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Severity and pattern of peri-implantitis-associated bone loss

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Abstract

Objective: The purpose of the present study was to describe the severity and pattern of peri-implantitis-associated bone loss.

Material and Methods: Intra-oral radiographs from 182 subjects were analysed. Bone-level measurements were performed in 419 implants with a history of bone loss. All radiographs obtained in the interval from the 1-year follow-up to the end-point examination (5–23 years) were analysed. The amount of bone loss that occurred from 1 year after prosthesis insertion was assessed and the pattern of bone loss was evaluated.

Results: The average bone loss after the first year of function was 1.68 mm and 32% of the implants demonstrated bone loss $\geqslant$2 mm. The multilevel model revealed that the bone loss showed a non-linear pattern and that the rate of bone loss increased over time. The model also revealed that the pattern of peri-implantitis associated bone loss was similar within the same subject.

Conclusion: It is suggested that peri-implantitis-associated bone loss varies between subjects and is, in most cases, characterized by a non-linear progression, with the rate of loss increasing over time.

Key words: bone loss; dental implants; multilevel analyses; peri-implantitis; radiographic measurements

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One of the main goals in implant therapy is to preserve tissue integration and thereby maintain bone support. Marginal bone loss is thus considered a critical outcome variable in the evaluation of implant therapy. It has been suggested that data on bone loss during the first year of function should be distinguished from that occurring during the subsequent period of service. According to the suggested success criteria for implants (Albrektsson et al. 1986, Albrektsson & Zarb 1993), marginal bone loss should not exceed 1.5 mm during the first year in function and should be $<$0.2 mm/year thereafter. A modification to these criteria that indicated a maximum bone loss of 2 mm between prosthesis installation and 5 years of follow-up was presented in a consensus report from the European Workshop on Periodontology in 1999 (Wennström & Palmer 1999). Whether certain amounts of bone loss around implants should be acceptable or not requires an understanding of the mechanisms involved in the process of bone resorption. Although the question on the aetiology of marginal bone loss around implants still has to be completely unravelled, previous studies have demonstrated the association between progressive bone loss during function and clinical signs of inflammation in peri-implant tissues (Roos-Jansåker et al. 2006, Fransson et al. 2008).

Conflict of interest and source of funding statement

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We have previously reported on the prevalence and extent of peri-implantitis-associated bone loss (Fransson et al. 2005, 2009). From the analysis of radiographs obtained from 662 subjects treated with implant-supported prosthesis, it was documented that 184 (27.8%) of the subjects had $\geqslant$1 implant with peri-implantitis-associated bone loss (Fransson et al. 2005, 2008). Within this group of subjects, about 40% of the implants were affected (Fransson et al. 2009). Using this subject sample, the purpose of the present study was to describe the severity and pattern of peri-implantitis-associated bone loss.

Material and Methods

Intra-oral radiographs of implants from 182 previously identified subjects were analysed. Among the total of 1070 implants, 419 were found to exhibit peri-implantitis-associated bone loss (for details, see Fransson et al. 2005, 2008, 2009). All subjects had been restored with fixed prosthesis supported by implants of the Brånemark system® (Nobel Biocare, Gothenburg, Sweden). Subjects, restored with removable prosthesis, i.e. overdentures, or who had received implant therapy in conjunction with osseous grafting or other augmentation procedures including the use of barrier membranes, were excluded. Furthermore, only implants with a function time of $\geqslant 5$ years were assessed in the present analyses.

In the radiographs of the 419 identified implants, the distance between the abutment–fixture junction and the most coronal position of bone to implant contact was assessed at the mesial and distal aspects using a magnifying lens ($\times$ 7) with a 0.1 mm graded scale. In cases where implants were displayed in different radiographs, the largest value for the distance was used. The measurements were performed on all radiographs obtained in the interval from the 1-year follow-up to the end-point examination (5–23 years).

