Clin Oral Invest (2005) 9: 98–104
DOI 10.1007/s00784-005-0303-x

ORIGINAL ARTICLE

Hans-Peter Müller · Martin Ulbrich

Alveolar bone levels in adults as assessed on panoramic radiographs. (I) Prevalence, extent, and severity of even and angular bone loss

Received: 5 October 2004 / Accepted: 14 January 2005 / Published online: 16 April 2005

Abstract There is limited information regarding the prevalence and intraoral distribution of infrabony lesions potentially suitable for regenerative procedures in common patients seeking regular dental care in a dental practice. The aim of the present study was to investigate the prevalence and extent of alveolar bone loss and infrabony defects in randomly selected orthopantomograms of adult patients in different age groups seeking treatment at the dental service of the German Armed Forces. A total of 240 panoramic exposures were available for analysis, 60 in each of the age groups <30, 30–39, 40–49, and ≥50 years of age. At each tooth, distances between the cementoenamel junction or margin of restoration and the alveolar crest as well as the bone level were measured with a calliper to the next 0.1 mm. Whereas virtually no bone loss was present in the youngest age group, a major change in bone level frequency distributions occurred after age 30 years. At age 50 years, about 50% of subjects had considerable bone loss of more than 4 mm at 10% or more sites, and 6 mm or more at about 5% sites. Deep infrabony defects were infrequently found before age 40 years. About 20% of patients at least 50 years of age had radiographic evidence of infrabony pockets of 4 mm or more at not more than 5% of sites. Bone loss was more pronounced in the maxilla, especially at molars. In this predominantly male population, periodontal bone loss gradually increased with age. However, prevalence of infrabony defects was very low.

The opinions expressed in this article are those of the authors and cannot be construed as reflecting the views of the German Armed Forces' Medical Service, the German Armed Forces at large, nor the German Ministry of Defence.

H.-P. Müller (✉)
Faculty of Dentistry, Kuwait University,
PO Box 24923 Safat, 13110, Kuwait
e-mail: hp.muller@hsc.edu.kw
Tel.: +965-266-4502
Fax: +965-263-4247

M. Ulbrich
Dental Unit, German Armed Forces' Medical Centre,
Bonn, Germany

Keywords Periodontal bone loss · Infrabony defects · Prevalence · Extent · Panoramic radiographs

Introduction

An essential characteristic of destructive periodontal disease is loss of the tooth-supporting alveolar bone. In general, even (or horizontal) bone loss is differentiated from angular bony defects (or vertical bone loss). Since the bottom of the defect is apical to the alveolar crest, these defects are preferentially termed infrabony [23]. A prerequisite for the development of destructive periodontitis is bacterial deposits on involved teeth. Various, mostly gram-negative, anaerobes have been implicated in the pathogenesis of the disease [25]. Infrabony lesions seem to be mainly the result of anatomical characteristics, for instance the form and volume of alveolar bone [22]. In addition, periodontitis has been associated with occlusal trauma [17] and infected root canal systems [11].

It has been shown that meaningful advantages of complicated therapeutic measures—for example, guided tissue regeneration—can only be expected in specific, well-defined osseous lesions. Based on the results of a recent meta-analysis [12] of studies dealing with different surgical procedures for infrabony defects, it was concluded that these defects need to be deeper than, say, 3.5 mm in order to effectively exploit, in terms of clinically relevant additional attachment gain, beneficial potentials of regenerative procedures. The same group also emphasized that, because of the presence of one or more defects of that size, not more than 30% of the patients seeking regular dental care at a University Dental School could benefit from this kind of surgical intervention [19].

