Radiographic quantification of alveolar bone level changes

Predictors of longitudinal bone loss

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The purpose of the present study was to determine the relative importance of a set of predictors for the radiographic change in alveolar bone level over 2 years in a group of 180 subjects and to assess the fit of the applied multivariate model. The included predictors were age, sex, initial bone level, type of initial lesion, tooth type, proximal tooth surface, calculus, and the presence of metal crowns or proximal fillings. The multivariate method of choice was multiple classification analysis. The results indicated that in descending order tooth type, initial bone level, and age were the most important predictors. Sex, calculus, and crown and filling margins also showed significant direct effects (beta) on longitudinal bone loss ($p < 0.05$). However, their relative importance was far less than that of tooth type, initial bone level, and age. Proximal side showed no significant direct effect. Using seven predictors, the applied multivariate model explained 20% of the variance in longitudinal bone loss. □ *Clinical study; multivariate analysis; periodontal disease*

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The random burst theory (1) has recently been subjected to empirical testing by determining the association between age, initial bone level, and longitudinal bone loss, and it was concluded that the disease activity was not random with regard to time and previous loss of periodontal support (2). Using standardized radiographs, Albander et al. (2) observed that the change in radiographic bone level was bivariately associated with age, sex, location of the site, and the extent and type of the initial lesion. Rohner et al. (3) found that longitudinal bone loss was greater in crowned than in uncrowned teeth. Although different factors might influence the progression of periodontal disease (4–6), these independent variables have not been combined into a multivariate model. The purpose of the present paper was to determine the relative importance of a set of predictors and to assess the fit of the applied multivariate model.

Materials and methods

The present study group consisted of 180 employees at a factory in Oslo (De-No-Fa og Lilleborg Fabriker A/S) who were twice examined radiographically for the assessment of bone level changes during 2 years. Their age at the start of the study ranged from 18 to 68 years (mean, 46.7 years), and most of them visited the dentist regularly.

The method used to examine the subjects and the criteria used to assess alveolar bone level changes have been described in detail in a previous report (2). In brief, each examination included six periapical radiographs for each subject, three in each jaw. All radiographs were taken with a mobile X-ray unit with a long cone (Siemens Heliodent, 50 kVp, 7 mA), and the films were fixed with an Eggen film holder for the intraoral standardized paralleling technique (7) and developed under standardized conditions (Dürr Periomat).

To facilitate the reading of the radiographs, each radiograph was magnified 10 times, using an ADA-Realist X-ray viewer. Transparent millimeter paper, which was magnified simultaneously, and a drawing compass were used to assess the distance between two reference points (8). The cementoenamel junction (CEJ) was used as one reference point. In sites where metal crowns or proximal restorations extended to or beyond the CEJ the most apical margin of the latter was used as a reference point instead of the CEJ. The alveolar crest, which represented the second reference point, was considered to be the most coronal level where the periodontal membrane retained its normal width (9). When widening of the cervical part of the periodontal membrane space was present, it was scored as bone loss only if evidence of oblique resorption also was present (2, 10–12).

A site with a distance of more than 2 mm between the two reference points at the initial examination was considered to have bone loss. An increase in this distance during the 2-year observation period was regarded as longitudinal bone loss. The measurements of initial and longitudinal bone loss were made to the nearest millimeter. Third molars were excluded. All the measurements were performed by one examiner.

Longitudinal bone loss was the dependent variable. Eight independent variables (predictors) were operationalized, and each was divided into various numbers of categories. Altogether, 5631 sites were assessable at both radiographic examinations; each site was given a score for each of the 8 predictors. These were as follows:

Age of the subject at the initial examination

1) 18–22 years
2) 23–27 years
3) 28–32 years
4) 33–37 years
5) 38–42 years
6) 43–47 years
7) 48–52 years
8) 53–57 years
9) 58–62 years
10) 63–68 years

Sex

1) Male
2) Female

Initial level of bone loss

1) 0 mm
2) 1 mm
3) 2 mm
4) 3 mm
5) 4 mm
6) 5 mm
7) 6 mm
8) ≥7 mm

Type of initial lesion

1) No bone loss
2) Horizontal bone loss
3) Vertical bone loss

Vertical bone loss was considered to be present when the radiograph showed obvious intraosseous defects (13).

Tooth type

1) Maxillary incisors
2) Maxillary premolars
3) Maxillary molars
4) Mandibular incisors
5) Mandibular premolars
6) Mandibular molars

Proximal side

1) Mesial
2) Distal

Calculus

1) No calculus
2) Calculus present

A tooth surface was considered to have calculus when irregular calcifications were seen on or apical to the CEJ.

Metal crowns or proximal fillings

1) No crown or restoration
2) Presence of crown or restoration

Score 2 was given to sites that indicated metal crown or proximal restoration extending to or apical to the CEJ.