Data Analyses

A mean value was calculated from the mesial and distal bone-level measurements of each implant and the amount of bone loss that occurred from year 1 was determined. In the absence of radiographs representing the 1-year follow-up, information was obtained from the 2-year examination. In 25 of the 419 implants (12 of 182 subjects), neither 1- nor 2-year data were available and these implants were hence excluded from the analyses regarding bone-level changes. For the remaining 394 implants, the cumulative percentage of implants with different amounts of bone loss after year 1 was calculated.

Because of the hierarchical structure (subjects/implants) of the data and the considerable variation regarding the follow-up time between subjects as well as the number of and time between radiographic examinations, a conventional regression analysis was not applicable. In order to facilitate the analysis of bone loss patterns, a multilevel *growth curve model* was built using the bone level of the implant as the dependent variable (Snijders & Bosker 1999). The levels that were identified for the hierarchical analysis were the subject ($n = 182$), the implant ($n = 419$) and the event of the radiographic examination (measurement occasion; $n = 1785$). The lowest level units were the implant bone-level data obtained from the radiographic examinations during follow-up, and the time-point of each examination was included as an explanatory variable. First, the hypothesis of a linear relation between bone loss and time was tested. Second, a curved relation model was built and compared with the linear model. In addition, the multilevel analysis included modelling the complex variance structures at the different levels.

Regression coefficients were estimated using iterative generalized least squares (IGLS), and the significance of each covariate was tested using a Wald test. Nested models were tested for significant improvements in model fit by comparing the reduction in -2LL (-2 log likelihood) with a χ^2 distribution.

A statistical package designed for multilevel modelling (MLwiN 2.10©, Centre for Multilevel Modelling, University of Bristol, UK) was used.

Results

The mean follow-up time for the 419 implants was 11.1 years. After the first year in function, the mean number of radiographic examinations was 4.2 (range 1–9) and the mean bone loss was 1.68 ± 1.32 mm. The cumulative % of implants in relation to bone loss is presented in Fig. 1. Bone loss $\geqslant 1$ mm occurred in 68% of the implants, while 32% of the implants exhibited $\geqslant 2$ mm bone loss after the first year in function. Bone loss of $\geqslant 3$ mm was observed in 10% of the implants.

Multilevel Model Building

The outcome of the model building is reported in Table 1. The null or the empty model, which did not include any covariate, resulted in a predicted bone level of -2.96 mm across all subjects, implants and examinations. 14% of the total variance was attributed to variation between subjects, 10% to variation between implants within subjects and the remaining 76% was due to variation in bone levels between examinations. A linear relation between bone level and time was then tested, which significantly improved the model ($p < 0.0001$). The intercept revealed a predicted mean bone level of -2.25 mm at year 1 and a predicted mean bone loss of 0.15 mm/year. This time trend accounted for about 50% of the variance between examinations. The introduction of polynomial terms to the power of three (curved model) based on the time of the radiographic examination significantly improved the model as indicated by a reduction in -2 log-likelihood ($p < 0.0001$; χ^2 test with two degrees of freedom). In order to explore the random part at the subject level, the linear, quadratic and cubic coefficients of time were allowed to vary randomly across the subjects, providing a unique growth trajectory for each subject. The introduction of complex variation at the subject level reduced the variance at the lowest level (measurement occasion) by 42% and the model fit improved significantly ($p < 0.0001$; χ^2 test with nine degrees of freedom). Furthermore, the random part at the implant level was modelled with the linear and the quadratic terms, further reducing the lowest level variance by 45%. The measurement occasion variance in this model was 84% lower than in the null model. The introduction of complex random variation at the implant level significantly improved the fit of the model ($p < 0.001$; χ^2 test with five degrees of