There is still limited information on the prevalence and intraoral distribution of infrabony lesions potentially suitable for regenerative procedures in common patients seeking regular dental care at a dental practice. The main objective of the present study was therefore to assess alveolar bone loss and the presence of infrabony defects on panoramic radiographs of patients of different age classes sampled at

Table 1 Number of teeth present and assessed by age group

Age group (year)	Number of teeth present		Number of teeth assessed	
	Mean±sd	Range	Mean±sd	Range
19–29	30.1±2.5	21–32	29.5±2.9	20–32
30–39	27.0±3.9	6–32	26.2±3.7	6–32
40–49	26.4±3.6	15–32	25.5±3.5	15–32
50+	24.7±5.1	6–32	24.0±5.0	6–32
	$p<0.001$		$p<0.001$	

the radiological archive of a dental unit at the German Armed Forces. The association of restorations, periapical condition, and other covariates with bone loss will be presented in a separate paper [15].

Materials and methods

Orthopantomograms from dentate patients in four age classes (under 30 years of age, 30–39, 40–49, and 50 years and older) were randomly selected from the radiological archive of the German Armed Forces' Medical Centre in Bonn, Germany, until 60 exposures were available for each age class. Radiographs with sufficient contrast and brightness were checked by one investigator (UM) for the presence of measurable distances between the tooth's cementoenamel junction or, if missing, another suitable landmark, and the alveolar bone crest, and the bottom of any periodontal defect. Orthopantomograms were eligible for analysis if the respective measurements could be made on more than 80% of the teeth. All films had been exposed to an X-ray source (Heliomat, Siemens, Bensheim, Germany) and automatically developed under controlled conditions (Periomat, Dürr Dental, Bietigheim-Bissingen, Germany). Enlargement factors of radiographs were calculated in a separate study. Steel balls with a defined diameter of 5 mm were fixed interdentally in a custom-made acrylic splint, and exposed. Images of the balls were measured in two dimensions. Vertical enlargement varied between 14–16% in regions of anterior teeth, 16–20% in premolar regions, and 22–28% in molar regions.

Radiographs were inspected in a darkened room on a viewing box (Maier, Garmisch-Partenkirchen, Germany). The following landmarks were identified at mesial and distal surfaces of any erupted tooth: (1) *coronal landmark* (CL): the interproximal projection of the cementoenamel junction or, if destroyed after restorative therapy, the apical termination of a restoration or crown margin; (2) *bone level* (BL): the most coronal interproximal projection of a periodontal ligament space with a constant width. If a periodontal ligament space was not visible, the observer had to choose a point where the alveolar crest crossed the root surface [3]; (3) if the observer was of the opinion that there was no infrabony lesion visible on the radiograph, BL was identical to the *alveolar crest* (AC). Otherwise, AC was measured as follows. The perpendicular from the most coronal part of the interproximal alveolar bone was raised to the root axis. The intersection between this perpendicular and the root surface was the second apical landmark, AC. Measurements of the distances between CL and BL, and AC and BL were made with a calliper to the next 0.1 mm. If one or more of these landmarks could not be determined, the tooth was excluded from the study. Whenever caries had destroyed the cementoenamel junction, the respective tooth was also excluded.

In addition to bone level measurements, possible furcation involvement of multirooted teeth, the condition of the apical periodontium and the quality of proximal restorations were graded. Respective results are reported in a companion paper.

A reliability study was conducted after intensive calibration of the principal observer. Two experienced periodontists were additionally involved. Twelve suitable orthopantomograms from all age categories were circulated among observers within 14 days.

Statistical analysis

Data acquired in the reliability study were analyzed according to Fleiss [7]. The intraclass correlation coefficient of reliability $R = \sigma_T^2/(\sigma_T^2 + \sigma_e^2)$ was estimated, where σ_T^2 is the true variance of distance and σ_e^2 is the variance of random error. The primary variables of the present study were the *bone loss* and the depth of *infrabony defect*. Using bitewing radiographs, it had been estimated that the normal distance between the cementoenamel junction and AC is 1.9 mm with 95% confidence [9]. Thus, bone loss was only assumed if the distance between CL and BL exceeded 2 mm. The orthopantomogram was the statistical unit. Patients' mean values and standard deviations were calculated. To describe differences in different age groups, one-way ANOVA was employed. Within-patient differences between mesial and distal sites were assessed by paired *t*-tests. Extent and severity of bone loss and infrabony defects was graphically displayed by bivariate quantile plots of frequency distribu-

