Marginal Bone Loss Over 5 years in an Adult Danish Population

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Purpose: To evaluate marginal bone loss on the individual and tooth level, with focus on the importance of the baseline marginal bone level.

Materials and Methods: In 1997, 616 randomly selected individuals (mean age 42 years, range 21–63 years) underwent a full-mouth radiographic survey. In 2003, the survey was repeated for 473 of the same individuals (239 females and 234 males). The marginal bone level of each tooth was measured in mm from the cemento-enamel junction to the marginal bone. These measurements were used to calculate marginal bone loss during the 5-year period, and to analyse the average marginal bone loss for the individual, and tooth group in relation to age and to baseline marginal bone level, calculated as the average between measurements in 1997 and 2003 to circumvent regression to the mean.

Results: Marginal bone loss rate was on average 0.1 mm per year. For the individual, marginal bone loss was associated with both baseline marginal bone level and age. A significant difference was shown ($p < 0.05$) in marginal bone loss between different age groups, with a stronger association between marginal bone loss and baseline marginal bone level in the youngest age group. Moreover, marginal bone loss differed between tooth groups ($p < 0.001$), with molars and premolars losing marginal bone more rapidly than incisors and canines and showing a stronger association with baseline marginal bone level.

Conclusions: Marginal bone loss over a 5-year period is associated with age and baseline marginal bone level. Younger individuals with a reduced marginal bone level were at high risk for further bone loss. Molars and premolars exhibit more rapid marginal bone loss than incisors and canines.

Key words: alveolar bone loss, longitudinal study, radiography

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From many longitudinal studies, it has become well known that marginal bone loss is related to age and smoking (Papapanou et al, 1988; Albandar, 1990; Salonen et al, 1991; Norderyd and Hugoson, 1998; Papapanou, 1999; Bergström, 2004a; Bergström, 2004b; Nitzan et al, 2005). Longitudinal studies also provide information about the progression rate of marginal bone loss (Albandar et al, 1986, 1987; Bolin, 1986; Albandar, 1990; Machtei et al, 1999; Hugoson and Laurell, 2000; Page et al, 2003; Schätzle et al, 2004), which has been reported to be on average 0.1 mm per year in Western populations.

While age and smoking are well-known factors influencing marginal bone loss, the relationship between an individual's initial marginal bone level and further marginal bone loss has been a subject of debate. Some studies have concluded that the initial marginal bone level is not a predictor for the progression rate of marginal bone loss (Laurell et al, 2003), while others have concluded the opposite (Bolin et al,

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1986; Albandar et al, 1987; Papapanou et al, 1989; Machtei et al, 1999). These latter studies have demonstrated that individuals with an already reduced marginal bone level experienced more rapid marginal bone loss; hence teeth with reduced marginal bone level are at severe risk to be lost. Therefore, if initial marginal bone level is identified as a predictor of rapid marginal bone loss, it will be of great prognostic importance. However, the conflicting results in previous studies may also reflect that an analysis of the relationship between the change and the initial value is subject to a regression to the mean phenomenon, which may complicate the interpretation (Bland and Altman, 1986, 1995).

There have to the authors' knowledge been no studies that take both age and marginal bone level into account when evaluating further marginal bone loss over a period of time.

The aim of the present study was to evaluate marginal bone loss and tooth level in the individual, with further elaboration on the importance of the baseline marginal bone level.

MATERIAL AND METHODS

Population

In 1997 a sample was drawn by the Civil Registration System, consisting of 1199 (601 men and 598 women) randomly selected individuals from Aarhus County, Denmark, born between 1935 and 1975. Of these, 616 (51%) individuals, (304 women and 312 men) signed and returned the consent form and were thereby included in the study in 1997 (Bahrami et al, 2006). In 2003, the 616 individuals were once more contacted by letter and invited to participate in a follow-up study where they would undergo a new full-mouth radiographic survey. The time period between the first (1997/1998) and the second (2003/2004) radiographic survey was on average 5.5 years (SD 0.4 yrs). The regional Committee of Ethics approved the study design in 1997 and 2003.

