodontal findings by age and sex in the oldest-old, Stockholm, Sweden

Sex/age group	Mean number of teeth (SD)	Mean pocket probing depth (SD)	Mean clinical attachment loss* (SD)	Mean percent bleeding sites (SD)	Percent† exhibiting ''serious periodontitis''‡
Females (years)					
80–84	16.0 (7.5)	2.5 (0.8)	3.5 (1.5)	45.1 (30.9)	40.0 (8/20)
85–89	17.2 (6.8)	2.6 (0.8)	3.5 (1.5)	41.6 (23.9)	45.7 (16/35)
90+	16.4 (7.2)	2.3 (0.4)	4.0 (1.4)	42.0 (25.4)	33.3 (5/15)
Total female	16.7 (7.1)	2.5 (0.7)	3.6 (1.4)	42.7 (26.2)	41.4 (29/70)
Males (years)					
80–84	17.8 (8.6)	2.5 (0.5)	3.3 (0.7)	51.1 (22.0)	66.7 (8/12)
85–89	15.1 (9.8)	3.0 (0.7)	4.0 (1.8)	65.0 (19.6)	66.7 (8/12)
90+	15.4 (5.5)	2.4 (0.5)	4.5 (1.1)	35.5 (29.4)	85.7 (6/7)
Total male	16.1 (8.3)	2.7 (0.6)	3.8 (1.3)	53.2 (25.1)	71.0 (22/31)
Total Study	16.3 (7.8)	2.6 (0.7)	3.7 (1.4)	46.3 (26.2)	50.5 (51/101)

*Means based upon subset of participants with measured AL ($n = 101$; 31 males and 70 females).
†Percentages based on those participants with attachment loss measurements only.
‡Possession of four or more sites with clinical attachment loss greater than or equal to 5 mm, with at least one site with probing pocket depth of 4 mm or greater, $n = 101$ (Beck et al. 1990).

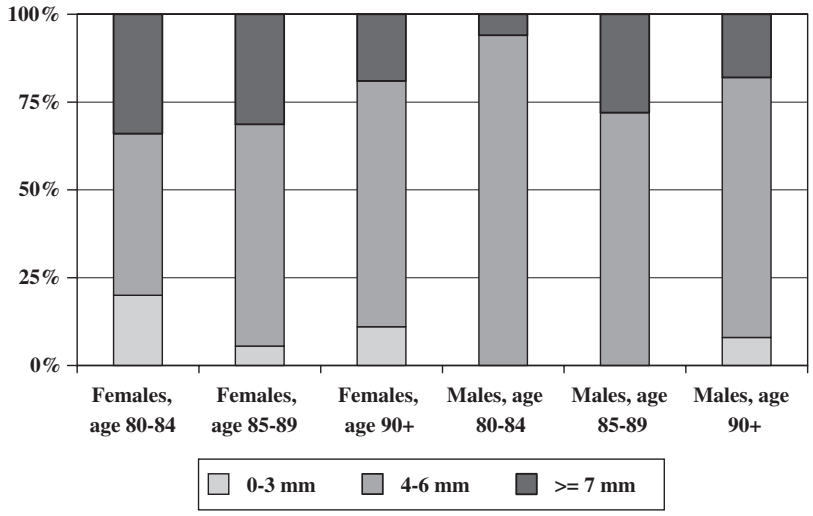

Fig 3. Worst surface pocket probing depth by age group and sex in the oldest-old, Stockholm, Sweden.

years of education than males (25.0% *versus* 54.8%, χ^2, $p = 0.01$). Most of the study participants reported having had blue-collar occupations (lowest social class) and white-collar occupations (middle social class) while the rest had had occupations considered higher than white collar. Males were more likely to report higher-level occupations than females (39.3% *versus* 3.5%, χ^2, $p \leqslant 0.001$). While only a minority of the participants were current smokers (8%, $n = 9$), males were more likely to report current smoking than females (χ^2, $p = 0.03$). Overall, the majority of study participants were relatively healthy and only a minority had multiple concomitant chronic diseases or conditions. Data regarding self-reported and clinically assessed chronic diseases and conditions have been previously presented (Holm-Pedersen et al. 2005b).

