Risk Indicators for a Reduced Marginal Bone Level in the Individual

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Purpose: The aim of this study was to assess risk indicators for reduced marginal bone level in the individual, with emphasis on apical periodontitis.

Materials and Methods: Six hundred and sixteen randomly selected Danish adults (304 women and 312 men), mean age of 42 years, underwent a full-mouth radiographic survey. The marginal bone level was measured from the cemento-enamel junction to the marginal bone. The measurements were performed at the mesial (A_m) and distal (A_d) aspect of the tooth. The marginal bone level for each individual was calculated: $A_{ind} = \sum A_{teeth}/n_{teeth}$, and $A_{ind} \geq 4$ mm was considered as reduced marginal bone level. The periapical status was assessed by the periapical index (PAI), which was dichotomised (healthy = PAI scores 1 and 2, and diseased = PAI scores 3, 4 and 5). Coronal restorations (crowns, fillings and inlays) and smoking status were also recorded. All variables were analysed in a logistic regression model with reduced marginal bone level as the outcome.

Results: The impact of age (odds ratio (OR) = 3.3), smoking (OR = 10.5) and apical periodontitis (OR = 4.7) on reduced marginal bone level was statistically significant ($p < 0.01$).

Conclusions: Not surprisingly, this study showed that smoking and older age were risk indicators for having reduced marginal bone level ≥ 4 mm. Even when adjusted for these factors, individuals with ≥ 1 tooth with apical periodontitis were five times more at risk of having a reduced marginal bone level than those with no periapical infection.

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Marginal periodontitis is a multi-factorial disease related to dental hygiene, bacterial infection, smoking, and other factors (Bascones et al, 2004; Bergström, 2004b; Grossi et al, 1995; Jenkins and Kinane, 1989; Paulander et al, 2004a; Paulander et al, 2004b).

It has been shown that individuals who have suffered periodontitis resulting in a reduced marginal bone level and have undergone periodontal treatment are more exposed to other tooth-related infectious diseases such as root caries, because of a shift in the microflora of the mouth, from periopathogens to cariogenic species of bacteria (De Soete et al, 2005; Quirynen et al, 1999; Ravald and Birkhed, 1992). One study has shown that 50% of the patients referred for periodontal treatment had one or more root caries lesions (Ravald and Birkhed, 1991). It is therefore not unreasonable to assume that these individuals could also be at higher risk of having other tooth-related infectious diseases.

The relationship between the marginal bone level and the periapical bone condition of a single tooth has been investigated in a limited number of cross-sectional studies. It has been demonstrated that teeth with periapical pathology more frequently had a reduced marginal bone level than teeth without periapical pathology (Hirsch and Clarke, 1993; Jansson et al, 1993a; Jansson et al, 1995b; Jansson et al, 1995a). In one retrospective study conducted on a periodontitis-prone population, the rate of marginal bone loss was approximately three times higher for

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Table 1 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%)

periapically infected single-rooted teeth, than for single-rooted teeth without a periapical infection (Jansson et al, 1995b). A more recent study investigated the possible influence of apical periodontitis (AP) on the furcation depth in mandibular molars. This study showed that mandibular molars with apical periodontitis had a higher frequency of having ≥ 3 mm furcation depth than mandibular molars with a healthy apical periodontium. Mesial and distal pocket depth measurements in the two groups of mandibular molars were not statistically significantly different (Jansson and Ehnevid, 1998). Another retrospective study on periodontitis referral patients revealed that the frequency of angular bony defects was significantly higher with increasing severity of periapical disease; 12.8% of teeth without periapical infection displayed angular bony defects, as opposed to 26.7% of teeth with periapical infection (Jansson et al, 1993a). These studies have demonstrated that periapically infected teeth possessed a higher risk for having a marginal bone loss. The teeth examined in these studies were either single-rooted or mandibular molars.

There have, to our knowledge, been no studies investigating the association between marginal and apical periodontal conditions in the individual, nor any determining the risk of an individual having apical periodontitis when a general, reduced marginal bone level is present. In an individual-based study, it is possible to determine whether apical periodontitis is a risk indicator for a general, reduced marginal bone level, not necessarily present on the same tooth. If apical periodontitis in one or more teeth is a risk indicator for a general, reduced marginal bone level in the individual, the explanation could lie in non-tooth-related factors, such as immunologic deficiency, which would lead to further study of this interrelation.

