Marginal Bone Level in an Adult Danish Population

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Purpose: To investigate the prevalence and distribution of marginal bone loss in the Danish population.

Materials and Methods: Six hundred and sixteen randomly selected Danish adults (304 females and 312 males), mean age of 42 years (range 21–63 years) underwent a full-mouth radiographic survey consisting of 14 periapicals and two bitewings. The marginal bone level was measured with a digital caliper in mm, rounded off to the nearest 0.1 mm. The measurements were performed at the mesial and distal aspect of the tooth, from the cemento-enamel junction to the marginal bone. These measurements were used to calculate the marginal bone level (A) in mm for each tooth and each patient. Three thresholds were defined: normal marginal bone level ($A < 3$ mm), borderline marginal bone level ($3 \text{ mm} \leq A < 4$ mm) and reduced marginal bone level ($A \geq 4$ mm).

Results: The prevalence of reduced marginal bone level in the individual and the frequency of teeth with reduced marginal bone level were almost similar. A reduced marginal bone level was evenly distributed among the tooth groups. Approximately 12% had reduced marginal bone level, 12% were in the borderline marginal bone level group, and the remaining 76% had a normal marginal bone level. The marginal bone level was ever more reduced with increasing age. No significant difference in bone level was observed between genders.

Conclusions: The prevalence of reduced marginal bone level in a random Danish population is approximately 12% and is comparable to findings in other European countries.

Key words: cross-sectional study, epidemiology, marginal bone level, prevalence, radiology

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Periodontal disease is one of the main causes of tooth loss, only exceeded by dental caries (Diamanti-Kipioti et al, 1995; Gilbert et al, 2002). Previous studies of European populations have shown the prevalence of Periodontal disease to be 10–20% (Kirkegaard et al, 1987; Papapanou, 1999), and that prevalence increases with age (Locker et al, 1998; Papapanou et al, 1988; Sheiham and Netuveli, 2002). The distribution of periodontal disease among nationalities and social classes is, however, not homogeneous (Hobdell, 2001; Hugoson et al, 1998; Papapanou et al, 1988; Papapanou et al, 1989; Soikkonen et al, 1998). In order to obtain correct prevalence data for loss of periodontal supporting tissues in a population, the study sample, therefore, must reflect the population of interest.

Previous studies in periodontal research have evaluated clinical parameters such as pocket depth, gingivitis, gingival recession, and attachment loss to describe periodontal disease, and relatively few epidemiological studies have been performed based on radiography to describe periodontal bone loss or defects (Albandar, 1990; Diamanti-Kipioti et al, 1995; Hugoson et al, 1998; Lavstedt et al, 1986a; Papapanou et al, 1988; Papapanou et al, 1989; Salonen et al, 1991; Soikkonen et al, 1998; Wouters et al, 1989).

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Table 1 Overview of previous studies of marginal bone level