The mean number of teeth was 16.3 (SD = 7.8, median = 19, range 1–30). Figure 2 shows the distribution of teeth present by tooth type. In general, anterior teeth were retained more frequently than posterior teeth; third molars were most frequently missing while canines were the teeth most often retained. The majority of all dentate persons examined (78.5%) retained teeth in both arches; 6% had teeth remaining only in the mandible and 15% of participants had teeth only in the maxilla. The detailed distribution of number of retained teeth of study participants by age and sex is shown in the first column of Table 2. There were no statistically significant differences in number of retained teeth between males and females (Mann–Whitney *U* test, $p = 0.76$). There was also no clear trend within the sex strata for fewer teeth with advancing age (Kruskal–Wallis χ^2 test, $p = 0.55$ for males, $p = 0.62$ for females). Bivariate analysis revealed that overall those with higher levels of education retained significantly more teeth (Kruskal-Wallis χ^2 test, $p = 0.005$); upon further examination, however, this relationship was found to be true for females (Kruskal–Wallis χ^2 test, $p = 0.02$) but not for males (Kruskal–Wallis χ^2 test, $p = 0.23$). Social class was unrelated to number of teeth in all cases (Kruskal–Wallis χ^2 test, $p = 0.80$; for females $p = 0.91$, for males $p = 0.67$).

Table 2 also displays periodontal findings by age/sex. The mean PPD was 2.6 mm (SD = 0.7; range 1.4–6.2 mm); overall, males exhibited a slightly deeper PPD when compared with females ($p = 0.03$, Mann–Whitney *U* test); however, differences across any of the three age/sex groups were not statistically significant. For 83.5% of the study participants in which the CEJ of all or some of the teeth could be visualized, the mean CAL was 3.7 mm (SD = 1.4; range 1.2–7.6 mm). Males exhibited slightly more CAL when compared with females; however, this difference was not statistically significant ($p = 0.50$, Mann–Whitney *U* test). Overall, 50.5% of the study participants with CAL measurements fulfilled the criteria established by Beck et al., for SP. All but one subject (99.2%) had at least one site that bled upon probing, and the mean per cent of bleeding surfaces was 46.3% (SD 26.2; range 0–100%). Within each sex stratum, there was no relationship between serious periodontal disease and number of teeth; however, this relationship approached significance when the sex strata were combined (Mann–Whitney *U* test, $p = 0.09$), with those with SP more likely to have retained more teeth.

Upon further examination, among males, the group of participants 85–89 –years old exhibited a greater mean PPD when compared with both the 80–84-year-old group (Student's *t* test, $p = 0.02$) and the 90+-year-old group (Student's *t* test, $p = 0.01$). In addition, males in the oldest age group (age 90+) exhibited more severe CAL than those in the youngest age group (age 80–84) (Student's *t* test, $p = 0.03$). Summary periodontal disease measures did not vary among the female age strata.

Table 3. Odds ratios and 95% confidence intervals for sociodemographic variables predicting ''serious periodontitis'' in the oldest-old, by multivariate logistic regression analysis, Stockholm, Sweden ($n = 101$)

Independent variables	Crude OR (95% CI)	Full model OR (95% CI)	Adjusted model OR (95% CI)
Age (years)			
90+	1.00 (0.34, 2.96)	1.29 (0.31, 5.30)	
85–89	1.04 (0.38, 2.87)	1.43 (0.37, 5.48)	
80–84	1.00	1.00	
Sex			
Male	3.46 (1.39, 8.58)	2.30 (0.71, 7.43)	3.09 (1.19, 8.02)
Female	1.00	1.00	1.00
Marital status			
Married	2.82 (1.16, 6.90)	1.33 (0.44, 4.04)	
	1.00	1.00	
Education (years)			
11+	2.01 (0.86, 4.68)	1.65 (0.59, 4.60)	1.35 (0.54, 3.40)
$\leqslant 10$	1.00	1.00	1.00
Social class			
Higher	2.50 (1.04, 6.00)	1.68 (0.62, 4.56)	
Lower	1.00	1.00	
# of teeth			
20 or more	1.97 (0.89, 4.36)	1.78 (0.70, 4.49)	1.78 (0.77, 4.15)
19 or fewer	1.00	1.00	1.00
-2 log likelihood		105.87	126.88
df		6	3