Of the 616 individuals contacted in 2003, 513 (83%) signed and returned the consent form; 481 (78%) agreed to participate in the study, while 32 individuals (5%) for various reasons were not able to participate. Some of the given reasons were: lack of time or interest (22), pregnancy (3), other diseases (2) and death (1). The remaining 103 individuals (17%) did not return the form. Of the 481 who agreed to participate, only 473 eventually participated in the study, since eight did not attend even after two recall invitations. Thus the attendance rate for the follow-up study in 2003 was 77%.

In 2003 the number of teeth was 11,851, which was 73% of total number of teeth in 1997 (n = 16,023). The difference in the total number of teeth between the two examinations was due to several factors, e.g. individuals who did not wish to participate in 2003 (n = 3498), lost teeth (n = 113), and immeasurable teeth (n = 561).

Radiographic recording

In 1997 the participants underwent a full-mouth radiographic survey consisting of 14 periapicals and two bitewings, one for each side, and in 2003 this procedure was repeated. Regions where tooth loss had occurred were still recorded in 2003. In 1997 all radiographs were taken with a GX 1000 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 in the same developing machine (Dürr 1330, AC 245L, Bietigheim-Bissingen, Germany) for both surveys. In 2003, the radiographic procedure was identical to 1997, except the choice of film, since Kodak Insight film (Eastman Kodak, Rochester, NY, USA) was used. By choosing the fastest well-documented film on the market, the radiation dose to the participants was minimised.

Radiographic assessments

From the radiographs all teeth except third molars were recorded according to the FDI nomenclature. In multi-rooted teeth, the following roots were defined as the reference root for the tooth: in premolars the longest root, as imaged on the radiographs, in mandibular molars the distal root, and in maxillary molars the palatal root.

Several factors, such as 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, and angling errors, had an effect on the marginal bone level measurements, resulting in some immeasurable tooth surfaces.

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

Table 1 Baseline bone level for attendees and non-attendees at the individual level (means ± SD)

	Attendees	Non-attendees	
Age group (years)	Baseline bone level (mm)	Baseline bone level (mm)	p-value
20–39	1.95 ± 0.45	1.96 ± 0.48	0.72
40–49	2.72 ± 1.04	3.05 ± 1.40	0.12
50–59	3.69 ± 1.72	4.67 ± 2.54	0.04*
60+	3.63 ± 1.60	4.10 ± 1.80	0.72

*statistically significant ($p < 0.05$)

The marginal bone was measured from the cemento-enamel junction to the most coronal part of the marginal bone (A), at the mesial (A_m) and distal (A_d) part of the tooth, at which the lamina dura had a normal width (Björn et al, 1969). In the case of a coronal restoration extending beyond the cemento-enamel junction, the border of the restoration was used as the reference point. The same observer (GB) assessed all the radiographs. This observer's measurement error, described in a previous study (Bahrami et al, 2006), was 0.05 mm ± 0.46 mm (mean ± SD).

Data treatment

The average marginal bone level for each tooth was calculated as:

$$A_{tooth} = (A_m + A_d)/2$$

The average marginal bone level for each individual was:

$$A_{ind} = \sum A_{tooth}/n_{teeth}$$

To avoid confusion and clearly distinguish between different aspects of the marginal bone, we used the following terminology:

- Initial marginal bone level was defined as the marginal bone level measured at first examination.
- Baseline marginal bone level was defined as the average between the marginal bone levels measured at first and second examination [(1997+2003)/2]. This variable was used to circumvent regression to the mean, which is present in studies of the relationship between a change and an initial value (Bland and Altman, 1986, 1995).
- Marginal bone loss was defined as the change (in mm) in marginal bone level between the two measurements (2003-1997).
- Relative marginal bone loss was defined as marginal bone loss divided by the baseline marginal bone level.

Statistical analysis

The development of marginal bone loss in an individual was studied by regression analyses, with the individual as the unit of analysis. Marginal bone loss for individuals was regressed on the baseline marginal bone level and the age of the individual at first examination. Age was entered as a categorical variable with four categories: 20–39, 40–49, 50–59, and 60+ years. The relative marginal bone loss was analysed in a similar way.

