The Role of Timing of Loading on Later Marginal Bone Loss Around Dental Implants: A Retrospective Clinical Study

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The aim of this study was to assess the relation between marginal bone loss (MBL) around dental implants after a loading period of 36 months and the timing of loading. A total of 87 patients with 252 implants were included in the study group. The time span from implant placement to beginning of loading of the implants was evaluated. Delay of loading of implants seems to increase MBL around dental implants as the result of disuse atrophy. Implants next to a tooth on 1 or 2 sides suffered less from MBL. No statistically significant difference in MBL rate was noted between single and splinted implants or between smooth collar and microgeometry neck implants. Results of this study encourage early loading, especially for the mandibular overdenture supporting implants.

Key Words: marginal bone loss, timing of loading, dental implants, early loading, panoramic radiograph

INTRODUCTION

Different concepts of loading for dental implants have been proposed in the literature. The original protocol included healing periods of 3 and 6 months before loading for the mandible and maxilla, respectively.[1–4] More recently, healing periods have been reduced to minimize treatment time. Immediate/early loading therefore is an attractive treatment modality, and numerous clinical follow-up studies have been published on this topic during the past 10 years.[5] On the basis of reviews of the literature, it has generally been concluded that this is a safe procedure in the anterior mandible, and immediate/early loading for other indications is not well documented.[5,6]

One of the most important success criteria that should be evaluated is the marginal bone level around implants.[7] Long-term clinical evaluation of dental implants and their superstructure is crucial, and measurement of marginal bone loss (MBL) over time is regarded as a sensitive tool for evaluation of the clinical performance of implants because gradual loss of marginal bone eventually will lead to implant failure. A pathologic decrease in bone level could lead to loss of bone anchorage of the implant. During the first year, marginal bone resorption of a maximum of 1.5 mm has been accepted, whereas MBL of 0.2 mm annually is considered acceptable for subsequent years.[8,9]

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In a recent review comparing bone reactions of immediate loaded implants vs those of conventional loaded ones, the following findings were discussed.[10] Immediately loaded implants showed approximately 0.6 mm bone loss in the first 12-month period, and the same amount or more in the second year. In contrast, conventionally loaded implants exhibited almost the same loss as immediately loaded implants in the first year but smaller magnitudes of loss in the second year. Early-loaded implants showed the least amount of bone loss in the first and second 12-month periods. It is unknown from this review whether bone loss continues beyond 24 months or becomes stable. This limits the ability to draw any conclusions beyond this period, and long-term follow-up studies are awaited.

The aim of this retrospective study was to assess the relation between the MBL around dental implants after a loading period of 36 months and the timing of loading and draw conclusions.

MATERIALS AND METHODS

Patient enrollment and clinical procedures

A total of 87 patients with 252 implants, who appeared in routine recall sessions consecutively at 6, 12, 24, and 36 months after loading, were included in the study group. Information was given to each patient regarding alternative treatment options. All subjects were required to be (1) at least 18 years old, (2) able to read and sign the informed consent document, (3) physically and psychologically able to tolerate conventional surgical and restorative procedures, and (4) willing to return for follow-up examinations as outlined by the investigators.

All implants were placed by the same surgeon and were restored by several prosthodontists at the University of Istanbul, Faculty of Dentistry, Department of Prosthodontics.

The fixed restorations and mandibular overdentures were evaluated separately.

The loaded implants were investigated in 2 groups: smooth collar implants (Straumann, Waldenburg, Switzerland; Swissplus, Zimmer Dental, Carlsbad, Calif) and microgeometry neck implants (Astratech, Mölndal, Sweden; Biolok-Biohorizons, Birmingham, Ala).

Implant sites included all interforaminal mandibular anterior positions for overdenture (OVD) support in the overdenture group (51 patients: 34 female and 17 male; mean age, 59.39 ± 9.99 years, with 126 implants), whereas all mandibular and maxillary anterior and posterior positions were found in the fixed restored group (36 patients: 21 female patients with 73 implants and 15 male patients with 53 implants; mean age, 54.97 ± 12.24 years, with 126 implants). In the fixed restored group, 106 implants were splinted, whereas 20 have been single. In the OVD group, the implants had no neighboring teeth, but in the fixed restored group, the neighboring teeth were recorded so their influence on MBL could be evaluated. A total of 81 implants had no neighboring teeth, 32 implants had 1 neighboring tooth, and 13 implants had teeth on both sides (mesially and distally).

The loading period was 36 months for all evaluated implants. The time span from implant placement to beginning of loading of the implants in the removable restored group was evaluated in 4 classifications ($<$60 days, 60–90 days, 91–140 days, $>$140 days), and the fixed restored group in 3 ($<$91 days, 91–180 days, $>$180 days). The groups were selected in such a manner that the implant counts were evenly distributed for better statistical assessment.

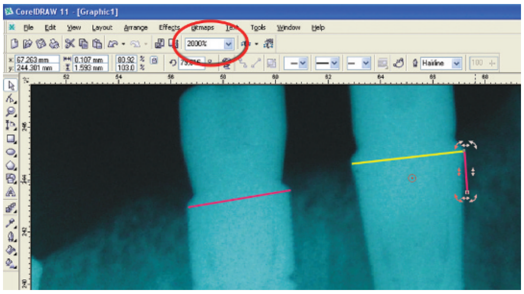
Clinical examination

Recalls were routinely performed 6, 12, 24, and 36 months after loading. At each recall session, a clinical examination was performed by the same examiner.