Table 2 Mean (±standard deviation) of patient average mesial and distal bone loss (in mm) by age group

Age group (year)	Mesial		Distal		*p*
	Mean±sd	Range	Mean±sd	Range	
19–29	0.031±0.088	0.000–0.496	0.045±0.118	0.000–0.635	<0.05
30–39	0.432±0.755	0.009–4.383	0.462±0.769	0.013–4.350	<0.05
40–49	0.896±0.880	0.000–4.660	0.907±0.805	0.000–4.725	ns
50+	1.792±1.550	0.009–6.330	1.729±1.422	0.018–5.729	ns
	$p<0.001$		$p<0.001$		

ns not significant

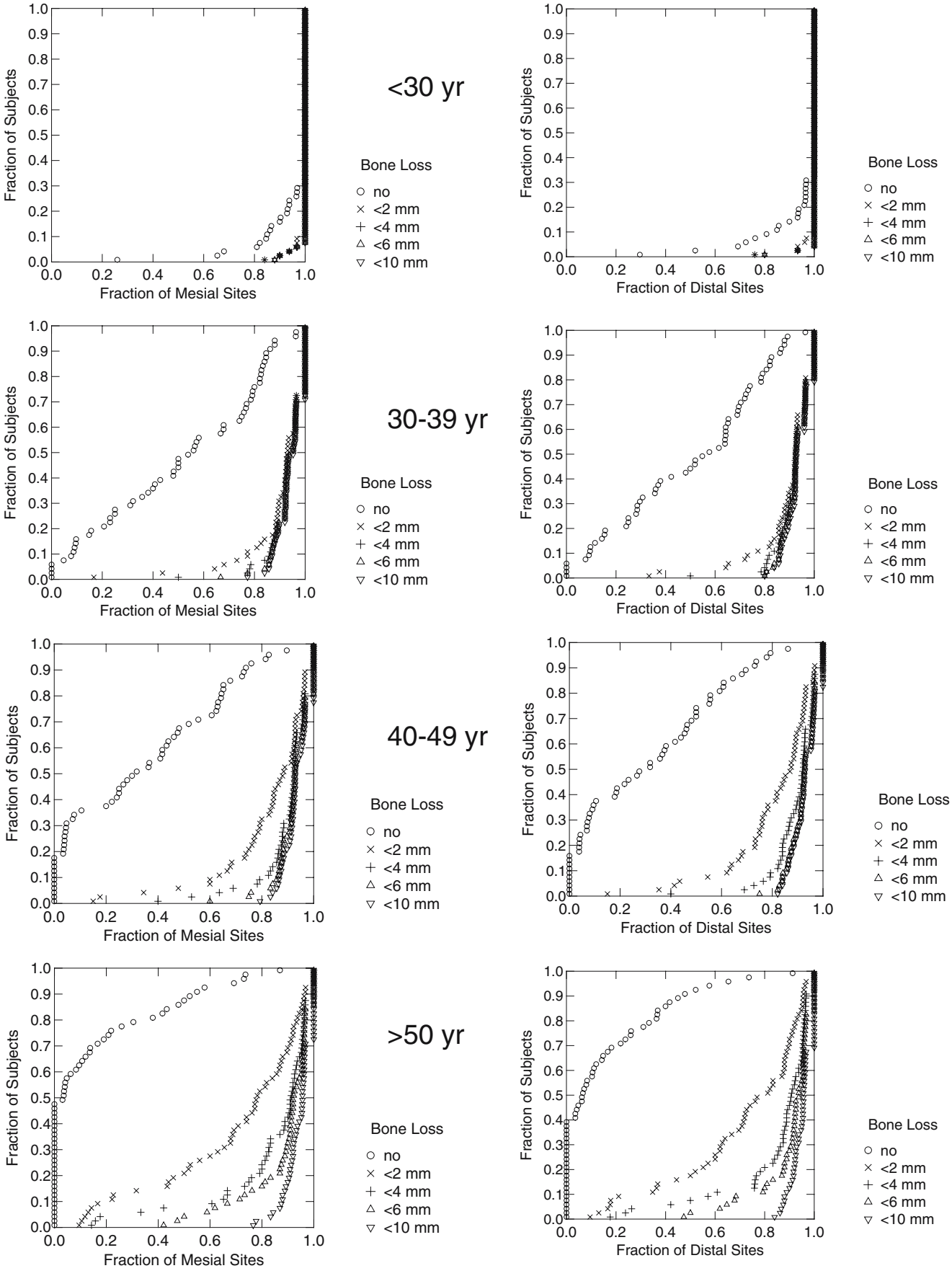

Fig. 1 Quantile plots (cumulative frequency plots) showing the percentage distribution of mesial (*left side*) and distal bone loss (*right side*) within subjects at different cut-offs of bone loss in different age classes

tions. A statistical programme was used (SYSTAT 8.0, SPSS, Chicago, IL, USA).

Results

The reliability study revealed a substantial intraclass correlation coefficient for bone level measurements of 0.725, indicating acceptable interexaminer reliability of measurements. Too few sites with infrabony, furcation and periapical defects were present for valid reliability estimation. Subsequent measurements were made by the principal examiner (UM).

Radiographs of mainly male patients (98%) between 19 to 62 years of age (mean±standard deviation 38.8±11.9 years) were examined. The mean ages in the different age classes were 22.4±2.3, 34.7±2.6, 44.7±2.9, and 53.5±3.0 years. A total of 6,490 teeth were present, and bone levels could be assessed at 6,309 (97%) (Table 1). There was a gradual and significant decrease in both parameters with increasing age. Mean bone levels also decreased with age, as shown in Table 2. In the two youngest age groups, slightly more bone loss, on average, was observed at distal sites than at mesial sites ($p<0.05$).

