Marginal Bone Loss Around Implants Supporting Fixed Restorations

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A key criterion of success following dental implants is the marginal bone level. Long-term clinical and radiographic evaluation is necessary to test the results of in vitro studies investigating how cantilevering of restorations or implant size affect bone level changes around implants. There is no consensus on the effect of several variables such as age, gender, implant size, and cantilever prostheses on marginal bone levels around fixed dentures supported by dental implants. Patients who received cemented, fixed restorations supported by implants and who were examined in routine recall sessions 6, 12, 24, and 36 months after loading were included in the study group. Comparative bone level measurements were obtained from images of radiographs at ×20 magnification using the CorelDraw 11.0 software program. Statistical analysis was performed using the Student *t* test and 1-way analysis of variance. In the 36-month observation period, there were no incidences of implant failure, excessive bone loss around implants, or peri-implant inflammation. One hundred twenty-six implants in 36 patients were evaluated, and the effect of several factors on marginal bone loss (MBL) during the 36 months after loading was analyzed statistically. There was no significant relationship between MBL and implant length or diameter, whereas age, gender, and cantilevers affected bone loss rates. MBL was elevated in older and female patients as well as in patients who received cantilevers. In cases of limiting anatomic conditions, short and/or narrow implants should be preferred over cantilever extensions.

Key Words: marginal bone loss, cantilever, size of implant, patient age

Introduction

Long-term clinical evaluation of dental implants is crucial for gaining more information about causes of implant success and failure. One of the most important criteria is the marginal bone level around implants.[1] Since bone-anchored prostheses are planned to be sustained in the oral environment for a lifetime,[2] a pathologic decrease in bone level could lead to loss of bone anchorage of the implant, and it is important to know what factors contribute to bone resorption.

Controversy exists about several variables influencing implant success and especially marginal bone loss (MBL). The size of the implants,[3–14] age and gender of patients,[15–19] and the presence of cantilevers[20–32] as influencing factors are subject of debate.

In this retrospective clinical study, the impact of these factors on MBL surrounding implants with fixed restorations was evaluated over a 36-month period following loading.

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DOI: 10.1563/AAID-JOI-D-10-00018

Figure 1. Nonstandardized radiography used for bone level measurement.

Materials and Methods

The study group included 36 patients with 126 implant-supported fixed restorations, who appeared for routine recall sessions 6, 12, 24, and 36 months after loading. Information was given to each patient regarding alternative treatment options. All subjects were required to be at least 18 years old, able to read and sign the informed consent document, physically and psychologically able to tolerate conventional surgical and restorative procedures, and willing to return for follow-up examinations as outlined by the investigators.

Four different brands of implants were used: 47 Astra Tech (Astra Tech AB, Mölndal, Sweden), 40 ITI Standard Plus (Institut Straumann AG, Basel, Switzerland), 10 Swiss-Plus (Zimmer Dental, Carlsbad, Calif), and 29 BioLok (Biohorizons, Birmingham, Ala).

The implants were all put in place by the same surgeon following the manufacturers' recommendations and were restored by various prosthodontists at a university clinic. All patients received fixed restorations ranging from single crowns to full-arch bridges (Figure 1).

The implant sites included all mandibular and maxillary positions. The implant loading period was 36 months. Data recorded for all implants included the patient's age and gender, the diameter and length of the implant, and the presence or absence of a cantilever.

Forty-six implants in 16 patients had been supporting a fixed prosthesis with a cantilever. In 10 patients, 2 implants were supporting the cantilever, whereas in 6 patients 3 or more implants have been the support. Recall sessions were routinely performed 6, 12, 24, and 36 months after loading. At each recall visit, a clinical examination was performed by the same examiner.