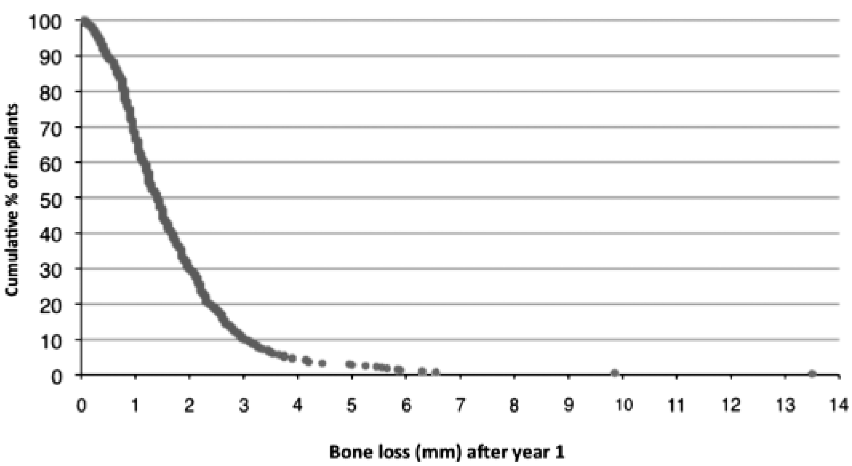

Fig. 1. The cumulative percentage distribution of implants in relation to bone loss after year 1.

Table 1. Multilevel model building with marginal bone level as the dependent variable

	Empty model	Standard error	Linear model	Standard error	Polynomial model	Standard error	Polynomial random	Standard error
Fixed part								
Intercept	− 2.960447	0.048034	− 2.247512	0.052731	− 2.147343	0.056864	− 2.140931	0.044273
Time			− 0.151378	0.003983	− 0.231876	0.020836	− 0.252922	0.028879
Time^2					0.009666	0.002991	0.014323	0.005634
Time^3					− 0.000269	0.000111	− 0.000456	0.000271
Random part								
Level: subject								
var (cons)	0.196420	0.044523	0.227191	0.047387	0.219293	0.046443	0.155326	0.038101
cov (t/cons)							− 0.007669	0.017191
var (t/t)							0.082786	0.015185
cov (t^2/cons)							0.001639	0.003276
cov (t^2/t)							− 0.015262	0.002831
var (t^2/t^2)							0.003028	0.000558
cov (t^3/cons)							− 0.000123	0.000156
cov (t^3/t)							0.000634	0.000127
cov (t^3/t^2)							− 0.000130	0.000026
var (t^3/t^3)							0.000006	0.000001
Level: implant								
var (cons)	0.146445	0.036332	0.267297	0.035884	0.267849	0.035766	0.290713	0.035289
cov (t/cons)							− 0.017023	0.009816
var (t/t)							0.022291	0.004394
cov (t^2/cons)							0.000752	0.000782
cov (t^2/t)							− 0.001568	0.000342
var (t^2/t^2)							0.000134	0.000028
Level: measurement occasion								
var (cons)	1.071489	0.040667	0.524132	0.019977	0.517929	0.019741	0.077131	0.018516
cov (t/cons)							− 0.006066	0.011779
var (t/t)							0.016765	0.007785
cov (t^2/cons)							0.000000	0.000000
cov (t^2/t)							− 0.001031	0.000422
var (t^2/t^2)							0.000068	0.000028
− 2 × loglikelihood:	5519.20		(1) 4536.68		(2) 4516.21		(3) 3722.85	

(1) The linear model is significantly different from the empty model ($p<0.0001$).
(2) The polynomial (curved) model is significantly different from the linear model ($p<0.0001$).
(3) The polynomial random model is significantly different from the polynomial (curved) model ($p<0.0001$).
var, variate; cov, covariate; cons, constant.

freedom). Finally, the random part at the lowest level was modelled with the linear and the quadratic terms. Again, the introduction of complex random variation at the measurement occasion level significantly improved the fit of the model ($p<0.0001$; χ^2 test with five degrees of freedom).

Thus, the multilevel growth model building revealed that (i) bone loss over time showed a non-linear pattern, (ii) the rate of bone loss increased over time and (iii) the variance increased with time for all levels and was, after 19 years, mostly due to variation between subjects.