Figure 1 presents eight quantile plots indicating frequency distributions of bone loss at mesial (left side) and distal sites (right side) within subjects (extent) in different age groups. Different cut-offs of bone loss (severity) in different age classes were considered. There was a remarkable decrease of alveolar bone level from the youngest (up to 29 years of age) to the second youngest age group (30–39 years of age). For instance, in the youngest age group, bone loss was uncommon. In a small minority of subjects (about 5%) some bone loss (2 to 4 mm) was discernible in not more than 15–20% of sites. In subjects of the second youngest age group mild bone loss was more prevalent and more widespread. Virtually all of these subjects presented with some bone loss, and 20% had mild bone loss of up to 4 mm at 10% or more sites. In the oldest age group, about 50% of subjects had considerable bone loss of more than 4 mm at 10% or more sites, and bone loss of at least 6 mm at about 5% sites.

A somewhat different picture emerged when considering the infrabony component of bone loss. Except for patients in the youngest age group, this portion was about twice as deep at mesial than at distal sites on average (Table 3). This was especially obvious in the respective quantile plots (Fig. 2). Deep infrabony pockets of more than 4 mm were virtually not detected before age 40 years. About 20% of patients 50 years of age and older had radiographic evidence of infrabony pockets of 4 mm or more at not more than 5% sites. A total of 119 infrabony pockets of 4 mm or more (1% of sites) were found in 38 orthopantomograms (15.8%), two in one patient of the youngest age class, five in four patients 30–39 years of age, 25 in 15 patients between 40 and 49 years, and 36 in 18 older patients. The intraoral distribution of these rather deep infrabony defects is shown in Fig. 3. They were more or less exclusively found in the two oldest age groups, although usually not exceeding 4–8% of respective teeth.