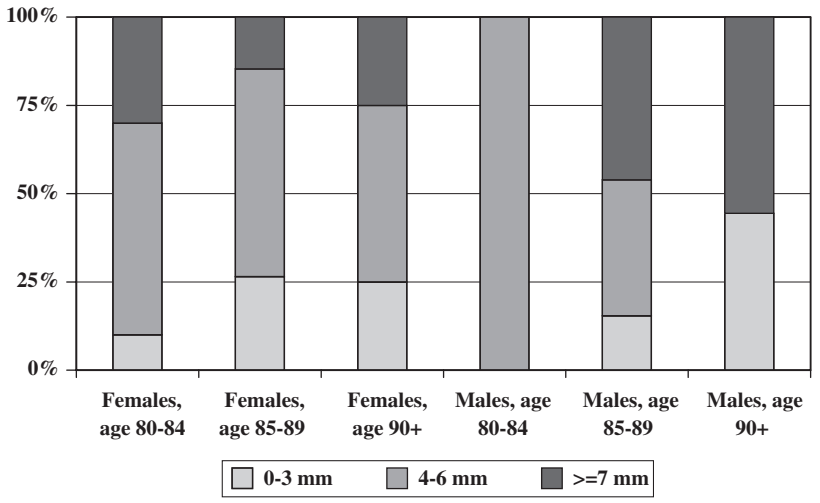

Fig 4. Worst surface attachment loss site by age group and sex in the oldest-old, Stockholm, Sweden.

When the sexes were compared regarding PPD and CAL measurements within the different age strata, a statistically significant difference was seen only between the males and females aged 85–89 ($p = 0.03$).

Figures 3 and 4 summarize the most severe periodontal pocket depth and CAL per person. Only a small proportion of subjects had probing depths and attachment loss of 3 mm or less; the majority exhibited a worst site of PPD and CAL in the 4–6 mm range. At least 25% of persons in three of six age strata exhibited a worst surface PPD of 7 mm or greater, and in four of six age strata a worst surface CAL of 7 mm or greater. There was no consistent pattern of greater pocket depth across age or sex strata. Notably, the proportion of subjects with greater surface attachment loss increased in the oldest age group of males; however, this was not the case for females.

Males aged 85–89 exhibited more bleeding upon probing than any other age/sex group ($p = 0.03$). Among 77.9% of the study sample that retained at least one multirooted tooth, three-quarters (75.8%) had considerable (i.e., $\geqslant$class II) furcation involvement on at least one tooth. The majority of participants (59%) had at least one mobile tooth of grade I or higher, 24% had at least one mobile tooth of grade II or higher, and 7% had a mobile tooth of grade III. Extent of furcation involvement and mobility did not vary by age/sex stratum.

Table 3 shows the crude and adjusted odds ratios of sociodemographic variables on having SP, using logistic regression analysis. The crude unadjusted ORs showed that men, married persons and persons in higher social class were significantly more likely to have SP compared with women, unmarried persons, and persons in lower social class. Specifically, the overall crude OR showed that males were 3.5 times more likely to have SP than females (OR = 3.5, 95% CI 1.4, 8.6; $p = 0.01$) as shown in Table 3.

Age, number of teeth and smoking were not found to be associated with having SP. When controlling for social class, the effect of sex on SP was reduced, suggesting that social class confounded the relationship of sex and SP. Indeed, males were much more likely than females to be classified as high or middle social class (likelihood ratio $\chi^2 = 12.4$; $p <= 0.001$). The relationship between education, sex and SP was similar in that males were more likely than females to report 11 or more years of education (likelihood ratio $\chi^2 = 8.2$; $p = 0.004$). When controlling for educational level, however, males were still more than three times as likely to have SP than females. Education and social class were mildly but significantly correlated (Kendalls $\tau_b = 0.27$; $p = 0.013$). As further examination of the modeling procedures revealed a large increase in the value of the -2 log likelihood when social class was removed from the model as opposed to when education was removed, our preferred final model for the adjusted OR calculation (i.e., the model that best fit the data and was a model unlikely to be influenced by problems of co-linearity between education and social class) is also shown in Table 3. In this ''best fit'' adjusted OR model, males were still 3.1 times more likely than females to have SP (OR = 3.1, 95% CI 1.2, 8.0), a statistically significant observation.