Predicted Bone Levels Over Time

The change of predicted bone levels over time is illustrated in Fig. 2. Each line represents one implant, while the red line depicts the mean predicted bone-level change. The predicted average bone level (95% C.I.) was − 2.15 mm (− 2.06, − 2.24) at year 1, − 2.95 mm (− 2.83, − 3.06) at year 5, − 3.60 mm (− 3.46, − 3.75) at year 10, − 4.10 mm (− 3.84, − 4.35) at year 15 and − 4.64 mm (− 3.76, − 5.52) at year 20. The total variance (Fig. 3) increased with time, and after 19 years in function, most of the variability was attributed to differences between subjects (Fig. 4).

Different bone loss patterns at implants in eight different subjects are illustrated in Fig. 5. In type A, the bone-level change was modest during the first years in function, while after 7/11 years, pronounced bone loss varying between 3 and 10 mm occurred during a 2–6-year period. The type B pattern was characterized by an overt bone loss of about 2–3 mm during the first 10 years in function, followed by a period of more gradual bone loss. In type C, the implants exhibited varying amounts of bone loss during the initial 10–15 years. A distinct bone-level change indicating some gain of bone support occurred around the implants in these two subjects after 13 and 17 years in function, respectively. A further analysis of the files of the two subjects revealed that the bone gain coincided with the treatment of peri-implantitis. The implants representing type D demonstrate varying amounts of continuous bone loss during the entire follow-up period. A general finding for the different patterns of bone loss, which was also supported by the current model of analysis, was that implants with peri-implantitis-associated bone loss within the same subject presented a similar pattern of bone loss.