Discussion

Different methods have been proposed to estimate bone loss due to periodontal disease on intraoral or panoramic radiographs. Calculating bone height relative to the root or tooth length [4, 6, 20, 21] may be the simplest way to assess periodontal destruction. This method is clearly too insensitive to uncover minimal catabolic or anabolic bone remodelling during relatively short periods of time. On standardized radiographs, linear measurements between the cementoenamel junction and the alveolar bone crest and bottom of defect can easily be made. The effect of X-ray beam vertical angulations on the alveolar crest level measurement has been studied [8], and tilting of the film during exposure can be avoided by using vertical bitewing radiographs [5]. While standardized intraoral radiographs are necessary to document, for example, small bone-level changes after therapy, panoramic radiographs provide a general overview of the extent and severity of periodontal disease and the distribution of osseous defects. They are invaluable tools for initial diagnosis and treatment planning. Because of the reduced radiation dose, panoramics are usually the only radiographs available in epidemiological surveys. As confirmed in the present pilot reliability study, bone level measurements could be reproduced sufficiently. Among the limitations of bone level measurements on orthopantomograms, varying image enlargements in different areas are of special concern. In the present study, enlargement varied between 14–16% in anterior and 22–28% in posterior areas of the dentition. For instance, a true 4 mm distance between anatomical landmarks would appear as 4.6 mm in anterior, but 5 mm in posterior regions, a difference of 0.4 mm. While measurements were generally made to the next 0.1 mm, results were mainly reported in millimetre categories (see Figs. 1, 2), taking into account the limited accuracy of the measurements.

Table 3 Mean (±standard deviation) of patient average infrabony component in mm by age group

Age group (year)	Mesial		Distal		*p*
	Mean±sd	Range	Mean±sd	Range	
19–29	0.006±0.035	0.000–0.247	0.007±0.037	0.000–0.262	ns
30–39	0.060±0.126	0.000–0.750	0.029±0.162	0.000–1.250	<0.05
40–49	0.149±0.225	0.000–1.165	0.065±0.161	0.000–1.090	<0.01
50+	0.311±0.395	0.000–1.940	0.165±0.258	0.000–1.056	<0.001
	$p<0.001$		$p<0.001$		