The following clinical parameters were recorded: plaque index (PI), sulcus bleeding index (SBI), peri-implant probing depth (PD), and peri-implant MBL. The PI was recorded visually with the aid of a probe moved along the abutment surfaces. For each implant, the presence of plaque was scored on 4 surfaces (0 = no plaque; 1 = plaque on probe; 2 = plaque on implant seen by the naked eye; 3 = abundance of soft matter).[11] The SBI, defined as bleeding elicited 20 seconds after a periodontal probe is moved 1 mm into the mucosal sulcus parallel to the abutment wall, was scored (0 = no bleeding; 1 = isolated bleeding spots visible; 2 = blood forms a confluent red line on margin; 3 = heavy or profuse bleeding). PD was measured with a periodontal probe (PW, Hu-Friedy, Chicago, Ill) at 4 sites around each abutment. After baseline scores were recorded, the periodontal examination was performed at each recall session, and the scores were recorded.

Radiographic evaluation and bone level assessment

Panoramic radiographs (Planmeca, Proline XC, Helsinki, Finland) were taken preoperatively, immediately after surgery, immediately after loading, and at every recall session. In cases of insufficient quality, intraoral radiographs were taken as well. Mesial and distal marginal bone levels of all implants were determined at baseline and recall evaluations. Measurements were obtained from images of successive radiographs, which were scanned and digitized (Epson 1680 Pro, Seiko Epson Cooperation, Nagano, Japan) before, and were analyzed at ×20 magnification with the use of a software program (CorelDraw 11.0, Corel Corp and Coral Ltd, Ottawa, Canada) (Figure 1). The known diameter of the implant at the collar region according to the manufacturer's dimensions of the respective implants was used as a reference point. The distance from the supracrestally widest part of the implant to crestal bone level was measured on the magnified images. To account for variability, the implant dimension (width) was measured and compared with the documentation dimensions; ratios were calculated to adjust for distortion. Bone levels were determined by applying a distortion coefficient (true bone height is equal to true implant width multiplied by bone height as measured on the radiograph, which is then divided by the implant diameter measured on the radiograph). The actual bone level measurement was performed independently by 2 examiners (a prosthodontist and a specialist in oral and maxillofacial radiology). The average from the 2 examiner calculations was used as the marginal bone level value. The level at which the marginal bone seemed to be attached was assessed by visual evaluation at the distal and mesial surfaces of all implants.



x: 67.263 mm
y: 244.301 mm
0.107 mm
1.593 mm
80.92 %
103.0 %
2000%
Hairline

FIGURE 1. Bone level measurement was performed on scanned and digitized radiographs with 2000% magnification in Corel Draw 11.0 software.

Statistical analyses

Statistical analyses were utilized in this study to assess mean marginal bone level changes at 6, 12, 24, and 36 months, as well as to explore the potential effects of the timing of loading on bone loss. For statistical analysis of the results, NCSS 2007 and PASS 2008 Statistical Software (NCSS, Kaysville, Utah) was used. Descriptive statistics (means and standard deviations for continuous variables, frequencies for categorical variables) was applied for the entire sample of implants

TABLE 1

Mesial and distal bone loss in the removable restored group

Bone Loss	Time from Implant Placement to Loading <60 Days Mean ± SD	60–90 Days Mean ± SD	91–140 Days Mean ± SD	>140 Days Mean ± SD	P†
Distal					
6 month	0.40 ± 0.12	0.47 ± 0.12	0.42 ± 0.13	0.56 ± 0.09	F: 11.214; *P*: .001*
12 month	0.71 ± 0.16	0.87 ± 0.15	0.76 ± 0.16	0.94 ± 0.13	F: 14.059; *P*: .001*
24 month	0.79 ± 0.16	0.97 ± 0.16	0.86 ± 0.18	1.01 ± 0.13	F: 11.768; *P*: .001*
36 month	0.83 ± 0.16	1.01 ± 0.15	0.90 ± 0.18	1.07 ± 0.13	F: 13.768; *P*: .001*
P‡	F: 250.980; *P*: .001*	F: 267.320; *P*: .001*	F: 204.769; *P*: .001*	F: 280.010; *P*: .001*	
Mesial					
6 month	0.39 ± 0.13	0.45 ± 0.11	0.42 ± 0.13	0.53 ± 0.09	F: 8.159; *P*: .001*
12 month	0.70 ± 0.13	0.83 ± 0.15	0.74 ± 0.14	0.90 ± 0.13	F: 13.159; *P*: .001*
24 month	0.77 ± 0.15	0.95 ± 0.17	0.83 ± 0.15	0.98 ± 0.14	F: 11.725; *P*: .001*
36 month	0.81 ± 0.15	0.99 ± 0.18	0.89 ± 0.17	1.06 ± 0.14	F: 13.201; *P*: .001*
P‡	F: 239.029; *P*: .001*	F: 201.663; *P*: .001*	F: 279.867; *P*: .001*	F: 290.151; *P*: .001*	

†One way ANOVA test.
‡Variance analysis in repetitious measurements.
*$P < .01$.

and subsequently for each type of implant. Comparison of quantitative data was accomplished with 1-way analysis of variance (ANOVA), and the group causing the difference was identified with the use of Tukey's honestly significant difference (HSD) test. The parameters of 2 groups were compared with the Student *t* test. For analysis of repetitious measurements, variance analysis was used, whereas for determination of the group causing the significance, the paired sample *t* test was chosen. Results were evaluated at a significance level of $P < .05$.

RESULTS

A total of 87 patients with 252 implants were evaluated in this retrospective study. No incidences of excessive bone loss at implants or peri-implant inflammation were noted.

Removable denture supporting implant group

In terms of timing of loading, a statistically significant difference was noted between sixth month distal bone loss averages ($P < .01$) (Table 1). At the sixth month, distal bone loss levels of the implants where the loading started after 140 days were significantly higher than bone loss levels of the implants loaded earlier than 60 days ($P = .001$; $P < .01$), between the 60th and 90th days ($P = .037$; $P < .05$), and between the 91st and 140th days ($P = .001$; $P < .01$). No significant difference was reported between the other loading timing groups in terms of distal bone loss rate at the sixth month ($P > .05$).