Authors (year of study), country	Sample	Methodology	Results
Lavstedt et al (1986), Sweden	406 randomly selected individuals. Age range: 18–65 years.	A 10-year longitudinal study. Full-mouth intraoral radiographs and bite-wings. Bone level measured with Schei ruler.	Annual mean bone loss for all ages: 5.5% of root length, corresponding to 0.09 mm.
Papapanou et al (1988), Sweden	531 individuals referred for various reasons to a university department of oral radiology. Examination year 1974–1976. Age range: 25–75 years.	Cross-sectional study. Full-mouth intraoral radiographs. Bone level measured from cemento-enamel junction to the most coronal bone.	Mean alveolar bone level ≥ 6 mm were observed in 11% of the subjects examined.
Papapanou et al (1989), Sweden	201 individuals from the study of Papapanou et al (1988) selected 10 years after the first radiographic examination (1985–1986).	A 10-year longitudinal study. Full-mouth intraoral radiographs.	Mean bone loss ≥ 0.5 mm observed in 75% of all subjects, and ≥ 3 mm in 7% of all subjects after 10 years.
Wouters et al (1989), Sweden	733 randomly selected individuals. Age: ≥ 20 years.	Cross-sectional study. Full-mouth intra-oral radiographs. Intrabony defects recorded as 1–2 mm difference in bone level between neighbouring teeth.	One or more intrabony defects recorded in 32% of the population.
Albander et al (1990), Norway	142 employees at an industrial plant volunteering for the study. Age range: 18–67 years.	A 6-year longitudinal study. Full mouth periapical radiographs. Thresholds: no bone loss, 1 mm bone loss, 2 mm bone loss, and ≥ 3 mm bone loss.	70% had very few or no sites with bone loss, 25% had moderate bone loss, and 5% had advanced bone loss.
Salonen et al (1991) Sweden	732 randomly selected individuals. Age: ≥ 20 years.	Cross-sectional study. Full-mouth intraoral radiographs. Bone height/root ratios (B/R) were calculated.	Reduction of mean B/R-ratio with age. 99% in the youngest age group had B/R-ratio > 80% while 1% of the oldest age group had the same B/R-ratio.
Diamanti-Kipioti et al (1995), Greece	503 individuals of rural and urban origin. Age range: 25–64 years.	Cross-sectional study. Full-mouth intraoral radiographs and bite-wings.	≥ 6 mm marginal bone loss was observed in 18% of rural and 8% of urban population.
Soikkonen et al (1998), Finland	169 randomly selected individuals. Age range: 76–86 years.	Cross-sectional study. Panoramic and intraoral radiographs of selected areas. Thresholds: no bone loss, slight bone loss, moderate bone loss, advanced bone loss, extreme bone loss.	5% of the individuals displayed no bone loss, 18% displayed slight bone loss, 31% displayed moderate bone loss and 46% displayed advanced or extreme bone loss.
Hugoson et al (1998), Sweden	537 randomly selected individuals in 1973, 550 in 1983 and 552 in 1993. Age range: 20–70 (not the same individuals at the various time points)	Cross sectional radiographic and clinical examination was performed in 1973, 1983 and 1993. Group 1, healthy periodontium; group 2, gingivitis without signs of alveolar bone loss; group 3, moderate alveolar bone loss not exceeding 1/3 of the normal alveolar bone height; group 4, severe alveolar bone loss ranging between 1/3 and 2/3 of the normal alveolar bone height; group 5, alveolar bone loss exceeding 2/3 of the normal bone height and angular bony defects and/or furcation defects.	1973: 3% of individuals in groups 4 and 5. 1983: 13% of individuals in groups 4 and 5. 1993:13% of individuals in groups 4 and 5. In 1993 the individuals had 2 more teeth in average than individuals in 1983.

Table 2 Distribution of the individuals in the study according to age and gender

	20–29 years	30–39 years	40–49 years	50–59 years	60+ years	Total
Female	55	80	81	67	21	304 (49.4%)
Male	58	74	87	78	15	312 (50.6%)
Total	113 (18.3%)	154 (25.0%)	168 (27.3%)	145 (23.6%)	36 (5.8%)	616 (100%)

Table 1 displays previous studies, which have evaluated the marginal bone level in adult populations. A Swedish radiographic study has shown that the prevalence of intrabony defects among a randomly selected Swedish population was as high as 32% (Wouters et al, 1989), and a study from Greece showed that 7.7% of the Greek urban population, and 18.2% of the rural population, had a mean radiographic marginal bone loss ≥ 6 mm (Diamanti-Kipioti et al, 1995).

No epidemiological study has been performed to assess the periodontal condition among Danish adults since Kirkegaard et al in 1982 performed a clinical study, which revealed that the prevalence of clinically measured pockets exceeding 5.5 mm was 10% in a randomly selected population (age 16–80 yrs) (Kirkegaard et al, 1987). This lack of new information on periodontal conditions in the Danish population was especially noted when, in 2004, the Danish National Board of Health published a report where an attempt was made to describe the future structure of the dental health care system in Denmark. The focus was on the need for various categories of personnel (e.g. dentists, dental hygienists and dental assistants) and the teamwork between these groups. The dental health situation for children and adolescents is well described in Denmark because a national register of dental disease and treatment exists, but such a register does not exist for adults. The most recent study of an adult Danish population (Petersen et al, 2004) was an interview survey that focused on the number of teeth present and the number of individuals wearing partial or complete removable dentures. The need for periodontal treatment was not investigated. It is crucial for any community to possess knowledge of the dental health situation in order to plan its future dental health care system.

The aim of this study was to investigate the distribution of a reduced marginal bone level in an adult Danish population and also to evaluate the reproducibility of bone level measurements on intraoral radiographs.