The aim of this study was to identify risk indicators for a general, reduced marginal bone level in the individual, with particular emphasis on apical periodontitis and its interrelation with other tooth- and patient-related factors.

MATERIAL AND METHODS

The material consisted of 616 individuals (304 women and 312 men; 16023 teeth in total), randomly selected in 1997–1998 from Aarhus County, Denmark. The year of birth ranged from 1935 to 1975, with a mean age of 42 (range 21–63 years) (Table 1). For more details about the population sample, the reader is referred to Bahrami et al (2006).

Radiographic recording

All participants underwent a full-mouth radiographic survey consisting of 14 periapicals and two bite-wings, 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 were recorded according to the FDI nomenclature. All third molars were excluded from the study.

The periapical status of each tooth was assessed using the PeriApical Index (PAI) (Ørstavik et al, 1986) by one examiner (L-LK) who had been calibrated to this index (Kirkevang et al, 2001). Healthy periapical condition was defined as PAI scores 1 and 2 and apical periodontitis (AP) was defined as PAI scores 3, 4 and 5 (Table 2).

All other recordings (marginal bone level, fillings and inlays, and crowns and endodontic treatment) were performed by the first author (GB) (Table 2). Information on the participants' smoking habits was collected through a questionnaire.

Table 2 Displaying the code definitions for different variables

	Filling	Inlay	Crown	Endodontic treatment	Root resection (rr)	Periapical status
0	No filling	No inlay	No crowns	No endo	No rr	
1	Amalgam	Tooth-coloured inlay	Metal-ceramic crown	Endo	rr with apical filling	Normal periapical structures
2	Composite	Non-tooth-coloured inlay (fixed prothesis)	Metal		rr without apical-filling	Small changes in bone structure
3		Tooth-coulored inlay (fixed prosthesis)	Full ceramic crown			Changes in bone structure with some mineral loss
4		Non-tooth-coloured inlay (fixed prosthesis)	Metal-ceramic crown (bridge)			Periodontitis with well defined radiolucent area
5			Metal (fixed prosthesis)			Severe periodontitis with exacerbating features
6			Full ceramic (fixed prosthesis)			
8			Other (e.g. temporary crowns)			

The marginal bone level for each tooth was measured using a sliding digital calliper (16 ES, Carl Mahr Esslingen GmbH), and a viewer magnifying the image approximately 33% was used to view the radiographs. The measurements were read in mm, rounded off to the nearest 0.1 mm. The bone level measurements were performed at the mesial (A_m) and distal (A_d) part of the tooth, from the cemento-enamel junction to the most coronal part of the bone, at which the lamina dura had the normal width. 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 reference root in multi-rooted teeth was the radiographically imaged longest root in premolars, the distal root in mandibular molars, and the palatal root in maxillary molars. These measurements were used to calculate for each tooth:

Tooth marginal bone level in mm: $A_{tooth} = (A_m + A_d)/2$

and for each individual:

Individual mean marginal bone level in mm:

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

Fillings and inlays, crowns and endodontic treatment were assessed as present or non-present with the tooth as the unit.

The codes used for the recordings of all tooth-related independent variables are shown in Table 2.

Diagnostic thresholds for the tooth-related variables

The thresholds used for defining marginal bone level in the individual (A_{ind}) was: $A_{ind} < 3$ mm = normal marginal bone level, $3 \le A_{ind} < 4$ mm = borderline marginal bone level, $A_{ind} \ge 4$ mm = reduced marginal bone level. The thresholds for fillings and inlays per individual were: 0–7, 8–16 and 17–25. These thresholds were based on the distribution of number of fillings and inlays in the individual. Two groupings were selected for apical periodontitis: a dichotomous group = no AP and AP ≥ 1; and a group with three subgroups: no AP, 1 tooth with AP and ≥ 2 teeth with AP. The threshold for the other tooth-related variables (crowns, endodontic treatment) was defined as: none and ≥ 1.