In terms of loading timing, a statistically significant difference was seen between 12th month distal bone loss averages ($P < .01$). At the 12th month, distal bone loss levels of the implants where loading started after 140 days were significantly higher than bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 12th month, distal bone loss levels of the implants where loading started between the 60th and 90th days were significantly higher than bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 90th and 140th days ($P = .024$;

$P < .05$). No significant difference between the other loading timing groups in terms of distal bone loss rate was noted at the 12th month ($P > .05$).

In terms of loading timing, a statistically significant difference was observed between 24th month distal bone loss averages ($P < .01$). At the 24th month, distal bone loss levels of the implants where the loading started after 140 days were significantly higher than bone loss levels of the implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 24th month, the distal bone loss levels of the implants where the loading started between the 60th and 90th days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .025$; $P < .05$). No significant difference was reported between the other loading timing groups in terms of distal bone loss rate at the 24th month ($P > .05$).

In terms of loading timing, a statistically significant difference was seen between the 36th month distal bone loss averages ($P < .01$). At the 36th month, the distal bone loss levels of the implants where the loading started after 140 days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 36th month, the distal bone loss levels of the implants where the loading started between the 60th and 90th days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .033$; $P < .05$). No significant difference between the other loading timing groups was seen in terms of the distal bone loss rate at the 36th month ($P > .05$).

In terms of loading time, a statistically significant difference was observed between the sixth month mesial bone loss averages ($P < .01$). At the sixth month, mesial bone loss levels of the implants where loading started after 140 days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), between the 60th and 90th days ($P = .029$; $P < .05$), and between the 91st and 140th days ($P = .001$; $P < .01$). No significant difference was noted between the other loading timing groups in terms of the mesial bone loss rate at the sixth month ($P > .05$).

In terms of loading timing, a statistically significant difference was observed between the 12th month mesial bone loss averages ($P < .01$). At the 12th month, mesial bone loss levels of the implants where the loading started after 140 days were significantly higher than the bone loss level of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 12th month, the mesial bone loss levels of the implants where implants have been loaded after 60 and before 90 days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .003$; $P < .01$). No significant difference was reported between the other loading timing groups in terms of distal bone loss rate at the 12th month ($P > .05$).

In terms of loading timing, a statistically significant difference was observed between the 24th month mesial bone loss averages ($P < .01$). At the 24th month, mesial bone loss levels of the implants where the loading started after 140 days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 24th month, the mesial bone loss levels of implants loaded between the 60th and 90th days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and

TABLE 2

Mesial and distal bone loss in the fixed restored group

	Time from Implant Placement to Loading			
Bone Loss	<91 Days Mean ± SD	91–180 Days Mean ± SD	>180 Days Mean ± SD	P†
Distal				
6 month	0.49 ± 0.12	0.47 ± 0.12	0.49 ± 0.14	F: 0.448; P: .640
12 month	0.87 ± 0.16	0.87 ± 0.15	0.79 ± 0.20	F: 1.766; P: .175
24 month	0.95 ± 0.17	0.95 ± 0.15	0.87 ± 0.18	F: 2.140; P: .122
36 month	1.00 ± 0.16	0.99 ± 0.15	0.95 ± 0.18	F: 0.699; P: .499
P‡	F: 253.315; P: .001*	F: 1054.201; P: .001*	F: 62.784; P: .001*	
Mesial				
6 month	0.47 ± 0.12	0.45 ± 0.09	0.48 ± 0.16	F: 0.861; P: .425
12 month	0.85 ± 0.16	0.81 ± 0.13	0.80 ± 0.21	F: 0.886; P: .415
24 month	0.96 ± 0.21	0.90 ± 0.13	0.87 ± 0.21	F: 2.091; P: .128
36 month	1.02 ± 0.21	0.95 ± 0.14	0.95 ± 0.19	F: 1.811; P: .168
P‡	F: 242.440; P: .001*	F: 1060.832; P: .001*	F: 58.965; P: .001*	

†One way ANOVA test.
‡Variance analysis in repetitious measurements.
*$P < .01$.

140th days ($P = .014$; $P < .05$). No significant difference was noted between the other loading timing groups in terms of mesial bone loss rate at the 24th month ($P > .05$).

In terms of loading timing, a statistically significant difference was reported between the 36th month mesial bone loss averages ($P < .01$). At the 36th month, the mesial bone loss levels of implants loaded after 140 days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$), and between the 91st and 140th days ($P = .001$; $P < .01$). At the 36th month, the mesial bone loss levels of implants loaded between the 60th and 90th days were significantly higher than the bone loss levels of implants loaded earlier than 60 days ($P = .001$; $P < .01$). No significant difference was noted between the other loading timing groups in terms of mesial bone loss rate at the 36th month ($P > .05$).

Cemented fixed restoration supporting implant group

In terms of loading timing, no statistically significant difference was observed between 6th, 12th, 24th, and 36th month distal and mesial bone loss averages ($P > .05$) (Table 2).

In the fixed restored group, 106 implants were splinted, whereas 20 have been single. Statistical analysis showed no statistically significant association between the 2 groups in terms of loading timing and later MBL (Table 3).

Evaluation of the implants in terms of the neighboring teeth situation showed that a neighboring tooth significantly decreased later MBL on the related side of the implant ($P < .01$) (Table 4).

Evaluation of smooth collar implants (Straumann; Zimmer Dental) and microgeometry neck implants (Astratech; Biolok-Biohorizons) showed no statistically significant association between loading timing and MBL (Tables 5 through 7).