Panoramic radiographs (Planmeca, Proline XC, Helsinki, Finland) were taken preoperatively, immediately after surgery, immediately after loading, and at every recall session. Intraoral radiographs were taken if visual assessment of the marginal bone attached at the distal and mesial surfaces for all implants was not possible with magnified panoramic radiographs. Mesial and distal marginal bone levels of all implants were determined during baseline and recall evaluations. Currently, the best method of measuring marginal bone levels around implants is examination of scanned and digitized conventional radiographs,[33,34] which were used in the present study. Measurements were obtained from images of successive radiographs that had been scanned and digitized (Epson 1680, Pro-Seiko Epson Corp, Nagano, Japan), and were analyzed at ×20 magnification using CorelDraw 11.0 software (Corel Corp and Coral Ltd, Ottawa, Canada). The implant diameter at the collar region, as specified by the manufacturer, was used as a reference point. The distance from the widest supracrestal part of the implant to the crestal bone level was measured on the magnified images. To account for variability, the implant width was measured and compared with the documented dimensions, and ratios were calculated to adjust for distortion. Bone levels were determined by applying a distortion coefficient (true bone height = [true implant width][measured bone height]/measured implant diameter). The actual bone level

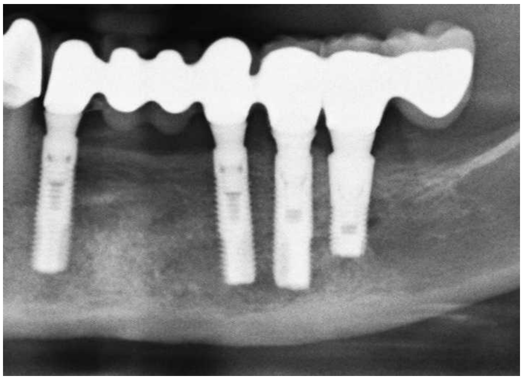

FIGURE 2. Fixed restorations supported by implants.

measurement was performed independently by 2 examiners, a prosthodontist and a specialist in oral and maxillofacial radiology. The average from both examiners' calculations was used as the marginal bone level value. The level at which the marginal bone appeared to be attached was assessed visually at the distal and mesial surfaces for all implants (Figure 2). The radiographs were reviewed by 2 examiners on 2 separate occasions, 1 week apart. The radiographs were available to none of the examiners between the first and second viewings. In addition, the examiners' measurements made at the first testing were not available during the second testing. During the first review, the observers did not know that they would be retested. Intraobserver reliability was determined via comparison of the measurements decided on by each individual observer for the first and second testing sessions. Interobserver reliability was assessed via comparison of the measurements decided on by the 2 different examiners. Statistical analyses were used to assess mean MBL changes at 6, 12, 24, and 36 months and to explore the potential effect of various parameters on bone loss. NCSS 2007 and PASS 2008 statistical software (NCSS, Kaysville, Utah) was used. The following clinical parameters were assessed relative to MBL: peri-implant parameters, demographic parameters (age and gender), implant brand, implant diameter and length, presence or absence of cantilever, and implant location. Descriptive statistics (means and standard deviations for continuous variables, frequencies for categorical variables) were used to analyze all implants as well as each type of implant. Quantitative data were compared using a one-way analysis of variance test, and comparisons between groups with normal distributions and outlier groups were detected with the Tukey honestly significant difference test. For comparison of the 2 groups with normal distributions, the Student *t* test was used. For analysis of repeated measures, variance analysis, and detection of the outliers, the paired sample *t* test was used. The results were assessed at 95% confidence interval, at a significance level of .05.

RESULTS

During the 36-month observation period, there was no incidence of implant failure or excessive bone loss around implants and no recorded peri-implant inflammation. One hundred twenty-six implants in 36 patients (21 female patients with 73 implants and 15 male patients with 53 implants; mean age 54.97 $\pm$ 12.24 years, minimum 18 years and maximum 68 years) were evaluated, and the effect of several factors on MBL during the 36-month period after loading was analyzed statistically.

No statistically significant differences in MBL changes were observed between male and female patients in the first 24 months ($P > .05$). By month 36, however, female patients showed higher MBL than male patients ($P < .05$) (Table 1).