MATERIAL AND METHODS

A sample was drawn by "The Civil Registration System" consisting of 1199 adults (601 men and 598 women), randomly selected individuals from Aarhus County, Denmark. The regional Committee of Ethics had approved the study design. The individuals were contacted by letter and offered a full-mouth radiographic survey in 1997–1998. Only dentate individuals were asked to reply to the letter.

Of these, 616 (51.4%) individuals, 304 women and 312 men, signed and returned the consent form and were thereby included in the study. The year of birth ranged from 1935 to 1975, with a mean age of 42 years (range 21–63 years). The age distribution of the individuals attending the study is displayed in Table 2.

Almost half of the contacted individuals (583) did not participate in the study. Various reasons were given, such as illness, lack of time or interest and unknown address. A dropout analysis was performed to elucidate factors possibly explaining the non-attendance of the individuals. The analysis was performed using information from 'Statistics Denmark' (analysis of non-attendees 1999, Statistics Denmark, data on file). Various socio-economical factors were taken into account in the analysis such as: gender, age, address, occupation, general education, occupational education, education in progress, degree of unemployment, gross income, children living at home, marital status, general health and dental health. The latter two factors were assessed by the usage of services from 'The Danish Health Security System' and reflect the frequency of visits to the doctor or the dentist. The analysis did not reveal any major differences between the participants and non-participants, except for the factor 'use of dental services'. The participants had visited the dentist more frequently than the non-attending individuals. Furthermore, there were more retired people in the non-attending group.

Radiographic recording

All participants underwent a full-mouth radiographic survey consisting of 14 periapicals and two bite-wings,

Fig 1 Illustration of the measurement points. A, marginal bone level: from cemento-enamel junction to the marginal bone. B, remaining bone: from the marginal bone to the apex. Both were measured in the long axis of the tooth.

one in each side. All radiographs were taken with a 'GX 1,000' X-ray unit (Gendex Corporation, Milwaukee, Wisconsin, USA), using the paralleling technique, 70 kV, 10 mA, a film-focus distance of 28 cm, and Kodak Ektaspeed Plus film (Eastman Kodak, Rochester, NY, USA). Film processing was automated (Dürr 1330, AC 245L, Bietigheim-Bissingen, Germany).

Radiographic assessments

From the full-mouth radiographic survey, all teeth except third molars were recorded according to the FDI nomenclature. The tooth was the statistical recording unit. Several factors (overlapping anatomical structures (e.g. zygomatic process, mylohyoid ridge) overlapping surfaces, presence of the third molar that could overlap the distal part of the second molars, angling errors and others) had an impact on the bone level measurements resulting in immeasurable tooth surfaces.

The marginal bone level was measured with a digital caliper (16 ES. Carl Mahr Esslingen GmbH), in mm, rounded off to the nearest 0.1 mm. A magnifying glass (x 1.3) was used to view the radiographs.

The first measurement was performed at the mesial (A_m) and distal (A_d) part of the tooth (Fig 1), from the cemento-enamel junction to the most coronal part of the bone, at which the lamina dura had a normal width. The second bone-level measurement was performed from the most coronal part of the bone, at which the lamina dura had a normal width, to the apex of the root in question, mesially (B_m) and distally (B_d) (Fig 1). In multi-rooted teeth, the following roots were used for the second bone-level measurements: in premolars, the longest root as imaged on the radiographs; in mandibular molars, the distal root; and in maxillary molars, the palatal root.

The measurements were used to calculate for each tooth:

1. Tooth marginal bone level in mm (A_{tooth}):
   $A_{tooth} = (A_m + A_d)/2$
2. Tooth remaining bone in mm (B_{tooth}):
   $B_{tooth} = (B_m + B_d)/2$
3. Tooth marginal bone level in relation to root length in % (C_{tooth}): $C_{tooth} = [A_{tooth} /(A_{tooth} + B_{tooth})] \times 100$
   The measurements were also used to calculate for each *individual:*
4. Individual mean marginal bone level in mm (A_{ind}):
   $A_{ind} = \Sigma A_{tooth}/n_{teeth}$
5. Individual mean remaining bone in mm (B_{ind}):
   $B_{ind} = \Sigma B_{tooth}/n_{teeth}$
6. Individual mean marginal bone level in relation to root length in % (C_{ind}): $C_{ind} = \Sigma C_{tooth}/n_{teeth}$

Diagnostic thresholds for a normal and reduced marginal bone level and percentage marginal bone level of the root length on the individual and tooth level

The thresholds for marginal bone level in mm (A) were defined as:

- $A < 3$ mm: normal marginal bone level
- $3 \leq A < 4$ mm: borderline marginal bone level
- $A \geq 4$ mm: reduced marginal bone level

The thresholds for percentage marginal bone level in relation to root length (C) were defined as:

- $C < 20\%$: normal marginal bone level
- $20 \leq C < 25\%$: borderline marginal bone level
- $C \geq 25\%$ C: reduced marginal bone level

Statistical analyses

Measurements were summarised as means and standard deviations. Categorical variables were described by frequency distribution.