DISCUSSION

The aim of this study was to document the influence of several variables on the MBL around implants supporting mandibular overdentures. Since it was proposed that bone-anchored prostheses could be sus-

TABLE 3

Mesial and distal marginal bone loss in fixed restorations differentiating whether splinted or not

Marginal Bone Loss	Splinted − (single crown) Mean ± SD	 + (bridge) Mean ± SD	*P*†
Distal			
6 month	0.43 ± 0.17	0.49 ± 0.11	t: −1.473; *P*: .155
12 month	0.81 ± 0.24	0.86 ± 0.14	t: −0.992; *P*: .332
24 month	0.89 ± 0.22	0.94 ± 0.14	t: −1.051; *P*: .305
36 month	0.96 ± 0.19	0.99 ± 0.15	t: −0.961; *P*: .338
P‡	F: 146.726; *P*: .001*	F: 899.606; *P*: .001*	
Mesial			
6 month	0.42 ± 0.15	0.46 ± 0.10	t: −1.091; *P*: .287
12 month	0.76 ± 0.22	0.83 ± 0.13	t: −1.319; *P*: .201
24 month	0.87 ± 0.28	0.91 ± 0.13	t: −0.606; *P*: .551
36 month	0.94 ± 0.26	0.97 ± 0.14	t: −0.467; *P*: .645
P‡	F: 157.466; *P*: .001*	F: 831.046; *P*: .001*	

†Student *t* test.
‡Variance analysis in repeated measurements.
$^*P < .01$.

tained in the oral environment for a lifetime,[2] it is important to know the effects of different factors on bone resorption. It was emphasized that it is worth noting that even the proposed rate of bone loss of less than 0.2 mm/y may be too liberal for young implant patients who could lose up to 8 mm of bone over the ensuing 40 years.[12] On the basis of clinical observations, bone loss ranging between 1 and 2.6 mm has been reported to occur around the margin of successfully osseointegrated dental implants.[13–15] In spite of lack of consensus, the values generally accepted as a reasonable guideline for bone loss since the late 80s are less than 1.5 mm for the first year post loading of the implants, with less than 0.2 mm of additional loss for each following year.[16,17]

Although it was stated that immediately and early loaded implants may be at greater

TABLE 4

Mesial and distal marginal bone loss and presence of neighboring tooth

Marginal Bone Loss	Neighboring Tooth No Mean ± SD	 One Side Mean ± SD	 Both Sides Mean ± SD	*P*†
Distal				
6 month	0.50 ± 0.11	0.45 ± 0.09	0.39 ± 0.18	F: 6.468; *P* .002**
12 month	0.89 ± 0.14	0.81 ± 0.14	0.70 ± 0.23	F: 9.607; *P*: .001**
24 month	0.98 ± 0.14	0.88 ± 0.14	0.79 ± 0.21	F: 10.593; *P*: .001**
36 month	1.03 ± 0.15	0.93 ± 0.13	0.89 ± 0.19	F: 7.987; *P*: .001**
P‡	F: 742.253; *P*: .001**	F: 306.907; *P*: .001**	F: 109.721; *P*: .001**	
Mesial				
6 month	0.47 ± 0.10	0.45 ± 0.11	0.35 ± 0.14	F: 6.050; *P*: .003*
12 month	0.84 ± 0.13	0.80 ± 0.14	0.66 ± 0.23	F: 8.513; *P*: .001*
24 month	0.93 ± 0.13	0.87 ± 0.14	0.81 ± 0.34	F: 3.929; *P*: .022*
36 month	0.99 ± 0.14	0.92 ± 0.13	0.91 ± 0.33	F: 2.119; *P*: .124
P‡	F: 789.060; *P*: .001**	F: 187.647; *P*: .001**	F: 58.569; *P*: .001**	

†One way ANOVA test.
‡Variance analysis in repeated measurements.
$^*P < .05$; $^{**}P < .01$.

TABLE 5

Evaluation of mesial and distal marginal bone loss related to implant type in the "Loading Earlier Than 90 Days Group"

	Implant Type		
<90 Days	Smooth Collar Mean ± SD	Microgeometry Neck Mean ± SD	*P*†
Distal			
6 month	0.50 ± 0.08	0.49 ± 0.13	t: 0.285; *P*: .778
12 month	0.93 ± 0.11	0.84 ± 0.17	t: 1.199; *P*: .242
24 month	1.01 ± 0.14	0.93 ± 0.18	t: 1.047; *P*: .306
36 month	1.07 ± 0.15	0.98 ± 0.16	t: 1.259; *P*: .220
P‡	F: 87.234; *P*: .001*	F: 220.230; *P*: .001*	
Mesial			
6 month	0.49 ± 0.09	0.47 ± 0.13	t: 0.363; *P*: .720
12 month	0.91 ± 0.10	0.83 ± 0.18	t: 1.155; *P*: .259
24 month	1.00 ± 0.12	0.95 ± 0.24	t: 0.515; *P*: .611
36 month	1.06 ± 0.13	1.01 ± 0.24	t: 0.530; *P*: .601
P‡	F: 83.529; *P*: .001*	F: 165.192; *P*: .001*	

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

risk of failure than conventionally loaded ones,[18] several randomized controlled trial studies and review articles have shown no important differences in terms of prosthesis failure, implant failure, and marginal bone level changes between the different loading strategies[6,19]—immediate vs conventional loading,[20–29] early vs conventional loading,[30–32] and immediate vs early loading.[33–37] Based on a review of the current literature, it can be concluded that immediate or early placement of implants may be a viable alternative to delayed placement.[38] Although a tendency toward higher losses where implants were also immediately loaded was pointed out in a review of the related

TABLE 6

Evaluation of mesial and distal marginal bone loss related to implant type in the "Loading Between 91 and 180 Days After Implant Insertion Group"