There was a significant difference between age groups in the average distal and mesial bone loss at month 6, with patients 45 years of age and younger showing lower MBL than patients 60 years of age and older ($P < .01$) (Table 2). There were no differences in distal ($P = .360$) and mesial ($P = .211$)

TABLE 1

Relation between marginal bone loss (mean values and SD in mm) and gender

		Male	Female	t	P†
Distal	6-month	0.47 ± 0.11	0.48 ± 0.12	−0.195	.845
	12-month	0.83 ± 0.16	0.87 ± 0.16	−1.241	.217
	24-month	0.91 ± 0.16	0.95 ± 0.15	−1.516	.132
	36-month	0.96 ± 0.16	1.01 ± 0.15	−2.047	.043*
F		383.535	843.388		
P‡		.001**	.001**		
Mesial	6-month	0.46 ± 0.11	0.45 ± 0.11	0.222	.825
	12-month	0.81 ± 0.16	0.82 ± 0.14	−0.126	.900
	24-month	0.88 ± 0.16	0.92 ± 0.16	−1.372	.172
	36-month	0.93 ± 0.16	0.99 ± 0.16	−1.996	.048*
F		379.324	772.286		
P‡		.001**	.001**		

†Student t test.
‡Variance analysis for repeated measurements.
*$P < .05$; **$P < .01$.

bone loss rates between 45- and 60-year-old patients and patients over 60 years of age at month 6. However, by month 12, the overall and mesial bone loss levels of patients 45 years of age and younger were significantly lower than those of the 46- to 60-year-old group ($P = .033$ and $P = .005$, respectively) and the over 60-year-old group ($P = .044$ and $P = .004$, respectively). There was no significant difference between the 46- to 60-year-old group and the over 60-year-old group, either in overall ($P = .099$) or mesial ($P = .988$) bone loss levels.

By month 24, mesial bone loss averages differed significantly between age groups ($P < .05$), with those of the 45 years of age and under group significantly lower those of the 46- to 60-year-old group ($P = .029$). There was no difference in mesial bone loss levels between the over 60-year-old group and either the under 45-year-old group ($P = .137$) or the 45- to 60-year-old group ($P = .612$).

There was no significant difference in mesial bone loss averages between month 24 and 36 month for any age group ($P > .05$). However, the mesial bone loss averages

TABLE 2

The influence of patient age on marginal bone loss (mean values and SD in mm)

		Age, y				
		≤45	46–60	>60	F	P†
Distal	6-month	0.39 ± 0.14	0.48 ± 0.11	0.51 ± 0.11	6.681	.002**
	12-month	0.76 ± 0.21	0.87 ± 0.15	0.87 ± 0.15	3.256	.032*
	24-month	0.85 ± 0.20	0.96 ± 0.15	0.94 ± 0.14	3.355	.038*
	36-month	0.92 ± 0.18	1.02 ± 0.16	0.98 ± 0.14	3.305	.040*
F		196.462	867.988	184.094		
P‡		.001**	.001**	.001**		
Mesial	6-month	0.39 ± 0.14	0.45 ± 0.10	0.48 ± 0.09	5.301	.006**
	12-month	0.70 ± 0.19	0.83 ± 0.14	0.83 ± 0.13	6.054	.006**
	24-month	0.83 ± 0.28	0.93 ± 0.14	0.90 ± 0.13	2.495	.087
	36-month	0.91 ± 0.26	0.99 ± 0.14	0.95 ± 0.14	2.285	.106
F		145.034	621.099	385.65		
P‡		.001**	.001**	.001**		

†One-way analysis of variance.
‡Variance analysis for repeated measurements.
*$P < .05$; **$P < .01$.