ns not significant

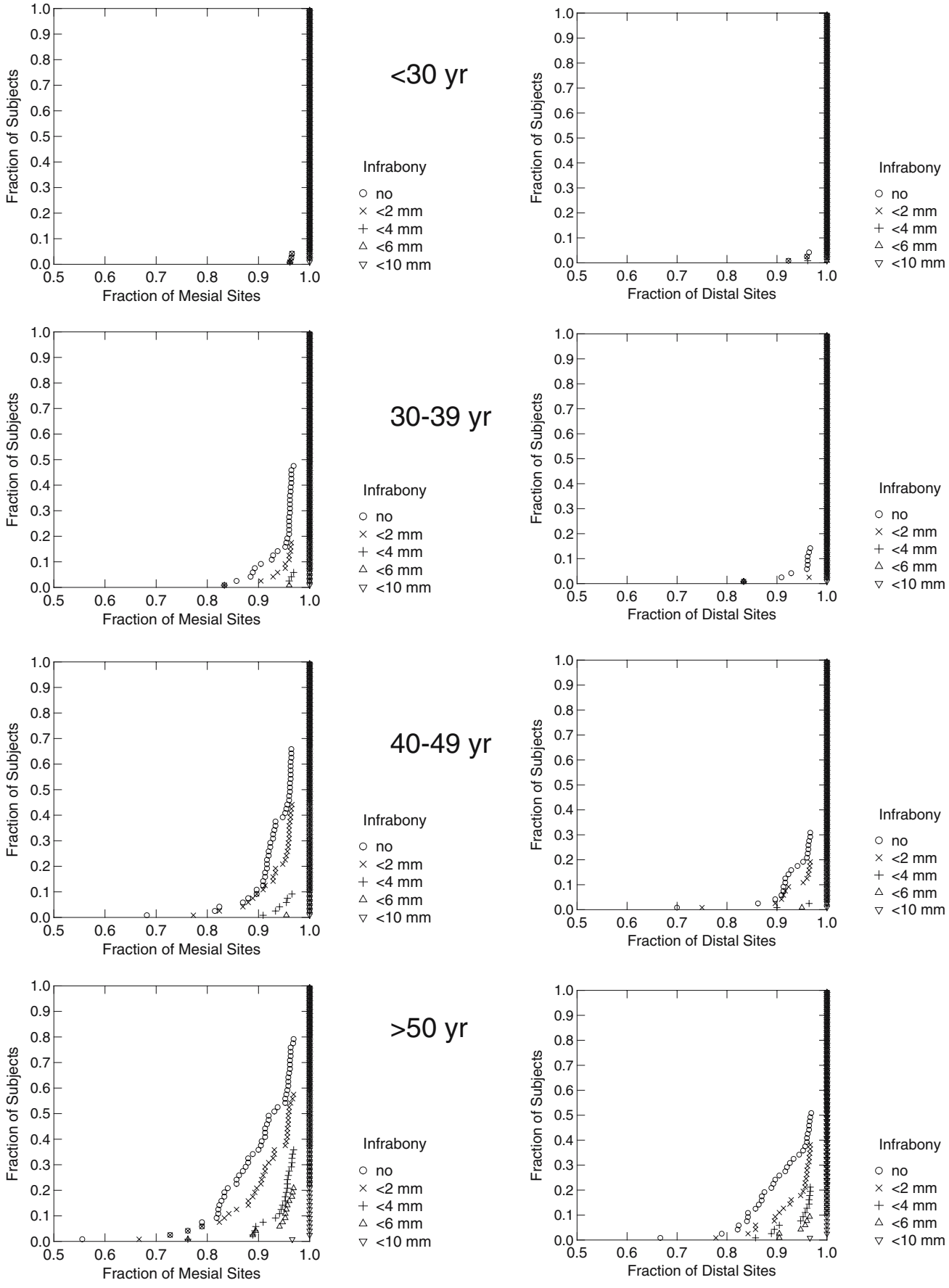

Fig. 2 Quantile plots of percentage distribution of mesial and distal infrabony defects

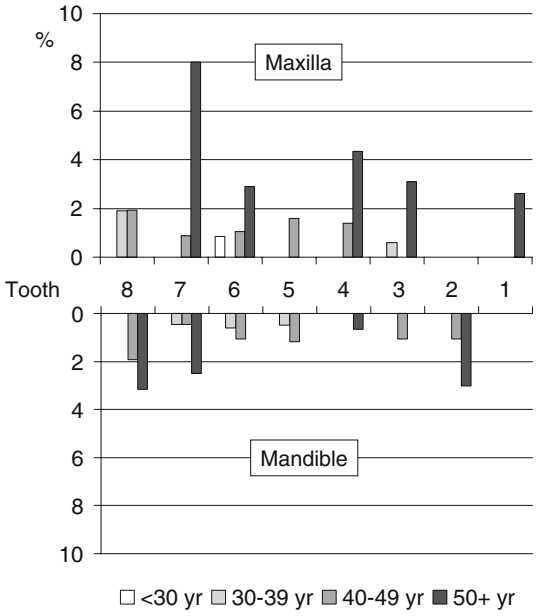

Fig. 3 Percentage of infrabony defects of 4 mm or more in different age groups by tooth type