The patient-related variables were gender, age and smoking habits. Age was divided into five groups

Table 3 Odds ratio (OR) with 95% confidence intervals (CI) and p-values (p) for various risk indicators estimating the individual's risk of having reduced marginal bone level

Variables	Category (n)	OR (initial), CI (p)	OR (intermed), CI (p)	OR (final), CI (p)	OR (final without AP), CI (p)
Gender	Women (304)	1	1		
	Men (312)	1.73, 1.04–2.87 (0.03)	1.84, 1.06–3.19 (0.03)		
Age	20-29 (113)	Omitted		Omitted, (*)	Omitted
	30-39 (154)	0.06, 0.01–0.47 (0.01)		0.08, 0.01–0.63 (0.02)	0.08, 0.01–0.61 (0.02)
	40-49 (168)	1		1	1
	50-59 (145)	4.14, 2.22–7.73 (0.00)		4.92, 2.37–10.20 (0.00)	5.72, 2.84–11.50 (0.00)
	60+ (36)	4.18, 1.74–10.04 (0.00)		3.03, 0.99–9.25 (0.05)	4.80, 1.65–13.94 (0.00)
Smoking	Yes (250)	8.82, 4.51–17.25 (0.00)	10.60, 5.14–21.87 (0.00)	10.49, 4.93–22.32 (0.00) (*)	10.07, 4.86–20.88 (0.00)
	No (355)	1	1	1	1
	Missing (11)				
Crowns	Yes (391)	2.43, 1.48–3.99 (0.00)	0.95, 0.55–1.66 (0.87)		
	No (225)	1	1		
Fillings and inlays	0-7 (125)	1			
	8-16 (353)	1.10, 0.58–2.09 (0.77)			
	17-25 (138)	0.97, 0.45–2.09 (0.93)			
AP (dich.)	Yes (259)	9.69, 4.98–18.85 (0.00)	4.66, 2.32–9.38 (0.00)	4.72, 2.20–10.12 (0.00)	
	No (357)	1	1	1	
AP (0,1, ≥ 2)	0 (357)	1	1	1	
	1 (130)	2.91, 1.23–6.88 (0.02)	1.74, 0.71–4.26 (0.22)	1.85, 0.68–4.98 (0.23)	
	2 (129)	19.91, 9.92–39.97 (0.00)	8.08, 3.86–16.91 (0.00)	7.51, 3.35–16.83 (0.00)	
Endodontic treatment	Yes (313)	2.61, 1.53–4.46 (0.00)	1.03, 0.57–1.87 (0.93)		
	No (303)	1	1		
Root resection	Yes (588)	0.57, 0.132–2.45 (0.45)			
	No (28)	1			

* For dichotomised apical periodontitis (AP)

(Table 1). The groups for smoking habits were: smokers and non-smokers.

Method validity evaluation

For evaluating the reproducibility of the measurements, a method error evaluation was performed. Five months into the radiographic registrations, with about half of the cases recorded, 20 individuals (514 teeth) were randomly selected from the cases, which were already registered, and a first reassessment of these cases was performed in a random order. A second reassessment of the same 20 cases was performed 14 months into the registration, when about three quarters of all cases had been recorded. A third reassessment of the same 20 cases was performed after 16 months, when all 616 cases had been recorded.

For evaluating the accuracy of the observer in recognising coronal restorations (fillings and inlays, and crowns) correctly in radiographs, 28 individuals (701 teeth) with coronal restorations were selected at random and examined clinically. The type of coronal restoration recorded clinically, fillings and inlays (n = 378) and crowns (n = 107), were compared with the recordings of the same teeth on radiographs. Using the clinical recordings as the 'gold standard', the sensitivities and specificities were calculated for fillings and inlays (0.98 and 0.96) and crowns (0.92 and 0.99). A kappa value for each type of coronal restoration was also calculated (fillings and inlays = 0.94, and crowns = 0.93).

Statistical analysis

The association between gender, age, smoking habits, number of fillings and inlays, crowns, endodontic fillings, root resection, periapical status and marginal bone level was analysed for both borderline and reduced marginal bone level.