For each tooth group (molars, premolars, canines and incisors) the age dependency of the marginal bone level was evaluated by computing the average marginal bone level of all the teeth in the tooth group for each individual, and subsequently regressing this average

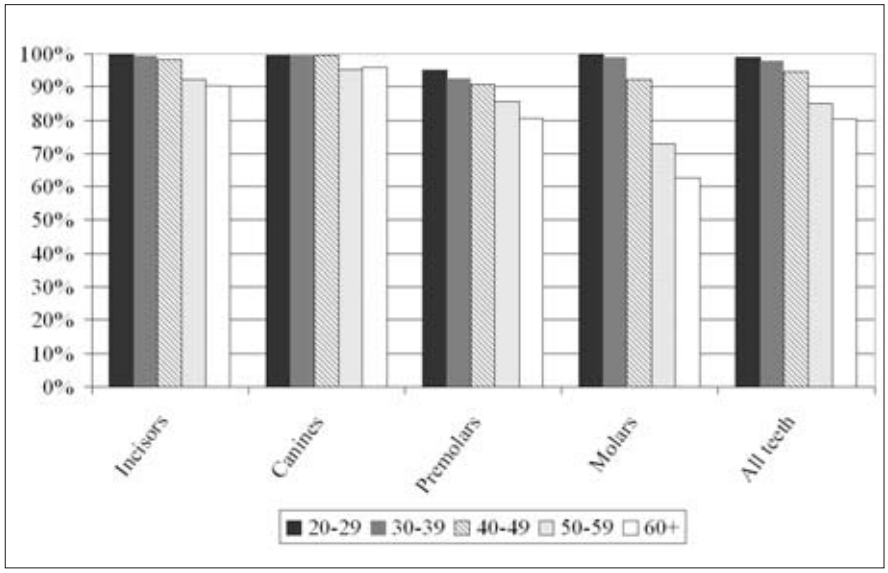

Fig 2 Distribution of the teeth present in the study population, in relation to a full dentition (excluding third molars).

on the age of the person. For each tooth group, the variation around the regression line was used to estimate the inter-individual variation. The intra-individual variation was estimated from the variation between teeth in same tooth group from the same person. Finally, the results were expressed as a relative change per year and a coefficient of variation (i.e. standard deviation in relation to the mean) was used to describe the magnitude of the inter- and intra-individual variation.

Sample for method error calculations

A sample of the radiographic recordings was further evaluated to assess the reproducibility of the measurements. Five months into the radiographic measuring period, with about half of the cases recorded, 20 individuals (514 teeth) were randomly selected from the cases, which had been already recorded, and a first re-assessment of these cases was performed in a random order. A second re-assessment of the same 20 cases was performed 14 months into the measuring period, when about three-quarters of all cases had been recorded. A third re-assessment of the same 20 cases was performed after 16 months, when all 616 cases had been recorded.

The reproducibility of the measurements was described by a pooled standard deviation of the four repeated measurements of each site. To assess a systematic trend in the measurement with time, the four measurements were regressed on the number of the measurement (0,1,2 and 3) giving a total of 1028 estimates of the average change between two successive measurements. For each tooth group a weighted average of these estimates was computed and the 10- and 90-percentile of the site-specific estimates were used to describe the variation in the average change between successive measurements at a site in a given tooth group.

RESULTS

There were 616 participants, and the average number of teeth per individual was 26 (range 3–28). The total number of teeth examined was 16023 (Fig 2), but 341 teeth were excluded because they could not be measured on the available radiographs.

Of the 616 participants, 72 (11.7%) had a reduced marginal bone level, 73 (11.9%) had a borderline marginal bone level, and the remaining 471 (76.5%) of the population had a normal bone level (Fig 3a). There was no statistically significant difference in bone level between genders (independent sample t-test, $p > 0.05$).