Table 3

The influence of implant diameter on marginal bone loss (mean values and SD in mm)

		Implant Diameter, mm				
		<4	4–4.5	>4.5	F	*P*†
Distal	6-month	0.44 ± 0.12	0.48 ± 0.10	0.51 ± 0.14	2.730	.069
	12-month	0.81 ± 0.18	0.87 ± 0.13	0.87 ± 0.18	1.879	.157
	24-month	0.89 ± 0.18	0.95 ± 0.13	0.96 ± 0.18	2.050	.133
	36-month	0.95 ± 0.17	1.00 ± 0.14	1.02 ± 0.15	2.258	.109
F		310.357	623.246	156.240		
P‡		.001**	.001**	.001**		
Mesial	6-month	0.42 ± 0.10	0.47 ± 0.10	0.46 ± 0.12	2.004	.139
	12-month	0.77 ± 0.15	0.85 ± 0.14	0.81 ± 0.15	2.798	.065
	24-month	0.86 ± 0.16	0.92 ± 0.14	0.93 ± 0.20	2.246	.110
	36-month	0.92 ± 0.15	0.98 ± 0.15	1.00 ± 0.19	2.070	.131
F		311.808	686.695	128.161		
P‡		.001**	.001**	.001**		

†One-way analysis of variance.
‡Variance analysis for repeated measurements.
***P* < .01.

differed significantly between age groups at month 36 ($P < .05$). For instance, mesial bone loss rates of patients under 45 years of age were significantly lower than those of patients 46 to 60 years old ($P = .036$). There was no significant difference between the over 60-year-old group and either the under 45-year-old ($P = .297$) or the 46- to 60-year-old ($P = .329$) age groups.

The length and diameter of the implants were measured and their effects on MBL were analyzed statistically. There was no significant association between implant diameter (Table 3) or implant length (Table 4) and mesial and distal bone loss averages at month 6, 12, 24, and 36 ($P > .05$).

There was no significant association between the presence of cantilevers and mesial and distal bone loss averages at month 6 ($P > .05$). However, by month 12, the mesial ($P < .05$) and distal ($P < .01$) bone loss in the presence of cantilevers was significantly higher. Similarly, mesial and distal bone loss at month 24 was higher in the presence of cantilevers ($P < .05$). At month 36, the distal bone loss with

Table 4

The influence of implant length on marginal bone loss (mean values and SD in mm)

		Implant Length, mm			
		≤10	>10	*t*	*P*†
Distal	6-month	0.51 ± 0.11	0.48 ± 0.12	0.639	.524
	12-month	0.92 ± 0.12	0.85 ± 0.16	1.117	.266
	24-month	0.98 ± 0.11	0.93 ± 0.16	0.659	.511
	36-month	1.03 ± 0.12	0.99 ± 0.16	0.781	.436
F		299.445	928.743		
P‡		.001**	.001**		
Mesial	6-month	0.46 ± 0.09	0.45 ± 0.11	0.038	.970
	12-month	0.82 ± 0.13	0.81 ± 0.15	0.064	.949
	24-month	0.88 ± 0.13	0.91 ± 0.17	−0.473	.637
	36-month	0.96 ± 0.16	0.97 ± 0.16	−0.119	.905
F		167.530	866.332		
P‡		.001**	.001**		

†Student *t* test.
‡Variance analysis for repeated measurements.
***P* < .01.

TABLE 5

The influence of cantilever on marginal bone loss (mean values and SD in mm)

		Cantilever, mm			
		Absent	Present	*t*	*P*†
Distal	6-onth	0.46 ± 0.12	0.50 ± 0.11	−1.672	.097
	12-month	0.82 ± 0.17	0.90 ± 0.13	−3.090	.002**
	24-month	0.90 ± 0.17	0.98 ± 0.14	−2.543	.012*
	36-month	0.96 ± 0.16	1.03 ± 0.15	−2.367	.020*
F		458.502	744.055		
P‡		.001**	.001**		
Mesial	6-month	0.44 ± 0.11	0.47 ± 0.10	−1.181	.240
	12-month	0.79 ± 0.16	0.85 ± 0.12	−2.393	.018*
	24-month	0.88 ± 0.18	0.94 ± 0.12	−2.030	.044*
	36-month	0.95 ± 0.18	0.99 ± 0.15	−1.482	.141
F		414.924	760.729		
P‡		.001**	.001**		

†Student *t* test.
‡Variance analysis for repeated measurements.
$*P < .05$; $**P < .01$.

cantilevers was higher ($P < .05$), whereas the mesial bone loss was not significantly affected by the presence of cantilevers ($P > .05$) (Table 5).