The analysis of the current material revealed that one subject exhibited

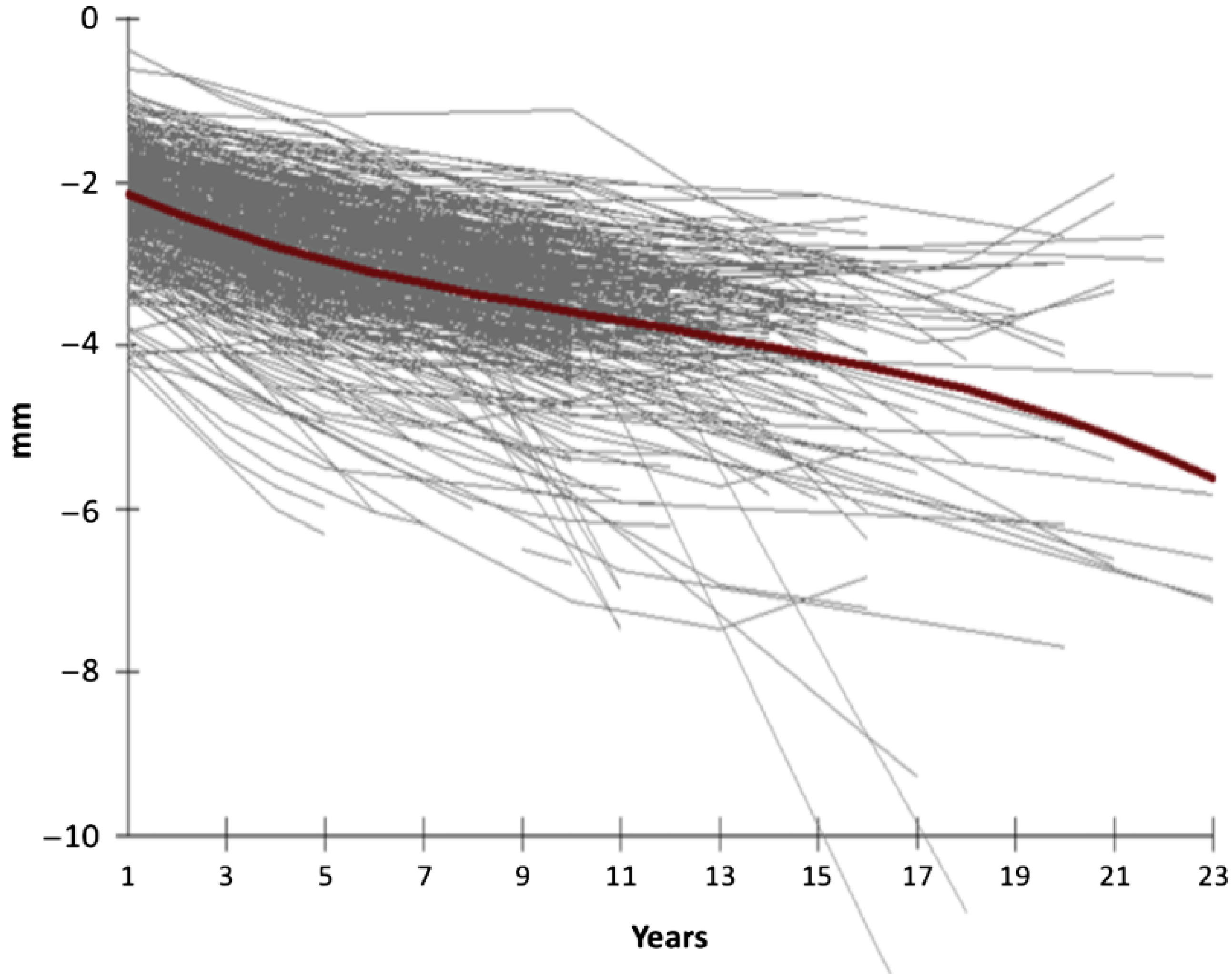

Fig. 2. Predicted bone-level changes over time. Each line represents one implant. The red line indicates the mean predicted bone level.

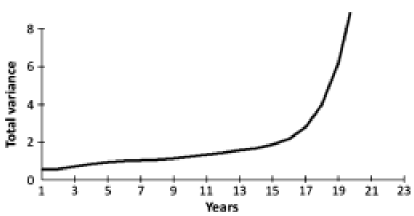

Fig. 3. Change in total variance of all levels over time.

implants with considerably more bone loss than others. When this subject was considered an outlier, repeated analyses of all data excluding this subject yielded similar results.

Discussion

In the present study, the severity and pattern of peri-implantitis-associated bone loss was described. The average bone loss after the first year of function was 1.68 mm, and 32% of the implants demonstrated bone loss ⩾2 mm. The multilevel model revealed that the bone loss showed a non-linear pattern and that the rate of bone loss increased over time. The model also revealed that the pattern of peri-implantitis-associated bone loss was similar within the same subject. It is suggested that peri-implantitis-associated bone loss varies between subjects and is, in most cases, characterized by a non-linear progression, with the rate of loss increasing over time.

The severity of peri-implantitis-associated bone loss was addressed in a cross-sectional study by Roos-Jansåker et al. (2006). They analysed the prevalence of peri-implantitis among 216 subjects at 9–14 years after implant placement. While at least 56% of the subjects had ⩾1 implant with peri-implantitis, 25% of all implants in the group exhibited bleeding on probing, together with bone loss of varying amounts after the first year of function. The amount of bone loss in the study by Roos-Jansåker et al. (2006) was expressed as the number of peaks of an implant thread of the Brånemark System®, indicating a distance of about 0.6 mm between peaks. Although no mean value of bone loss after year 1 was presented, the relative proportion of implants with peri-implantitis that exhibited bone loss of ⩾3 peaks of a thread was about 27%. Their finding regarding the proportion of affected implants with bone loss ⩾1.8 mm accords with the current study, in which 32% of the affected implants had bone loss ⩾2 mm.

The hierarchical data structure and the large heterogeneity regarding the number of and time between examinations as well as the time of follow-up in this study prompted the use of multilevel modelling for data analysis. A similar approach was presented in studies reporting on periodontal disease progression. Thus, Albandar & Goldstein (1992), in a model paper, suggested that multilevel models had several advantages over unilevel methods, such as statistical validity and efficiency. The ability to incorporate explanatory variables at different levels into multilevel modelling was also pointed out. Gilthorpe et al. (2003) and Tu et al. (2004) applied multilevel modelling in the analysis of periodontal disease progression in a cohort of 100 young males. It was reported that the model provided new information on the dynamic hierarchical system of periodontal disease progression and that both ''linear'' and ''burst'' concepts had validity at different levels of this system.