Of the 15682 measured teeth, 1878 (12%) had a reduced bone level, 2073 (13.2%) were in the borderline bone level group and the remaining 11731 (74.8%) had a normal bone level (Fig 3b).

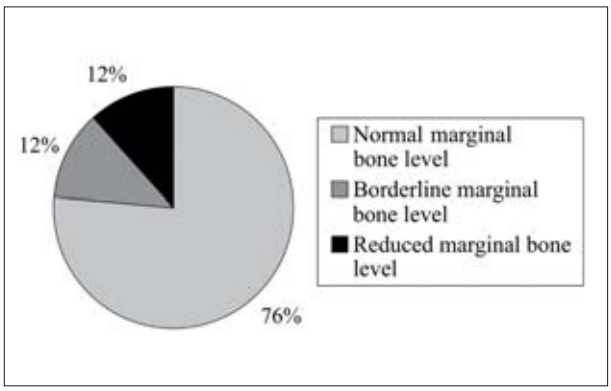

Fig 3a

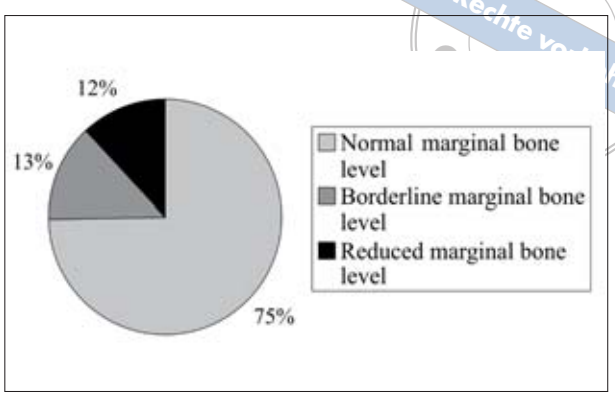

Fig 3b

Fig 3a to 3b (a) Distribution of mean marginal bone level for all individuals (n = 616). (b) Frequency of marginal bone level for all teeth (n = 15682).

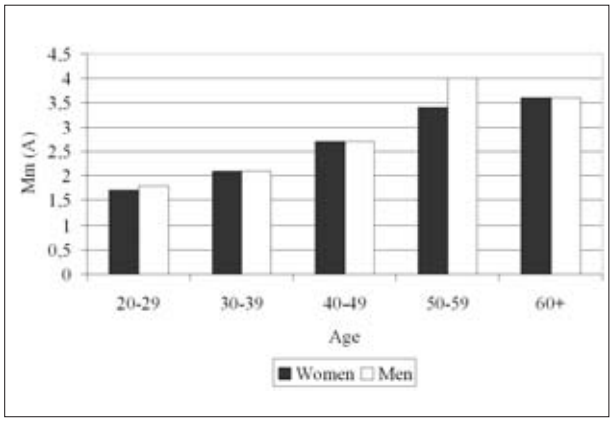

Fig 4 Average mean marginal bone level (A, in mm) for the two genders in relation to age.

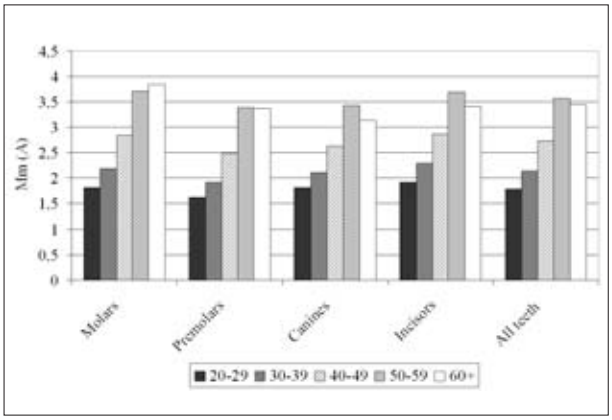

Fig 5 Mean marginal bone level (A, in mm) among tooth groups in relation to age.