A sub-analysis of the differences in proportion of participants with SP revealed that the difference by sex

increased with age – in the younger two age groups, roughly two-thirds of the males fulfilled Beck's definition, while for females the proportion was less than 50%. In the oldest age group, all but one male (85.7%) but only one-third of women (33.3%) fulfilled the criteria of SP.

Discussion

The KEOHS seeks to describe the oral health status of community-dwelling, generally healthy persons over the age of 80 years living in Kungsholmen, Sweden. The present study focuses on the prevalence and severity of periodontal disease.

The findings revealed a high prevalence of SP among these very old KEOHS participants. Using the definition of SP as four or more sites with a CAL of 5 mm or more with one or more of those sites having a periodontal pocket depth of 4 mm or more (Beck et al. 1990), we found that more than 50% had SP. In comparison, Beck et al. (1990) reported that 16% of 65+-year-old white subjects and 46% of 65+-year-old black subjects had SP according to this definition. Another study of community-dwelling older adults living in Ontario, Canada, found that 22% had severe disease based on this definition (Locker & Leake 1993a). These results suggest that while there may be a variation in the degree of periodontal disease among older adults living in different geographical areas of the world, the higher mean age of this KEOHS study sample is the most likely explanation for the observed differences with the other studies of persons aged 65+ years. This variation may also reflect a number of other factors, including the impact of the methodology used, the number and type of teeth remaining, and differences in sociodemographic characteristics of the populations studied as well as cultural and national differences in the availability and use of dental services. It should be noted that the papers by Beck et al. and Locker et al. were published in 1990–1993, and that data were collected some years before. Therefore, the different findings of their studies and our study regarding severity of periodontitis could also, in part, reflect cohort differences.

Although these well-functioning very old people had a high prevalence of SP, they may also be seen as exceptional, because they have lived beyond the normal life expectancy and in some ways may appear to be a ''biological elite'' (Menec & Chipperfield 1997; Avlund 2004). This selection bias may also be applicable at the individual tooth level, because the severely affected teeth may have already been lost in particular elderly subjects. Our findings suggest that those with SP tend to be more likely to have retained more teeth, although this difference was not statistically significant. One explanation could be that more teeth were at risk of periodontitis and that elders with fewer teeth had already lost teeth during middle age because of periodontal disease. Indeed, our finding that smoking was unrelated to serious periodontal disease in both bivariate and multivariate analyses is unusual; most studies to date have revealed smoking to be highly related to periodontitis. However, few of the KEOHS study participants who received a periodontal examination smoked, and it is probable that we did not examine smokers because they might have been less likely to have been healthy enough to have received a dental examination.

Overall, the majority of participants in the studies by Beck et al. (1990) and Locker & Leake (1993a) were considerably younger than the KEOHS participants (mean age of the subjects in Locker & Leake's study was almost 25 years lower). In a subsequent investigation including the same study population, Locker & Leake (1993b) used a different definition of severe periodontitis, based on disease experience as measured by attachment loss. In multivariate analyses, age, education, current smoking status, and number of teeth had the most consistent independent effects predicting severe periodontal disease. When those persons aged 75 years and over were compared with those aged 74 years or younger, age showed the strongest association with severe disease judged in terms of odds ratio.

All three studies cited used gingival recession and probing pocket depth measures defined by the NIDCR (USDHHS 1987), but scored for the entire mouth, and CAL scores were computed. In our study, probing assessments of pocket depth and attachment level were made at four sites on each tooth, while these assessments were made at two sites on each tooth in the studies of Beck et al. (1990) and Locker & Leake (1993a). This may have caused an underestimation of the severity of disease in the latter two studies because it has been recognized that a full-mouth design with probing measurements at four or more sites on each remaining tooth more correctly classifies an individual with periodontitis (e.g., Hunt 1987; Douglass 1989; Papapanou 1996).