	Implant Type		
91–180 Days	Smooth Collar Mean ± SD	Microgeometry Neck Mean ± SD	*P*†
Distal			
6 month	0.48 ± 0.13	0.47 ± 0.11	t: 0.385; *P*: .702
12 month	0.86 ± 0.16	0.87 ± 0.15	t: −0.309; *P*: .759
24 month	0.94 ± 0.16	0.96 ± 0.15	t: −0.718; *P*: .475
36 month	0.99 ± 0.17	0.99 ± 0.15	t: 0.065; *P*: .948
P‡	F: 436.730; *P*: .001*	F: 614.558; *P*: .001*	
Mesial			
6 month	0.44 ± 0.09	0.45 ± 0.10	t: −0.792; *P*: .431
12 month	0.80 ± 0.13	0.82 ± 0.13	t: −0.842; *P*: .403
24 month	0.87 ± 0.14	0.92 ± 0.12	t: −1.155; *P*: .124
36 month	0.95 ± 0.15	0.95 ± 0.12	t: −0.157; *P*: .876
P‡	F: 380.708; *P*: .001*	F: 708.125; *P*: .001*	

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

TABLE 7

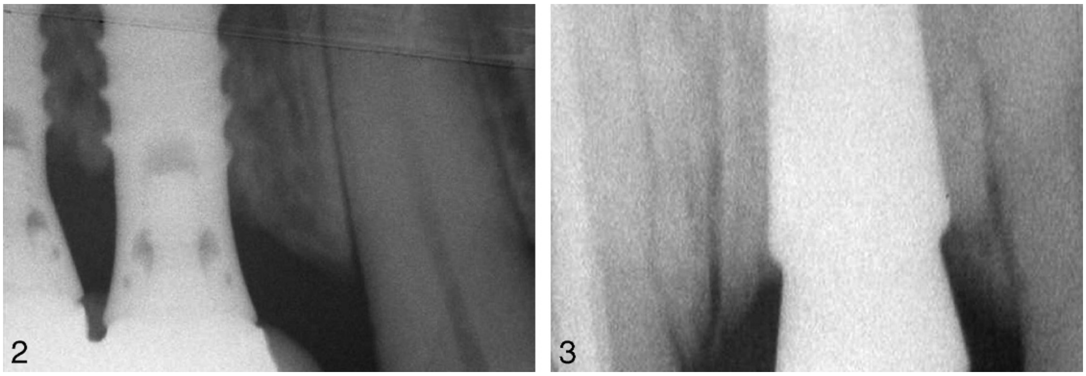
Evaluation of mesial and distal marginal bone loss related to implant type in the "Loading Later Than 180 Days Group"

>180 Days	Implant Type Smooth Collar Mean ± SD	 Microgeometry Neck Mean ± SD	*P*†
Distal			
6 month	0.40 ± 0.12	0.55 ± 0.13	t: −2.532; *P*: .021*
12 month	0.78 ± 0.19	0.80 ± 0.22	t: −0.243; *P*: .811
24 month	0.86 ± 0.15	0.87 ± 0.20	t: −0.090; *P*: .929
36 month	0.97 ± 0.12	0.94 ± 0.21	t: 0.404; *P*: .691
P‡	F: 129.376; *P*: .001*	F: 110.725; *P*: .001*	
Mesial			
6 month	0.41 ± 0.13	0.52 ± 0.16	t: −1.541; *P*: .142
12 month	0.81 ± 0.22	0.79 ± 0.21	t: 0.127; *P*: .901
24 month	0.88 ± 0.21	0.86 ± 0.21	t: 0.107; *P*: .916
36 month	0.98 ± 0.16	0.94 ± 0.22	t: 0.363; *P*: .721
P‡	F: 122.975; *P*: .001*	F: 21.820; *P*: .001*	

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

literature,[39] the results of several clinical studies have indicated that immediate loading of implants placed in immediate extraction sites can be carried out successfully.[40–42]

As is well known, bone responds to local mechanical forces with changes in internal architecture and external shape. Cortical and trabecular bone is modified by modeling and remodeling. The cellular behavior of bone cells is determined largely by the mechanical environment of strain or deformation of the bone cells.[43] As was described by Frost,[44] disuse of bone increases remodeling and results in decreased bone mass, similar to an overload situation. The remodeling rate is the period of time needed for new bone to replace existing bone and allows for the adaptation of bone to its environment, for example, next to an implant. Lamellar bone forms at a rate of 1 to 5 μm each day, whereas woven bone can form at rates of more than 60 μm each day. Hence a higher bone turnover rate is taking place for woven bone. Three types of bone are found next to an osseointegrated implant: lamellar, woven, and composite bone. Lamellar bone is the best organized, most highly mineralized, and strongest of all bone types. It is the load-bearing bone that is most desired next to an implant.[45] Woven bone is also called immature bone because it is unorganized and less mineralized and has less strength than other types. Composite bone is a combination of lamellar and woven bone. After an implant is inserted, remodeling in the implant-bone interface allows formation of a viable bone. By the end of 4 months of a maturation phase bone next to a healing implant interface, osteoblasts deposit about 70% of the mineral found in mature vital bone. The remaining 30% of mineral deposition occurs during secondary mineralization over the next 8-month period. Once the bone has healed and the implant is loaded, the interface remodels again, as influenced by its local strain environment, and this remodeling process is continuous.[46] Crestal bone loss is reported to be the result not only of overload situations, but also of disuse atrophy as a consequence of smooth collar designs, causing reduced strain transmission to neighboring bone.[47–50] This point is important in explaining the results of this



Figures 2 and 3. Neighboring teeth seem to help to maintain marginal bone levels of implants. Implants placed next to teeth have shown less bone loss at the tooth-facing side than at the implant-facing side.

present study. However, in terms of loading timing, the implants with microgeometry neck design when compared with smooth collar implants did not show less MBL in this study. The microthreads in the implant neck are designed to conduct functional forces to the surrounding bone in a favorable way. Because of missing functional forces during the unloaded period, the bone seems to recede, irrespective of collar design. Delay of loading of implants seems to increase MBL around dental implants caused by disuse atrophy. A possible reason for the indifference in the fixed restoration supporting implant group could be the support of neighboring teeth. Implants placed next to teeth have shown less bone loss at the tooth-facing side than at the free end or implant-facing side (Figures 2 and 3, Table 4). Teeth must be conducting functional forces to the surrounding bone, thus protecting it from disuse atrophy. Once the bone has healed and the implant is loaded, the interface remodels again, as influenced by its local strain environment. A major secondary remodeling action due to late loading could be the reason of higher MBL observed later.