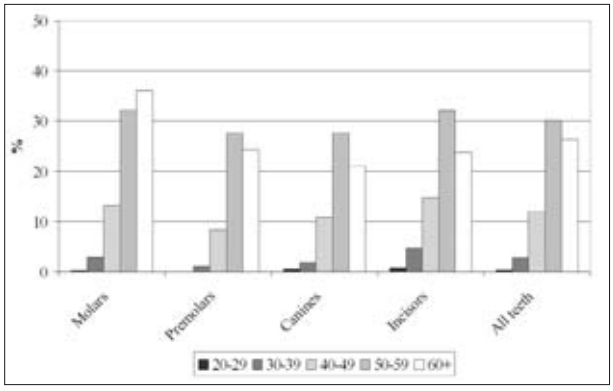

Fig 6 Frequency of teeth with reduced marginal bone level among the tooth groups, in relation to age.

Table 3 Display of the average change (in mm) between successive measurements

Tooth group	Average change	10th percentile	Median	90th percentile
Molar	0.05	-0.21	0.05	0.27
Premolar	0.02	-0.16	0.05	0.30
Canine	0.04	-0.25	0.04	0.37
Incisor	0.09	-0.16	0.07	0.30

The association between the reduction of marginal bone level and age was statistically significant ($p < 0.05$), both when measured in mm (Fig 4) and when measured relative to the root length.

Fig 5 shows the age dependency of marginal bone level in mm (A) by tooth group. The differences in average reduction of marginal bone level per year between molars and premolars and between canines and incisors were not statistically significant. On the other hand, the association between marginal bone level and age was significantly stronger in the distal part of the dental arch (marginal bone level reduction per year for molars and premolars were 2.4% and 2.3% respectively), compared with the frontal region (marginal bone level reduction per year for canines and incisors were both 1.8%). The coefficient of variation of the inter-individual variation in marginal bone level for a given age was approximately 30% for molars and premolars and 32% and 35% for canines and incisors. The intra-individual variation in marginal bone level between teeth in the same tooth group had a coefficient of variation of approximately 25%.

The age dependency was very similar when marginal bone level was measured relative to the root length (C). The age dependency of the relative marginal bone level in the posterior part of the dental arch (reduction in relative marginal bone level per year for molars and premolars was 2.4% and 2.3%, respectively) was again significantly higher than the frontal region (reduction in relative marginal bone level per year for canines and incisors was 1.8% and 1.9%, respectively). The coefficient of variation of the inter-individual variation in relative marginal bone level for a given age was 31% for molar and premolars and 33% and 35% for canines and incisors. The intra-individual variation in relative marginal bone level between teeth in the same tooth group had a coefficient of variation of approximately 25%.

The frequency of teeth with reduced marginal bone level when measured in mm was similar in the various tooth groups (Fig 6) while the canines exhibited a lower frequency of reduced marginal bone level when measured as a percentage of root length compared with the other tooth groups.

Reproducibility

The pooled standard deviation of the four repeated measurements on each site was 0.46 mm, and the overall average change between two successive measurements was 0.05 mm (95% CI 0.04 mm – 0.07 mm) for all sites. The estimates for each tooth group are given in Table 3.

DISCUSSION

This study showed that the prevalence of reduced marginal bone level (> 4 mm) for the individual was 12% in a representative Danish adult population. The prevalence of borderline marginal bone level was also 12%. The most recent available Danish study showed a prevalence of 10% for clinically measured pockets > 5.5 mm (Kirkegaard et al, 1987). In that study, the observers measured the clinical pockets at the mesiofacial part of the upper-jaw teeth, and the mesio-lingual part of the lower-jaw teeth. Despite the difference in the measuring methods, the results of the two studies are comparable.

Although most of the previous epidemiological studies in periodontal research have used clinical parameters to evaluate the periodontal condition, radiographic evaluation, both intraoral radiography (Diamanti-Kipioti et al, 1995; Hugoson et al, 1998; Lavstedt et al, 1986b; Papapanou and Wennström, 1989; Papapanou et al, 1988; Papapanou et al, 1989; Salonen et al, 1991; Wouters et al, 1989) and panoramic radiography (Soikkonen et al, 1998) have been applied. Periapical radiography using the paralleling technique is the most reliable method to image the marginal bone level because there is no distortion and little magnification in the image (Lang and Hill, 1977). This technique has also been shown to detect osseous

destructions more reliably than panoramic radiography (Molander et al, 1991; Pepelassi and Diamanti-Kipioti, 1997). Still, a bone loss has to be > 1 mm to be detectable in periapical radiographs, and the measurement error has to be small (SD < 0.14 mm) in order to detect minor, although clinically relevant, progression of bone loss in longitudinal studies (Benn, 1990). The observer's measurement error in this study was 0.05 mm ± 0.46 mm (mean ± SD), which is an acceptable variation for bone level measurements in cross-sectional studies and even lower than a previous epidemiological study where the measurement error was found to be 0.1 mm ± 0.62 mm (mean ± SD) (Papapanou et al, 1988).