A mixed analysis of variance model with tooth as the unit of analysis was used to compare the development of marginal bone loss in incisors, canines, premolars, and molars. This multilevel model had person as a random factor, tooth group as a fixed factor, and baseline marginal bone level within tooth group as covariates.

An analysis of tooth loss showed that 113 teeth were lost during the 5-year time period. Of these teeth, 52 (46%) belonged to 33 individuals (7% of the population), with $A_{ind} > 5$ mm. It was further shown that 57 (50%) of the lost teeth belonged to the oldest age group (60+ years). The lost teeth were omitted from the bone loss analysis.

Dropout analysis

A dropout analysis was performed to determine whether there were significant differences the attendees and the non-attendees of the follow-up study, with respect to initial marginal bone level, number of

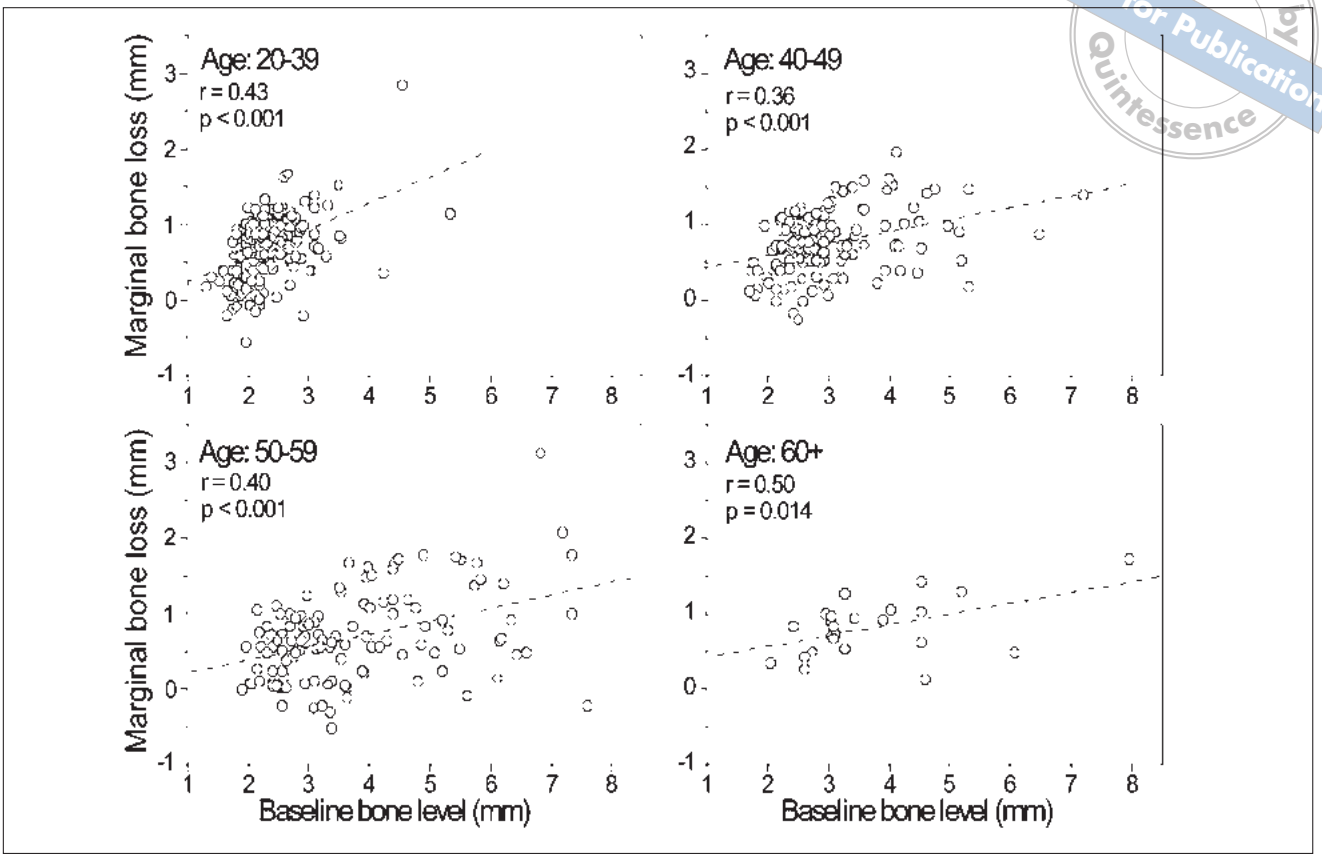

Fig 1 Marginal bone loss versus baseline bone level for each individual in four age categories. Dotted lines show estimated regression linear relationship. P and r values are displayed.

teeth, gender and age. For analysis of initial marginal bone level and number of teeth, Mann-Whitney test on the individual level was used, for each age group (20–39, 40–49, 50–59 and 60+ years) as well as for all age groups. Comparison of age was done by *t*-test, while the analysis for gender was performed using chi-squared test.

There was no statistically significant difference with respect to age and gender between the attendees and non-attendees. The difference between the number of teeth was not significant when all age groups were considered, or within the age groups, except for the 50–59-years age group, where a statistically significant difference was found ($p < 0.05$), the attendees displaying a significantly higher number of teeth (mean 24.6) than the non-attendees (mean 20.9). There was no