The present study was conducted to gain more information on the prevalence, extent and severity, as well as the distribution of alveolar bone loss and infrabony defects possibly suitable for regenerative periodontal treatment. For this purpose, panoramic radiographs of dentate patients in four age classes (<30, 30–39, 40–49, and 50+ years) were randomly selected from a radiological archive of a greater Medical Centre of the German Armed Forces. One consequence of this sampling schedule (and a limitation on the generalization of results) was that most of the radiographs had been made in male patients. On the other hand, patients were not preselected for periodontal disease, as can generally be assumed in cases in which a full-mouth periapical status was indicated. Radiographic findings in this study might rather reflect oral conditions in common patients seeking all kinds of dental care. In a study with a similar purpose [19], bone levels on full-mouth periapical radiographs were assessed, which had been made in 416 individuals attending a University Dental Clinic over a defined period of time. At 47.2 years, the mean age was more than eight years higher than that in the present study. These authors looked, in particular, for infrabony defects suitable for regenerative periodontal procedures. From results of a previous meta-analysis, the same group had concluded that these defects should exceed 3.5 mm to predictably obtain benefits from regenerative procedures beyond what can be achieved from surgical debridement alone [12]. Among their study population, Persson et al [19] identified about 30% patients presenting with one or more infrabony defects of that size, in total 126 out of more than 10,000 teeth. Since bone loss is usually underestimated in periapical radiographs [1], their conservative threshold was set, however, to 3 mm. Although bone loss also seems to be underestimated on panoramic radiographs, a substantial mean enlargement of about 27% had been reported [1], whereas it varied between 15% in anterior regions and about 26% in molar regions in the present study. Therefore, on orthopantomograms, infrabony defects of 4 mm or more were to be identified. A total of 119 sites (1%) were affected, similar to the results of Persson et al [19]. One or more defects of that depth were found in 15.8% of patients, more or less exclusively in the two oldest age groups. A 3 mm threshold would not have altered this low prevalence, since only four additional defects had that respective depth. Thus, the lower percentage of patients presenting with this condition in our study might be explained mainly by the lower mean age of the patients. Prevalence of infrabony defects clearly generally depends on the definition of the critical size. For example, in another study of patients presenting for treatment in a Dental School, infrabony defects of 2 mm width and depth were found in 18% patients [16]. In a study on randomly sampled adults in Sweden [24], the authors reported a prevalence of patients with infrabony defects of at least 1 mm width and 2 mm depth of 32%. The overall impression of rather low prevalence of osseous lesions probably suitable for regenerative periodontal treatment is in line with a study on furcation involvement in patients attending a University Dental School [14]. In a retrospective analysis of data acquired in 558 patients with more than 1,100 furcation-involved teeth, who were treated by two periodontists over a period of six years, regenerative furcation therapy was indicated in only 20% and 27% patients and not more than 16% of diseased furcations.

In the present study, bone loss virtually did not occur before age 30, and average bone loss gradually increased at each decade up to 50 years and older, when it reached about 1.8 mm. Bearing in mind that bone level measurements of up to 2 mm were regarded as no bone loss (and limitations with interpreting cross-sectional data), an overall slow regression of bone level is in accordance with Persson et al [19] and several longitudinal studies on alveolar bone loss [2, 6, 10, 18]. A similar trend was observed with the depth of the infrabony component of bone loss, which seemed to be deeper at mesial than at distal sites. This observation could be supplemented in bivariate quantile plots illustrating frequency distributions of bone level measurements. Thus, infrabony defects were more prevalent at mesial than at distal sites, which is in accordance with other studies [19, 24]. There appears to be no compelling biological reason for this observation, but it may support the view that the development of periodontal disease in any site cannot be entirely explained by the etiological factors present [13]. Quantile plots of frequency distributions also showed decisive differences in bone level between the youngest and the second youngest age group. Bone loss became more widespread with age. Finally, it was also apparent that rather deep infrabony defects of 4 mm or more with a potential for superior healing after guided tissue regeneration were found in not more than 16% of the patients. They virtually only occurred after age 40 years, in a small percentage of sites. The association of bone loss with imperfect restorations, periapical lesions, and other covariates will be presented in a separate paper [15].