The 'physiologic' distance from the cemento-enamel junction to the marginal bone crest has been reported to be between 0.4 mm and 3 mm (Tugnait et al, 2000). This distance and the observed measurement error were taken into account when deciding the threshold for a reduced marginal bone level (A > 4 mm) and the borderline marginal bone level (3 mm < A < 4 mm) in the present study. There is no well-established threshold for a reduced marginal bone level in periodontal research, and other studies have used other thresholds to define reduction in marginal bone level (Diamanti-Kipioti et al, 1995; Hugoson et al, 1998; Kirkegaard et al, 1987; Papapanou, 1996; Soikkonen et al, 1998). Since different thresholds have been used in previous studies, it is important to consider the threshold for defining pathology when comparing prevalence data for a reduced marginal bone level among different studies.

The thresholds for borderline and reduced marginal bone level in the individual were based on the mean between all the individual's teeth. This seems justified since the bone level measured in mm generally was about the same among all tooth groups in the individual, as described above.

Reduction of marginal bone level is normally an irreversible process. The individuals included in our study were between 20 and 65 years old, and, as expected, the marginal bone level decreased with increasing age. A combined clinical and radiographic longitudinal study performed in a Swedish population divided a randomly selected adult population into five categories according to the marginal bone level (Hugoson et al, 1998). The authors found 13% of the study population to be in categories four or five (the two groups with the most severe periodontal conditions) defined as: alveolar bone loss around the majority of the teeth ranging between 1/3 and 2/3 of the length of the roots; or alveolar bone loss around the majority of the teeth exceeding 2/3 of the length of the roots and angular bony defects and/or furcation defects. Approximately 600 individuals (age 20–70+) were randomly selected. During a period of 20 years, the authors observed an increase in the prevalence of individuals with no marginal bone loss and a decrease in the prevalence of individuals with moderate alveolar bone loss. Furthermore, the prevalence of individuals in the severe periodontal condition groups (4 and 5) was unchanged during the last 10 years of observation, although, the number of teeth per subject increased. Thus the frequency of severe periodontal loss seems to be unchanged in the later birth cohorts, but the disease resulted in fewer teeth lost (Hugoson et al, 1998).

The prevalence of 12% for a reduced marginal bone level in our study is in accordance with data reported from other parts of Europe (Papapanou, 1999). A radiography-based study performed in Sweden reported that 11% of the selected population had a mean alveolar bone loss > 6 mm (Papapanou et al, 1988). Although the researchers used a higher threshold when defining bone loss, they found the same disease prevalence as in the present study. While the design, methods and sample size resembled the present study, the sample selected for the study were patients referred to a dental school, whereas our sample was randomly selected individuals within the population of Aarhus County. The Swedish sample may thus not reflect the situation in the general Swedish population.

An epidemiological radiographic study from Greece compared an urban and a rural population and showed that 18% of the rural population had a mean alveolar bone loss > 6 mm compared with the urban population, for whom the prevalence of the > 6 mm bone loss was only 8% (Diamanti-Kipioti et al, 1995). The study design was similar to our study with respect to the radiographic recording method and the number of individuals participating in the study, and when the two subgroups are considered as one, the results are comparable to ours.

In contrast to clinical measurements and bite-wing radiography, periapical radiography offers the possibility that the bone level is expressed as a percentage of root length. It may be evident that the remaining bone around a tooth must be in focus in clinical treatment planning where the prognosis of the tooth is considered. In longitudinal epidemiological studies, it can also be useful to estimate bone level as a percentage of root length instead of using absolute millimetres since variation in projection geometry will then no longer be of importance. The results from this study showed that measurements in mm and measurements as a percentage of root length gave comparable

results, with the exception of canines, which had more remaining bone than the other tooth groups. The development of marginal bone loss among Danish adults will be investigated in a future longitudinal study of the present population sample.

In conclusion, the prevalence of a reduced bone level is 12% in a random Danish population and is comparable to findings in other European countries. Marginal bone level can be assessed both in exact mm measured from the cemento-enamel junction to the bone margin and as a percentage of the root length, which may be useful in longitudinal studies.

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