While the multilevel growth model in the current study revealed that bone loss over time had a non-linear pattern and that the rate of bone loss increased over time, it also indicated that the variance increased with time for all levels and was, after 19 years, mostly due to variation between subjects. Thus, the validity of the results obtained from the multilevel analysis appears to be consistent up to 17 years of function. The results also revealed that the most common pattern of peri-implantitis-associated bone loss in the current study was type A (Fig. 5), indicating a modest bone-level change during the first years in function, followed by pronounced bone loss towards the late phase of the function period. Other patterns of peri-implantitis-associated bone loss were also observed in the present material and different forms of progression of peri-implantitis may therefore occur. In a review, Schwartz-Arad et al. (2005) suggested four different hypothetical implant bone loss patterns. Data on mean marginal bone loss after varying periods of function were obtained from 15 studies. One of the patterns in the review by Schwartz-Arad et al. (2005) described the traditional concept of a low-rate marginal bone loss over time, whereas a second pattern reflected an initial period of a low rate of bone loss, followed by a rapid loss of bone support. A third pattern of bone-level change was a high rate of initial bone loss, followed by almost no bone-level change, while a fourth type described a continuous high rate of bone loss leading to complete loss of bone support. It should be taken into account that the four different patterns of bone loss in the review by Schwartz-Arad et al. (2005) were hypothetical and assessed on data presented for all implants in the studies, irrespective of variation in bone-level changes between implants. This concern regarding interpretation of data is important and underlines the necessity for a critical approach regarding the appraisal of information on bone-level changes.

In the current study, it was also demonstrated that variations in peri-implantitis-associated bone loss were related to variations between subjects. Thus, the different patterns of disease progression suggested in the current study may reflect differences between individuals. The implants that represented the pattern of type C (Fig. 5) had varying amounts of bone loss during the initial phase, followed by a period of bone gain, which occurred after surgical treatment of peri-implantitis. In a previous study (Fransson et al. 2008), we reported on the clinical characteristics in 84 of the 182 subjects included in the present study. Analysis of patient files revealed that 19 (23%) of the 84 examined subjects received surgical treatment for peri-implantitis.

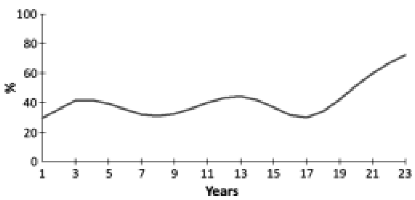

Fig. 4. Percentage distribution of variance at the subject level in relation to the total variance over time.