There was no incidence of excessive bone loss at implants, and there was no recorded incident of peri-implant inflammation.

Discussion

The aim of this study was to examine the effect of several variables on MBL around dental implants supporting fixed restorations. In spite of lack of consensus on what factors affect MBL, the generally accepted guidelines for implant-induced bone loss since the late 1980s are less than 1.5 mm for the first year after implant loading and less than 0.2 mm for each additional year.[35,36] However, other studies have suggested that these guidelines may be too lax, especially for young implant patients.[15] Indeed, significant variability in MBL following dental implants has been reported. There are studies describing a mean crestal bone loss of 0.6 mm for the first year and 0.2 mm for the following years up to 36 months after implant loading.[37,38] Mean annual losses of 0.03–0.05 mm have also been reported,[38,39] and some studies have reported no change or even gains in bone level for individual implants.[40–42] Implant surface roughness has been shown to balance bone apposition and facilitate remodeling at the bone-implant interface, thereby minimizing crestal bone loss.[43–46] In our study, the bone loss rate was about half of that suggested by Albrektsson et al,[35] possibly due to the use of rough surfaced implants.

No significant differences in marginal bone level changes were observed between male and female patients in the first 24 months ($P > .05$), consistent with results from a previous study.[19] By month 36, however, female patients showed higher MBL than male patients ($P < .05$). Further studies observing a larger number of patients over a longer period of time are necessary to investigate this further.

According to a 4-year clinical follow-up study, elderly and young patients should expect similar levels of oral implant success.[15] However, only implant survival was examined in this study, with no mention of the condition of the surrounding bone and soft tissues. While another study showed comparable bone level changes for younger and older patients,[16] others report that bone and soft tissue healing after implant placement can be compromised by aging.[17,18] In the present study, the MBL was found to proceed more slowly in patients under 45 years of age, possibly due to lower bone vascularity and healing potential in older individuals. Moreover, although clinicians generally expect more bone loss around dental implants in women of increased age due to hormonal changes, few clinical studies have examined the effect of gender on bone loss, and in one study, no gender differences were found.[19]

Stress distribution in the surrounding bone has been reported to depend on the dimensions of the implant,[3–7] as the implant directly affects the area of possible bone retention.[8] It has been recommended that implants be as long and as wide as possible within the anatomic limitations of the patient.[9] Although a number of investigators reported higher rates of loss in shorter implants,[10,11] and the importance of implant length in sustaining the load of fixed restorations has been pointed out,[21] there are also studies where implant length was reported to have little influence on the amount of stress in vertical loading[6] and to have a smaller effect on stress distribution in the bone than the implant diameter.[8,13] Indeed, finite element method (FEM) analysis of implants has shown stress reduction with increasing diameter,[8] and radiographically measured bone loss for 4.0-mm diameter implants has been found to be less than for 3.5-mm implants.[14] However, in the present study, neither the diameter ($P > .05$) nor the length ($P > .05$) of the implant caused a significant impact on MBL. Thus, once implant stability and successful osseointegration are established, MBL is not influenced by implant size. An important result of the present study was that in the presence of cantilevers, MBL after the first year had been significantly higher.