statistically significant difference in initial marginal bone level between the attendees and non-attendees on the individual level for all age groups (Table 1). Within age groups, a statistically significant difference was found only for the 50–59-years age group, the non-attendees displaying a more reduced marginal bone level than the attendees ($p < 0.05$) (Table 1).

RESULTS

The average annual marginal bone loss was 0.1 mm (SD 0.15 mm) for all age groups. The regression analysis showed that the marginal bone loss was associated both with the baseline marginal bone level and the age of the individual. Moreover, the slope of the regression line on the baseline marginal bone level was considerably steeper in the youngest group and differed significantly between the four age groups ($p < 0.05$). Fig 1 shows marginal bone loss versus baseline marginal bone level in each of the four age groups. When the development of marginal bone loss was expressed as a relative marginal bone loss, the association between age and marginal bone loss was still present. The relative marginal bone loss in the four age groups was estimated to 30%, 25%, 18%, and 22% re-

spectively, although some inter-individual variation was observed.

The comparison of tooth groups (incisors, canines, premolars and molars) showed that both the marginal bone loss and the regression of the marginal bone loss on the baseline marginal bone level differed between tooth groups ($p < 0.001$). The estimated relations are presented in Fig 2, which shows that the estimated marginal bone loss in the four tooth groups was very similar when the baseline marginal bone level was around 2 mm, but the association with baseline marginal bone level was much stronger for premolars and molars than for incisors and canines.

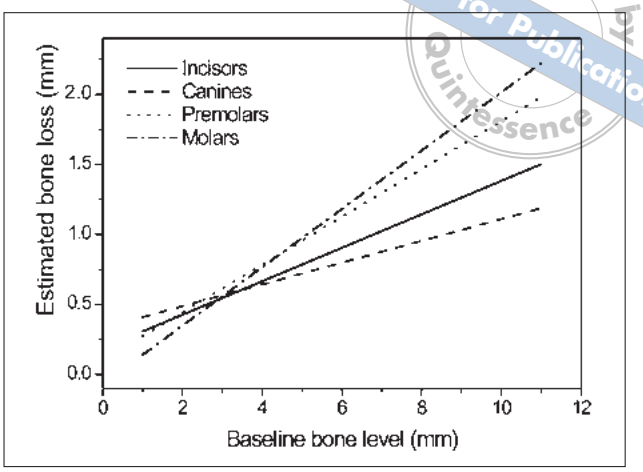

Fig 2 Estimated linear relation between marginal bone loss and baseline bone level for each tooth group.