Initially, crude estimates were obtained from a series of logistic regression analyses with reduced marginal bone level as the dependent variable, and each of the independent variables were fitted one at the time. In step two, a logistic regression analysis was performed, in which smoking and each of the abovementioned tooth-related variables, were entered into the model together with age and gender. Finally, we considered a logistic regression model that included all the independent variables that were statistically significant in step two. In the final analysis, we also fitted a model without apical periodontitis as an independent variable. The same procedure was used to analyse borderline marginal bone level. The level of significance was chosen as 5%.

RESULTS

The crude analyses showed that all variables, with the exception of root resection, had a statistically significant association with reduced marginal bone level, with age being highly significant. Age was highly significant with odds ratios (OR) between 0.62 and 4.2. The 20–29-year age group was omitted from the regression model because there was no individual suffering a reduced marginal bone level.

When the variables were adjusted for age in the analyses, the results were that all variables were non-significant except AP (OR = 4.7, 95% CI 2.2–10.1) and smoking (OR = 10.5, 95% CI 4.9–22.3).

The final logistic regression models contained the periapical status, smoking habits, age and gender as the independent variables, and reduced marginal bone level as the outcome variable. The risk indicators in the final model with reduced marginal bone level as the dependent variable were: AP (OR = 4.7, 95% CI 2.2–10.1), smoking (OR = 10.5, 95% CI 4.9–22.3) and age, which was an increasing risk indicator with increasing age (Table 3). When repeating the final regression model without AP as one of the independent variables, the results for smoking (OR = 10.1, 95% CI 4.9–20.8) and age were not significantly different from the model where all the variables were included (Table 3).

If the threshold ≥ 2 teeth with AP was used in the model, it was an even higher risk indicator for a reduced marginal bone level (OR = 7.5, 95% CI 3.4–16.8).

The same analyses were performed for borderline marginal bone level with results similar to the analyses for reduced marginal bone level, but with less pronounced odds ratios. The results for the final analysis were that ≥ 1 AP (OR = 2.4, 95% CI 1.5–3.9), smoking (OR = 7.0, 95% CI 4.1–11.9) and age had a significant association with borderline marginal bone level (Table 4). Also in this model, we found a stronger relationship if AP was defined as ≥ 2 teeth with AP in the model (OR = 3.6, 95% CI 2.0–6.4). The results for the final analysis without AP as an independent variable did not differ statistically significantly from the final analysis including all the independent variables (Table 4).

Table 4 Odds ratio (OR) with 95% confidence intervals (CI) and p-values (p) for various risk indicators estimating the individual's risk of having borderline marginal bone level

Variables	Category (n)	OR (initial), CI (p)	OR (intermed.), CI (p)	OR (final), CI (p)	OR (final without AP), CI (p)
Gender	Women (304)	1			
	Men (312)	1.22, 0.84–1.78 (0.29)			
Age	20–29 (113)	Omitted		Omitted (*)	Omitted
	30–39 (154)	0.21, 0.1–0.45 (0.00)		0.24, 0.11–0.53 (0.00)	0.23, 0.11–0.52 (0.00)
	40–49 (168)	1		1	1
.	50–59 (145)	45, 2.73–7.26 (0.00)		5.72, 3.19–10.25 (0.00)	6.59, 3.71–11.71 (0.00)
	60+ (36)	2.73, 1.29–5.79 (0.01)		2.39, 096–5.98 (0.06)	3.23, 1.34–7.82 (0.01)
Smoking	Yes (250)	4.86, 3.21–7.34 (0.00)	7.00, 4.17–11.78 (0.00)	6.97, 4.08–11.90 (0.00) (*)	7.12, 4.21–12.04 (0.00)
	No (355)	1	1	1	1
	Missing (11)				
Crowns	Yes (391)	2.29, 1.57–3.35 (0.00)	0.89, 0.56–1.39 (0.59)		
	No (225)	1	1		
Fillings and inlays	0–7 (125)	1	1		
	8–16 (353)	2.03, 1.17–3.53 (0.01)	0.63, 0.30–1.30 (0.21)		
	7–25 (138)	2.18, 1.17–4.07 (0.02)	0.46, 0.20–1.02 (0.05)		
AP (dich.)	Yes (259)	5.17, 3.43–7.79 (0.00)	2.61, 1.64–4.15 (0.00)	2.4, 1.45–3.98 (0.00)	
	No (357)	1	1	1	
AP (0,1, >2)	0 (357)	1	1	1	
	1 (130)	2.31, 1.37–3.89 (0.00)	1.42, 0.79–2.53 (0.24)	1.54, 0.83–2.86 (0.18)	
	2 (129)	110.37, 6.43–16.71 (0.00)	4.39, 2.56–7.53 (0.00)	3.55, 1.97–6.42 (0.00)	
Endodontic treatment	Yes (313)	2.92, 1.96–4.36 (0.00)	1.27, 0.79–2.03 (0.32)		
	No (303)	1	1		
Root resection	Yes (588)	1.86, 0.84–4.14 (0.13)			
	No (28)	1			