Radiography plays an important role in clinical routine practice and in research projects evaluating dental implants. Measurements of marginal alveolar bone level changes that occur over time in radiographs have been reported to be important parameters.[51] Panoramic radiographs are widely used for evaluation of the condition of the bone around implants supporting mandibular OVDs.[52–57] Annual bone loss of 0.2–0.32 mm, measured from panoramic radiographs, has been reported. Different methods have been used to assess bone height in the implant region—from just counting the number of threads on screw-type implants, to taking measurements by using a computer-based interactive image analysis system. However, the accuracy of the computerized method was reported to be higher than that of conventional methods, such as the use of a magnifying glass or a sliding gauge by several authors.[58,59] Another author pointed to the fact that intraoral direct digital radiographs are not an equivalent substitute for conventional radiographs in evaluating alveolar bone levels.[60] Currently, the best object to use when measuring marginal bone levels around implants seems to be the scanned and digitized conventional radiograph,[61,62] which was used in the present study, too. The bone loss documented in this study was caused by a reduction in bone levels at the mesial and distal sides of the implants, ignoring the so-called saucerization of the crestal bone around the neck of the implants caused by eventual excessive dynamic loading,[63] because only 2-dimensional imaging was used. To be able to gain data especially about vestibular crestal bone changes, a 3-dimensional imaging technique, such as volumetric tomography, is necessary. Nevertheless, a panoramic radiograph includes both of the jaws and the teeth and is a simple examination method.[64] Although most panoramic machines provide varied and unreliable magnification, intraoral radiographs have a higher resolution and they are more time consuming to obtain.[65] Furthermore, the anatomy of the patient, for example, an extremely resorbed mandible or the inclination of the implant, can make placement of the intraoral radiograph impossible. Alternatively, panoramic exposure offers ease of operation and a shorter working time. Given that the radiographs were of a high quality, Åkesson concluded that for assessment of MBL around the teeth, the radiographic examination of choice would be the panoramic radiograph,[66] which is in accordance with findings of a study by Persson et al.[67] A recent study by Kullman et al[68] also showed that panoramic radiographs were as reliable as conventional intraoral radiographs when used to assess the point of bone attachment to implant threads. Interobserver agreement on MBL assessment from intraoral and panoramic radiographs was studied in several investigations.[69,70] It was stated that reliability can be improved with multiple readings by a single observer or, even better, by letting several observers make several, independent readings, which limits the probability that a single observer may be an outlier. In light of these studies, we decided to use panoramic radiographs in routine recall sessions of all patients and to supplement them 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 level on all radiographs.

CONCLUSIONS

Within the limitations of this study, our results encourage early loading because delay of loading of implants seems to increase MBL around dental implants caused by disuse atrophy obviously seen in removable denture supporting implants. Implants next to natural teeth seem to be protected by functional forces conducted to the crestal and alveolar bone. So that more reliable conclusions can be drawn, higher numbers of implants should be observed in future studies.

ABBREVIATIONS

ANOVA: analysis of variance
HSD: honestly significant difference test
MBL: marginal bone loss
OVD: overdenture
PD: probing depth
PI: plaque index
SBI: sulcus bleeding index

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REFERENCES

1. Branemark PI, Adell R, Breine U, Hansson B, Lindstrom J, Ohlsson A. Intraosseous anchorage of dental prostheses. 1. Experimental studies. *Scand J Plast Reconstr Surg*. 1969;3:81–100.

2. Branemark PI, Hansson B, Adell R. Osseointegrated implants in the treatment of the edentulous jaw: experience from a 10-year period. *Scand J Plast Reconstr Surg*. 1977;16:1–32.

3. Schroeder A, Pohler O, Sutter F. Gewebsreaktion auf ein Titan-Hohlzylinder—Implantat mit Titan-Spritzschichtoberflache. *Schweizer Monatsschrift für Zahnheilkunde*. 1976;86:713–727.

4. Schroeder A, van den Zypen E, Stich H, Sutter F. The reaction of bone, connective tissue and epithelium to endosteal implants with titanium-sprayed surfaces. *J Maxillofac Surg*. 1981;9:15–25.

5. Attard NJ, Zarb GA. Immediate and early implant loading protocols: a literature review of clinical studies. *J Prosthet Dent*. 2005;94:242–258.

6. Esposito M, Grusovin MG, Achille H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. *Cochrane Database Syst Rev*. 2009;21:CD003878.

7. Esposito M, Hirsh JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants. (II) Success criteria and epidemiology. *Eur J Oral Sci*. 1998;106:527–551.

8. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The longterm efficacy of currently used dental implants: a review and proposed criteria for success. *Int J Oral Maxillofac Implants*. 1986;1:11–25.

9. Smith DE, Zarb G. Criteria for success of osseointegrated endosseous implants. *J Prosthet Dent*. 1989;62:567–572.

10. Kawai Y, Taylor JA. Effect of loading time on the success of complete mandibular titanium implant retained overdentures: a systematic review. *Clin Oral Implants Res*. 2007;18:399–408.

11. Mombelli A, Lang NP. Clinical parameters for the evaluation of dental implants. *Periodontol. 2000*. 1994;4:81–86.

12. Bryant SR, Zarb GA. Crestal bone loss proximal to oral implants in older and younger adults. *J Prosthet Dent*. 2003;89:589–597.