References

1. Åkesson L, Håkansson J, Rohlin M (1992) Comparison of panoramic and intraoral radiography and pocket probing for the measurement of the marginal bone level. J Clin Periodontol 19:326–332
2. Albandar JM (1990) A 6-year study on the pattern of periodontal disease progression. J Clin Periodontol 17:467–471
3. Benn DK (1992) A computer-assisted method for making linear radiographic measurements using stored regions of interest. J Clin Periodontol 19:441–448
4. Björn H, Halling A, Thyberg H (1969) Radiographic assessment of marginal bone loss. Odontol Revy 20:165–179
5. Duckworth JE, Judy PE, Goodson JM, Socransky SS (1983) A method for geometric and densitometric standardization of intraoral radiographs. J Periodontol 54:435–440
6. Eliasson S, Bergström J (1997) Minimum periodontal bone loss in dentally-aware adults. A 10-year prospective study. J Clin Periodontol 24:34–38
7. Fleiss JL (1986) The design and analysis of clinical experiments. Wiley, New York, pp 1–32
8. Hausmann E, Allen K, Christersson L, Genco RJ (1989) Effect of x-ray beam vertical angulation on radiographic alveolar crest level measurement. J Periodontal Res 24:8–19
9. Hausmann E, Allen K, Clerehugh V (1991) What alveolar crest level on a bite-wing radiograph represents bone loss? J Periodontol 62:570–572
10. Hugosson A, Laurell L, Lundgren D (1992) Frequency distribution of individuals aged 20–70 years according to severity of periodontal disease experience in 1973 and 1983. J Clin Periodontol 19:227–232
11. Jansson L, Ehnevid L, Lindskog S, Blomlöf L (1993) Relationship between periapical and periodontal status. J Clin Periodontol 20:117–123
12. Laurell L, Gottlow J, Zybutz M, Persson R (1998) Treatment of intrabony defects by different surgical procedures. A literature review. J Periodontol 69:303–313
13. Mombelli A, Meier C (2001) On the symmetry of periodontal disease. J Clin Periodontol 28:741–745
14. Müller HP, Eger T (1997) The overall significance of regenerative procedures in the treatment of furcations. Quintessence Int 28:321–328
15. Müller HP, Ulbrich M, Heinecke A (2004) Alveolar bone loss in an adult population as assessed on panoramic radiographs. (II) Multilevel models. Clin Oral Investig (submitted)
16. Nielsen IM, Glavind L, Karring T (1980) Interproximal periodontal intrabony defects. Prevalence, localization and etiological factors. J Clin Periodontol 7:187–198
17. Nunn ME, Harrel SK (2001) The effect of occlusal discrepancies on periodontitis. I. Relationship of initial occlusal discrepancies to initial clinical parameters. J Periodontol 72:485–494
18. Papapanou PN, Wennström JL, Gröhndahl K (1989) A 10-year retrospective study of periodontal disease progression. J Clin Periodontol 16:403–411
19. Persson RE, Hollender LG, Laurell L, Persson GR (1998) Horizontal alveolar bone loss and vertical bone defects in an adult patient population. J Periodontol 69:348–356
20. Salonen LWE, Frithiof L, Wouters FR, Helldén LB (1991) Marginal bone loss in an adult Swedish population. A radiographic cross-sectional epidemiologic study. J Clin Periodontol 18:223–232
21. Schei O, Waerhaug J, Lövdal A, Arno A (1959) Alveolar bone loss as related to oral hygiene and age. J Periodontol 30:7–16
22. Waerhaug J (1979) The infrabony pocket and its relationship to trauma from occlusion and subgingival plaque. J Periodontol 50:355–365
23. Weinberg MA, Eskow RN (2000) Osseous defects: proper terminology revisited. J Periodontol 71:1928
24. Wouters FR, Salonen LE, Hellden L, Frithiof L (1989) Prevalence of interproximal intrabony defects in an adult population in Sweden. A radiographic study. J Clin Periodontol 16:144–149
25. Zambon JJ (1996) Periodontal diseases: microbial factors. Ann Periodontol 1:879–925