Using the criteria described, we assessed the alveolar bone level twice at a 2-week interval in 50 sets of radiographs randomly selected among the total 180 sets. Comparison of the bone loss scores in the two examinations showed identical readings in 95.4% of the sites. The standard deviation of the mean difference between the duplicates of measurements was 0.37.

Data analyses

Multiple classification analysis (MCA) was the statistical method of choice, being suitable for analysis of categorical independent variables (14). The method provides a bivariate correlation coefficient (eta), and the direct effect of a predictor, when the effects of other variables are adjusted for, is expressed in terms of beta. The rank order of the betas indicates the relative importance of the predictors in explaining the variance in the dependent variable when all other predictors are held constant. Finally, R^2 was computed, indicating the goodness of fit of the multivariate model. MCA works within the framework of an additive model (14). Therefore, AID (15) was used to detect whether interaction effects were present, and in this context R^2 includes both additive and interactive effects. Eta and beta were tested for statistical significance by a one-way analysis of variance (14). The following formula was applied:

$$F = \frac{SS_{v_i}/(C_i - 1)}{SS_{tot} - SS_{v_i}/(n - C_i)}$$

where SS_{v_i} = the sum of squares of either unadjusted (eta) or adjusted (beta) deviations for predictor v_i, C_i = the number of categories of predictor v_i, and SS_{tot} = the total sum of squares of unadjusted and adjusted deviations for all predictors.

Results

The results of the MCA analysis are presented in Table 1. According to the bivariate correlations in terms of eta, tooth type (0.30), initial bone loss (0.26), age (0.21),

Table 1. The relative importance in terms of eta and beta of some selected independent variables for longitudinal bone loss: multiple classification analysis (MCA)

Predictor	Eta	*P*	Beta	*P*
Tooth type	0.30	***	0.27	***
Initial bone loss	0.26	***	0.17	***
Age	0.21	***	0.15	***
Presence of calculus	0.11	***	0.04	**
Sex	0.07	***	0.05	***
Presence of crown/filling	0.05	***	0.03	*
Proximal side	0.03	*	0.01	NS

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; and NS = not significant. $R^2 = 0.20$.

and presence/absence of calculus (0.11) had greatest effects. The same rank order also remained for the direct effects (beta) when the other variables were accounted for. The only exception was presence/absence of calculus, which had a negligible direct effect (0.04). However, it can be observed that the effects of all independent variables were reduced during the adjustment procedure. As to the direct effect of tooth type, the highest bone loss scores during the 2 years were observed in lower incisors, followed by upper incisors and upper molars. Bone loss also increased with increasing level of initial bone loss and with increasing age. Altogether, the independent variables could account for 20% of the variance in longitudinal bone loss.

Discussion

The present study showed that 20% of the total variance in longitudinal bone loss was explained by the selected predictors with various degrees of importance. In descending order, tooth type, initial bone level, and age were the most important predictors.

A model that contained interaction effects did not improve the fit. This means that the additive model provided an adequate description of the empirical data on longitudinal bone loss. However, it is difficult to judge the fit of this multivariate model owing to the lack of comparable data sets. Since periodontal disease is a complex multifactorial disorder (16), it is likely that the inclusion of independent variables pertaining to plaque (6, 17–20) and other predisposing factors (4, 5) would have improved the fit of the model to some extent.

If one is interested in explaining as much as possible of the variance in a dependent variable, one should select independent variables that are relatively unrelated to each other (21). The circumstances of moderately or strongly related predictors might render the estimates of the coefficients more sensitive to sampling and measurement errors (multicollinearity). In this study two predictors, initial bone loss and type of initial lesion, were moderately correlated ($r = 0.54$). To avoid multicollinearity (21), one of them had to be dropped from the MCA analysis. Thus, the inclusion of both initial type of lesion and level of initial bone loss produced some odd results, and the magnitude of R^2 did not increase. Therefore, type of lesion was excluded, to provide less ambiguity in the interpretation of the effects.

Although sex, calculus, and crown and filling margins had a significant direct effect (beta) on longitudinal bone loss, the relative importance of these three predictors was far less than age, tooth type, and initial bone level. However, it is likely that measurement of calculus on radiographs is subject to random error and of disputable validity. These circumstances would appear to imply that the effect of calculus tends to become attenuated (22). Proximal side showed no significant direct effect on longitudinal bone loss.

The present results are consistent with those of other studies suggesting that the degree of periodontal breakdown is associated with age (23). Epidemiologic studies also show higher prevalence of periodontal destruction and longitudinal bone loss in the incisors and maxillary molars than in other types of teeth (3, 24). In addition, a significantly greater rate of bone loss has been observed in crowned than in uncrowned teeth (3). However, it should be noted that although the difference in bone loss between crowned and uncrowned teeth was statistically significant, its importance was too small (beta = 0.03) to warrant any clinical considerations.

The results of the present study add validity to the theory that the progression of periodontal disease might be dependent on initial bone level, time, and location of the site (2). Thus, the three variables: tooth type, initial bone level, and age were the most important predictors among the eight variables that were included.

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