13. Lekholm U, Zarb GA. Patient selection and preparation. In: Branemark PI, Zarb GA, Albrektsson T, eds. *Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence; 1999:199–209.

14. Weber HP, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. *Clin Oral Implants Res*. 2000;11:144–153.

15. Mericske-Stern R, Aerni D, Buser D, Geering AH. Long-term evaluation of non-submerged hollow cylinder implants. *Clin Oral Implants Res*. 2001;12:252–259.

16. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The longterm efficacy of currently used dental implants: a review and proposed criteria for success. *Int J Oral Maxillofac Implants*. 1986;1:11–25.

17. Smith DE, Zarb G. Criteria for success of osseointegrated endosseous implants. *J Prosthet Dent*. 1989;62:567–572.

18. Ottoni JM, Oliveira ZF, Mansini R, Cabral AM. Correlation between placement torque and survival of single-tooth implants. *Int J Oral Maxillofac Implants*. 2005;20:769–776.

19. De Smet E, Duyck J, Vander Sloten J, Jacobs R, Naert I. Timing of loading—immediate, early, or delayed—in the outcome of implants in the edentulous mandible: a prospective clinical trial. *Int J Oral Maxillofac Implants*. 2007;22:580–594.

20. Chiapasco M, Abati S, Romeo E, Vogel G. Implant-retained mandibular overdentures with Branemark System MKII implants: a prospective comparative study between delayed and immediate loading. *Int J Oral Maxillofac Implants*. 2001;16:537–546.

21. Romeo E, Chiapasco M, Lazza A, et al. Implant-retained mandibular overdentures with ITI implants: a comparison of 2-year results between delayed and immediate loading. *Clin Oral Implants Res*. 2002;13:495–501.

22. Cannizzaro G, Leone M. Restoration of partially edentulous patients using dental implants with a microtextured surface: a prospective comparison of delayed and immediate full occlusal loading. *Int J Oral Maxillofac Implants*. 2003;18:512–522.

23. Hall JA, Payne AG, Purton DG, Torr B. A randomized controlled clinical trial of conventional and immediately loaded tapered implants with screw-retained crowns. *Int J Prosthodont*. 2006;19:17–19.

24. Assad AS, Hassan SA, Shawky YM, Badawy MM. Clinical and radiographic evaluation of implant-retained mandibular overdentures with immediate loading. *Implant Dent*. 2007;16:212–223.

25. Turkyilmaz I, Tumer C. Early versus late loading of unsplinted TiUnite surface implants supporting mandibular overdentures: a 2-year report from a prospective study. *J Oral Rehabil*. 2007;34:773–780.

26. Crespi R, Capparé P, Gherlone E, Romanos GE. Immediate versus delayed loading of dental implants placed in fresh extraction sockets in the maxillary esthetic zone: a clinical comparative study. *Int J Oral Maxillofac Implants*. 2008;23:753–758.

27. Donati M, La Scala V, Billi M, Di Dino B, Torrisi P, Berglundh T. Immediate functional loading of implants in single tooth replacement: a prospective clinical multicenter study. *Clin Oral Implants Res*. 2008;19:740–748.

28. Güncü MB, Aslan Y, Tümer C, Güncü GN, Uysal S. In-patient comparison of immediate and conventional loaded implants in mandibular molar sites within 12 months. *Clin Oral Implants Res*. 2008;19:335–341.

29. Schincaglia GP, Marzola R, Fazi G, Scapoli C, Scotti R. Replacement of mandibular molars with single-unit restorations supported by wide-body implants: immediate versus delayed loading. A randomized controlled study. *Int J Oral Maxillofac Implants*. 2008;23:474–480.

30. Payne AG, Tawse-Smith A, Duncan WD, Kumara R. Conventional and early loading of unsplinted ITI implants supporting mandibular overdentures. *Clin Oral Implants Res*. 2002;13:603–609.

31. Tawse-Smith A, Payne AG, Kumara R, Thomson WM. Early loading of unsplinted implants supporting mandibular overdentures using a one-stage operative procedure with two different implant systems: a 2-year report. *Clin Implant Dent Relat Res*. 2002;4:33–42.

32. Fischer K, Stenberg T. Early loading of ITI implants supporting a maxillary full-arch prosthesis: 1-year data of a prospective, randomized study. *Int J Oral Maxillofac Implants*. 2004;19:374–381.

33. Testori T, Galli F, Capelli M, Zuffetti F, Esposito M. Immediate non-occlusal versus early loading of dental implants in partially edentulous patients: 1-year results from a multicenter, randomized controlled clinical trial. *Int J Oral Maxillofac Implants*. 2007;22:815–822.

34. Cannizzaro G, Leone M, Esposito M. Immediate versus early loading of two implants placed with a flapless technique supporting mandibular bar-retained overdentures: a single-blinded, randomized controlled clinical trial. *Eur J Oral Implant*. 2008;1:33–43.

35. Cannizzaro G, Torchio C, Leone M, Esposito M. Immediate versus early loading of flapless-placed implants supporting maxillary full arch prostheses: a randomised controlled clinical trial. *Eur J Oral Implant*. 2008;1:127–139.

36. Merli M, Merli A, Bernardelli F, Lombardini F, Esposito M. Immediate versus early non-occlusal loading of dental implants placed flapless in partially

edentulous patients: one-year results from a randomized controlled clinical trial. *Eur J Oral Implant*. 2008;1: 207–220.

37. Zöllner A, Ganeles J, Korostoff J, Guerra F, Krafft T, Brägger U. Immediate and early non-occlusal loading of Straumann implants with a chemically modified surface (SLActive) in the posterior mandible and maxilla: interim results from a prospective multicenter randomized-controlled study. *Clin Oral Implants Res*. 2008;19:442–450.