DISCUSSION

In this Western population the average annual marginal bone loss was found to be approximately 0.1 mm per year for all ages, which is in accordance with several other studies of Western populations (Lavstedt et al, 1986; Papapanou et al, 1989; Hugoson et al, 1992; Machtei et al, 1999; Norderyd et al, 1999). To ensure adequate group sizes, the youngest age group in our study was 20–39 years and the remaining age groups were defined in 10-year intervals. The regression analysis showed that marginal bone loss was associated with both the baseline marginal bone level and the age of the individual, and it also showed that the youngest age group (20–39 years) had the steepest slope of the regression on baseline marginal bone level (Fig 1). In addition, the relative marginal bone loss was higher in the younger individuals. A relative marginal bone loss of 30% for an individual with 5 mm baseline marginal bone level would be 1.5 mm marginal bone loss, while for an individual with 1 mm baseline marginal bone level it would be 0.3 mm marginal bone loss. Moreover, two individuals in different age groups with the same baseline marginal bone level do not have the same expected marginal bone loss pattern. The younger individual is more likely to have a more reduced marginal bone level after 5 years than the older individual. The slight increase in the relative marginal bone loss for the oldest age group (60+ years) could be due to the fact that most of the lost teeth belonged to this age group.

These tendencies have been discussed in a previous study, in which initial marginal bone level was found to be a risk factor for marginal bone loss only for the youngest age group (20–29 years) after adjusting for age and smoking (Laurell et al, 2003). However, the conclusion of their study was that initial marginal bone level was not a predictor of future marginal bone loss. In contrast, in the present study we conclude that marginal bone loss is more rapid in individuals with a reduced baseline marginal bone level, which is in accordance with other previous studies (Bolin et al, 1986; Papapanou et al, 1989; Albandar, 1990; Machtei et al, 1999). In these studies marginal bone loss in older individuals (60+ years) tended to be greater than that in younger individuals (< 40 years). The initial level of marginal bone and age were not, however, considered together, and their possible interactions were not examined as in the present study, which concludes that younger individuals with initially reduced marginal bone level lose marginal bone more rapidly than older individuals with the same level of marginal bone.

Fig 2 shows the estimated relationship between the marginal bone loss and the baseline marginal bone level for each tooth group. If the baseline marginal bone level is 2 mm, there is no difference between the rates of marginal bone loss in different tooth groups, but for baseline marginal bone level exceeding 2 mm, molars and premolars showed a more rapid marginal bone loss compared with incisors and canines. This could be due to the morphology of the teeth (e.g. furcations in molars and mesial concavity of the first maxillary premolar) and their posterior position in the oral cavity, which may make it difficult to maintain proper oral hygiene by the individual, and to perform adequate supporting periodontal therapy by the dental professional. Several other studies have found a tendency for more marginal bone loss for maxillary molars, premolars and mandibular incisors (Albandar, 1990; Laurell et al, 2003; Paulander et al, 2004; Airila-Månsson et al, 2005).

The dropout analysis showed that there was no significant difference in the number of teeth in the attending and non-attending group. There was, however, a significantly higher number of teeth in the attending groups for the 50–59-years age group than among the non-attendees. This means that there could be a slight underestimation of the marginal bone loss within this age group, since marginal bone loss is a risk factor for tooth loss (Diamanti-Kipioti et al, 1995; Gilbert et al, 2002), and it is therefore possible that individuals with fewer teeth also have more severe marginal bone loss. There was no statistically significant difference between the attendees and non-attendees concerning initial marginal bone level, except for the previously mentioned age group (50–59 years), the non-attendees having a more reduced initial marginal bone level than the attendees. This supports the theory of underestimation of marginal bone loss in this age group.

The fact that 46% of all lost teeth belonged to 7% of the population with > 5 mm initial marginal bone level supports the theory of reduced marginal bone level as a risk factor for tooth loss (Diamanti-Kipioti et al, 1995; Gilbert et al, 2002). A more detailed analysis of risk factors for tooth loss, which is beyond the aim of this study, will be presented in the future.

In conclusion, the present study shows that age and baseline marginal bone level are important factors in the development of further marginal bone loss.

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