* For dichotomised apical periodontitis (AP)

DISCUSSION

Age, smoking and apical periodontitis were demonstrated to be highly significant risk indicators for a general reduced marginal bone level. The fact that age and smoking were related to a reduced bone level may not be surprising since these variables have been shown in many previous studies to be significantly associated with the marginal bone level (Amarasena et al, 2002; Bergström, 2004a; Bergström, 2004b; Craig et al, 2001; Grossi et al, 1995; Hugoson et al, 1992; Lavstedt et al, 1986; Khader et al, 2003; Papapanou et al, 1988). It is therefore even more interesting that when apical periodontitis was entered into the regression model along with these two known risk indicators, it still was highly significant, and the association between smoking, age and a reduced marginal bone level was not significantly altered. This result indicates a strong relation between apical periodontitis and the marginal bone level.

In other studies that have shown an association between periodontal bone support and apical periodontitis, the focus was on single teeth. A relationship was shown between an endodontically infected tooth and loss of its periodontal support, i.e. teeth with apical periodontitis had more severe loss of periodontal support than endodontically healthy teeth (Bergenholtz and Hasselgren, 2003; Jansson et al, 1995a). With the focus on the single tooth, there may be many possible explanations for the association between marginal and apical periodontitis, such as presence of accessory root canals, or removal of the protecting cement layer on the root as a result of instrumentation, which eases the passage of bacteria between the pulp and the marginal periodontium (Ehnevid et al, 1993a; Ehnevid et al, 1993b; Jansson and Ehnevid, 1998; Jansson et al, 1993a; Jansson et al, 1993b; Jansson et al, 1995b). Other previous studies have shown an epithelial down-growth of the marginal periodontium when a tooth is infected with endodontic pathogens, and demonstrated that the cementum has a role in protecting the marginal periodontium from getting infected via the dentine tubules (Blomlöf et al, 1992).

The design of the present study, however, had the individual as the statistical unit, and a multivariate analysis was used to take known risk indicators for a reduced marginal bone level into the same model as periapical disease. This means that the periapically infected teeth were not necessarily the teeth with the most severe reduction of the marginal bone level. We used a mean distance between the cemento-enamel junction and the alveolar bone of 4 mm as the threshold for a reduced marginal bone level, which means that for each individual, the average bone level between all teeth was 4 mm or more. The choice of bone level threshold was based upon the results of a previous study (Bahrami et al, 2006). It was evident from the results that individuals with one or more apical periodontitis lesion(s) had an almost five times higher risk of having a mean bone level ≥ 4 mm. Our study does not reveal a possible cause for this relationship. Whether apical periodontitis increases the risk of developing marginal bone loss, or vice versa cannot be determined by our study, due to the cross-sectional study design. The findings of this study might be the result of the before-mentioned tooth-related factors, such as accessory canals etc., but it is also possible that the answer lies elsewhere. There might be a common immunologic-related susceptibility for the two diseases, since the host defence is suspected to play a role in the pathogenesis of both periapical (Takahashi, 1998) and marginal periodontitis (Berglundh and Donati, 2005; Kinane and Lappin, 2002; Madianos et al, 2005).

Coronal restorations and endodontic treatment per se were not found to be risk indicators for a reduced marginal bone level, which is in accordance with other studies (Jansson and Ehnevid, 1998; Jansson et al, 1994).

The final conclusion from this study of a randomly selected population may be that, even when adjusted for age and smoking, individuals with periapical infection were at higher risk of having a reduced marginal bone level than those without periapical infection. Future longitudinal studies can provide new information on the disease entities, and allow a better understanding of the relationship between the two conditions.

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