In our study, the mean number of remaining teeth ranged from 15 to 18 across age/sex stratum. These values are somewhat lower than the average number of teeth observed in the North Carolina study and in the Ontario cohort. In a recent investigation, Elter et al. (2005) reported that third molars were associated with the presence of deep periodontal pockets on adjacent secondary molars in middle-aged and older adults. While third molars were included in the present study, given that only a small proportion of subjects had retained their second and/or third molars (see Fig. 2), it is unlikely that our results are due to the retention of these teeth. In addition, the overall findings across several studies suggest that the risk of SP in the oldest-old is attributable to more than simply the number and type of teeth present, e.g., variations in host defense mechanisms and personal behaviours may be important in explaining disease progression that has occurred over time.

Another important finding was that males had more than three times the odds of having SP than females, as revealed in both an unadjusted OR (OR = 3.5) and an adjusted OR (OR = 3.1), with both findings being statistically significant. Our study confirms findings from several other studies that older males have more severe periodontal disease than females (Locker & Leake 1993a; Fox et al. 1994; Elter et al. 2005; Kocher et al. 2005).

The observed difference between males and females as regards the association with SP could, in part, be because of the large number of prosthetically crowned teeth in our study population of very old Swedes (Morse et al. 2002b), i.e. that males of higher social position and longer education might have had more crowned teeth than females of lower social position and shorter education. Therefore, two separate post hoc analyses were performed to examine the relationship between social class and number of crowns and the relationship between number of crowns and SP. There was no association between social class and number of crowns or between number of crowns

and periodontitis. However, in 16.5% ($n = 20$) of the 121 study participants who underwent periodontal examination, CAL could not be measured, because crowns margins obscured the CEJ. These 20 subjects had fewer teeth and more severe periodontal disease based on periodontal pockets depth measurements. When we repeated the analyses and included these subjects, making the assumption that they all had SP, social class was no longer related to having severe periodontal disease. The findings suggest that variations in periodontal disease are related to additional factors not included in our models, e.g., psychosocial factors may be related to periodontal disease in elderly persons. While there is indeed increasing evidence that life events are associated with periodontal disease either by impacting upon physiological processes such as the brain–neuroendocrine immunoregulation of the plaque-induced inflammatory response (e.g., Hugoson et al. 2002) and/or by affecting disease-promoting behaviours such as poor oral hygiene, such analyses were beyond the scope of the present analyses.

In the interpretation of our findings, several aspects of the study should be taken into consideration. The small sample size of this early oral health study of the ''oldest-old'' sets constraints on the complexity of the analyses we were able to undertake. As a consequence, we have presented findings that approached but did not achieve statistical significance at the 0.05 level. Nevertheless, the directional findings from early exploratory descriptive studies such as this report has utility in identifying relationships for evaluation in future, larger-scale studies. As is typical with descriptive epidemiologic studies, our findings should be viewed as hypothesis generating rather than hypothesis testing. It should be kept in mind, however, that data of the type presented here are difficult and expensive to collect. Despite the limitations imposed by size, the study nonetheless allows an important, ''first glimpse'' into periodontal disease levels in a generally healthy very old, community-dwelling population.

In conclusion, this study of oral health in those over the age of 80 years revealed high levels of severe periodontitis, especially among the old males. The findings underscore the importance of continued prevention and treatment of periodontal disease in the very old.

Acknowledgements

This study was supported by a grant from the Velux Foundation.

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Clinical Relevance

Scientific rationale: Despite increased tooth retention in older adults, relatively few investigations have reported on the periodontal status of the oldest-old, those over the age of 80 years. As a consequence, information on the periodontal health condition of this segment of the population is limited.

Principal findings: The study revealed high levels of SP in non-institutionalized, generally healthy persons over the age of 80 years, especially among old males.

Practical implications: The findings underscore the importance of continued prevention and treatment of periodontal disease in the very old.