As well known, in partially dentate patients with bone deficits or limiting anatomic structures, such as expanded maxillary sinuses or a high mandibular canal, 2 options for treatment with fixed prostheses may be considered: bone augmentation or rehabilitation of the partially edentulous site with cantilever extensions (Figure 3). Mechanical studies have demonstrated that implant-supported cantilevers can induce stress concentration in the supporting alveolar bone,[20,21] which might lead to excessive bone resorption under functional occlusal loads, especially around the implant shoulder, thus resulting in failure.[22–26] In a more recent FEM study,[19] cantilevers longer than 9 mm were found to significantly contribute to bone stress. Another FEM study showed that the maximum von Mises stress occurred at the most distal bone/implant interface on the load side, and significantly increased with the length of the cantilever.[28] Most studies using FEM analysis on cantilever extensions showed higher stress at implants adjacent to the cantilevers compared with implants distant to cantilevers. Highest stress values were found in the cortical bone at the surface of the implant facing the cantilever.[20,29] On the other hand, several clinical studies have reported that cantilevers do not lead to a higher implant failure rate or to increased bone loss around supporting implants.[30–32] The outcomes of a recent systematic review showed that fixed partial dentures with cantilever extensions represented a predictable treatment modality.[47]

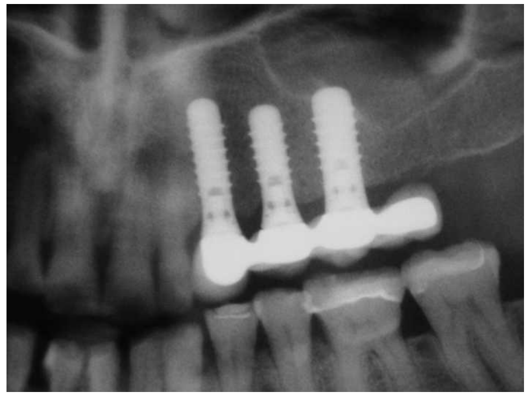

Figure 3. Use of cantilever extensions due to anatomic limitations.

No major detrimental effects with respect to peri-implant tissues were observed at implants in the proximity of cantilever extensions. However, in another recent systematic review it was pointed out that the incorporation of cantilevers into implant-borne prostheses may be associated with a higher incidence of minor technical complications.[48]

Radiography is important for routine clinical practice and in research projects evaluating dental implants. In particular, radiographic measurements of the marginal alveolar bone level change over time have been reported to be important parameters.[49] Different methods have been used to assess bone height in the implant region, from simply counting the number of threads on screw-type implants to using a computer-based interactive image analysis system. Panoramic radiographs of the jaws and the teeth are widely used as a simple and fast method of evaluating the condition of the bone around implants.[50–55] A recent study showed that panoramic radiographs were as reliable as conventional intraoral radiographs when used to assess the point of bone attachment to implant threads.[56] Thus, provided that the images are of high quality, the radiographic examination of choice for assessing the marginal bone level is the panoramic radiograph.[55,57] Moreover, the interobserver agreement in marginal bone assessment from intraoral and panoramic radiographs was investigated in several studies.[58,59] The authors concluded that reliability can be improved by one observer making multiple readings or by multiple observers making several independent readings. This approach limits the effects of single observers who may be outliers. In the present study, we have preferred to use 2 readings of 2 observers to increase the reliability.

The bone loss documented here measured the reduction of the bone levels at the mesial and distal sides of the implants and ignored the so-called saucerization of the crestal bone around the neck of the implants, since only 2-dimensional imaging was used. To obtain data on vestibular crestal bone changes, a 3-dimensional imaging technique such as volumetric tomography is necessary. Nevertheless, since panoramic radiographs have been reported to be a simple and reliable method of measuring bone level changes,[55–57] they were used in this study in the routine recall sessions of all patients and supplemented in cases of insufficient quality with intraoral radiographs. To ensure reliable bone loss measurements, a prosthodontist and a specialist in oral and maxillofacial radiology assessed the bone levels in the radiographs.

Although further studies observing a larger number of patients are necessary, our results prompt discussion about whether small diameter or short implants should be preferred over cantilevers when anatomic limitations make standard-sized implants impossible.

Conclusions

Within the limitations of this study the following conclusions were drawn:

(1) The size of the implants supporting fixed prostheses does not influence marginal bone levels after 36 months.
(2) MBL was higher in older patients at all recall sessions and in female patients after the second year.
(3) In the presence of cantilevers, MBL occurring after the first year in fixed restoration-supporting implants was higher.

Abbreviations

FEM: finite element method
MBL: marginal bone loss

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