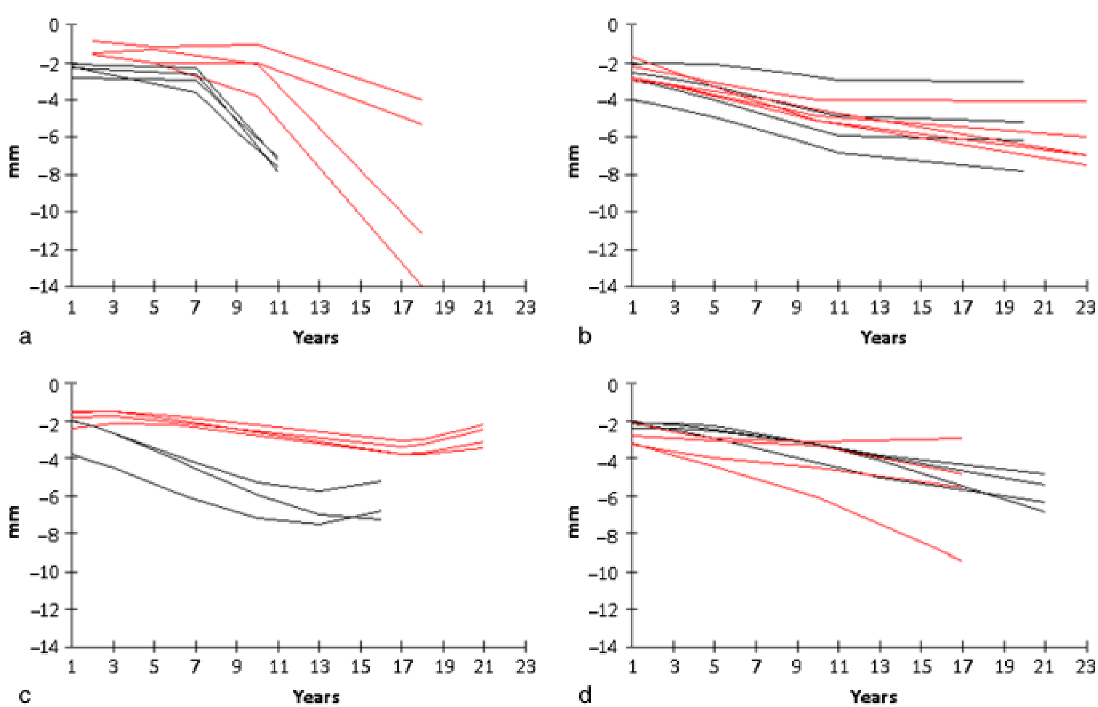

Fig. 5. Different bone loss patterns at implants in eight different subjects. Lines with the same colour represent implants in one subject.

The average marginal bone loss around the affected implants after the first year in function in the present study was 1.68 mm. Given the findings that peri-implantitis-associated bone loss showed a non-linear pattern and that the rate of bone loss increased over time in the present study, the commonly used calculation on annual bone loss for the function period of implants becomes redundant and misleading. The approach of using annual bone loss, however, was also used in the description of progression of periodontitis around teeth. In a classical longitudinal study, Löe et al. (1986) reported on natural progression of periodontitis in a Sri Lanka population. Of the 161 subjects examined at the 15-year follow-up, 8% exhibited rapidly progressive periodontitis, while 81% showed moderate disease progression. The remaining 11% of the subjects presented minimal signs of disease progression. In the group of subjects with rapidly progressive periodontitis, the calculated annual bone loss varied between 0.1 and 1.0 mm. In the large group of moderately progressive periodontitis, the annual bone loss varied between 0.05 and 0.5 mm. Norderyd et al. (1999), in a study on periodontal disease progression during 17 years in 357 adults in Jönköping County, Sweden, reported that the average annual bone loss was 0.06 mm. The annual bone loss, however, differed between subjects and was 0.03 mm for subjects with no progression of disease, 0.06 mm for the ''intermediate group'' and 0.12 mm for the severe disease progression group.

In a longitudinal study, Schätzle et al. (2003) reported on patterns on attachment loss in a well-maintained Norwegian population. While 25% of the subjects had stable periodontal conditions over the 26-year period, the remaining 75% exhibited slight to moderately progressing rates varying between 0.02 and 0.1 mm/year. Thus, the description of annual bone loss does not reveal the pattern of disease progression in periodontitis and peri-implantitis. Comparisons of the values on annual bone loss presented in the longitudinal studies on teeth above and data obtained from the present study are difficult because the analysis on peri-implantitis-associated bone loss was restricted to affected implants only. On the other hand, the general concept of using annual bone loss around implants as a criterion for implant success may be questioned as the suggested values of <0.2 mm annual bone loss after the first year in function (Albrektsson et al. 1986) may include levels of bone loss that correspond to the progression of rapid and moderate forms of periodontitis.

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Clinical Relevance

Scientific rationale for the study: Peri-implantitis is an increasing problem in dentistry. While data on the prevalence and extent of the disease have been presented, there is a lack of information regarding its severity. In the present study, the severity and pattern of peri-implantitis-associated bone loss were reported.

Principal findings: The average bone loss around the affected implants after the first year of function was 1.68 mm and 32% of the implants demonstrated bone loss $\geqslant 2$ mm. The bone loss showed a non-linear pattern and the rate of bone loss increased over time. Furthermore, the pattern of peri-implantitis-associated bone loss was similar within the same subject.

Practical implications: Clinicians should be aware that the rate of peri-implantitis-associated bone loss may increase over time.