38. Schropp L, Isıdor F. Timing of implant placement relative to tooth extraction. *J Oral Rehabil*. 2008;35:33–43.

39. Quirynen M, Van Assche N, Botticelli D, Berglundh T. How does the timing of implant placement to extraction affect outcome? *Int J Oral Maxillofac Implants*. 2007;22:203–223.

40. Crespi R, Capparè P, Gherlone E, Romanos GE. Immediate occlusal loading of implants placed in fresh sockets after tooth extraction. *Int J Oral Maxillofac Implants*. 2007;22:955–962.

41. Crespi R, Capparé P, Gherlone E, Romanos GE. Immediate versus delayed loading of dental implants placed in fresh extraction sockets in the maxillary esthetic zone: a clinical comparative study. *Int J Oral Maxillofac Implants*. 2008;23:753–758.

42. Aires I, Berger J. Immediate placement in extraction sites followed by immediate loading: a pilot study and case presentation. *Implant Dent*. 2002;11:87–94.

43. Jones DB, Nolte H, Scholubbers JG, et al. Biomechanical signal transduction of mechanical strain in osteoblast-like cells. *Biomaterials*. 1991;12:101–110.

44. Frost HM. The mechanostat: a proposed pathogenetic mechanism of osteoporosis and bone mass effects of mechanical and nonmechanical agents. *Bone Miner*. 1988;2:73–85.

45. Roberts WE, Smith RK, Zilerman Y, et al. Osseous adaptation to continuous loading of rigid endosseous implants. *Am J Orthod*. 1984;86:95–111.

46. Bidez MW, Misch CE. Clinical biomechanics in implant dentistry. In: Misch CE, ed. *Dental Implant Prosthetics*. St. Louis: Elsevier-Mosby; 2005:338–339.

47. Quirynen M, Naert I, van Steenberghe D. Fixture design and overload influence marginal bone loss and fixture success in the Branemark system. *Clin Oral Implants Res*. 1992;3:104–111.

48. Pilliar RM, Deporter DA, Watson PA, Valiquette N. Dental implant design: effect on bone remodelling. *J Biomed Mater Res*. 1991;25:467–483.

49. Deporter DA, Watson PA, Pilliar RM, et al. A prospective clinical study in humans of an endosseous dental implant partially covered with a powder-sintered porous coating: 3- to 4-year results. *Int J Oral Maxillofac Implants*. 1996;11:83–91.

50. Vaillancourt H, Pilliar RM, McCammond D. Finite element analyis of crestal bone loss around porous-coated dental implants. *J Appl Biomater*. 1995;6:267–282.

51. Chaytor DV, Zarb GA, Schmitt A, Lewis DW. The longitudinal effectiveness of osseointegrated dental implants. The Toronto Study: bone level changes. *Int J Periodontics Restorative Dent*. 1991;11:113–125.

52. Donatsky O. Osseointegrated dental implants with ball attachments supporting overdentures in patients with mandibular alveolar ridge atrophy. *Int J Oral Maxillofac Implants*. 1993;8:162–166.

53. Boerrigter EM, Van Oort RP, Raghoebar GM, Stegenga B, Schoen PJ, Boering G. A controlled clinical trial of implant-retained mandibular overdentures: clinical aspects. *J Oral Rehabil*. 1997;24:182–190.

54. Versteegh PM, Van Beek GJ, Slagter AP, Ottervanger JP. Clinical evaluation of mandibular overdentures supported by multiple-bar fabrication: a follow-up study of two implant systems. *Int J Oral Maxillofac Implants*. 1995;10:595–603.

55. Mericske-Stern R, Steinlin Schaener T, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdentures: a five-year longitudinal study. *Clin Oral Implants Res*. 1994;5:9–18.

56. Spiekermann H, Jansen VK, Richter EJ. A 10-year follow-up study of IMZ and TPS implants in the edentulous mandible using bar-retained overdentures. *Int J Oral Maxillofac Implants*. 1995;10:231–243.

57. Leimola-Virtanen R, Peltola J, Oksala E, Helenius H, Aponen RP. ITI titanium plasma-sprayed screw implants in the treatment of edentulous mandibles: a follow-up study of 39 patients. *Int J Oral Maxillofac Implants*. 1995;10:373–378.

58. Weber HP, Buser D, Fiorellini JP, Williams RC. Radiographic evaluation of crestal bone levels adjacent to non-submerged titanium implants. *Clin Oral Implants Res*. 1992;3:181–188.

59. Meijer HJA, Steen WHA, Bosman F. A comparison of methods to assess marginal bone height around endosseous implants. *J Clin Periodontol*. 1993;20:250–253.

60. Khocht A, Janal M, Harasty L, Chang KM. Comparison of direct digital and conventional intraoral radiographs in detecting alveolar bone loss. *J Am Dent Assoc*. 2003;134:1468–1475.

61. Batenburg RHK, Meijer HJA, Geraets WGM, van der Stelt PF. Radiographic assessment of changes in marginal bone around endosseous implants supporting mandibular overdentures. *Dentomaxillofac Radiol*. 1998;27:221–224.

62. Bittar-Cortez JA, Passeri LA, de Almeida SM, Haiter-Neto F. Comparison of peri-implant bone level assessment in digitized conventional radiographs and digital subtraction images. *Dentomaxillofac Radiol*. 2006;35:258–262.

63. Duyck J, Rønold HJ, Van Oosterwyck H, Naert I, Vander Sloten J, Ellingsen JE. The influence of static and dynamic loading on marginal bone reactions around osseointegrated implants: an animal experimental study. *Clin Oral Implants Res*. 2001;12:207–218.

64. Åkesson L, Håkansson J, Rohlin M, Zöger B. An evaluation of image quality for the assessment of the marginal bone level in panoramic radiography. *Swed Dent J*. 1992;17:9–21.

65. Mupparapu M, Singer S. Implant imaging for the dentist. *J Can Dent Assoc*. 2004;70:32.

66. Åkesson L. Panoramic radiography in the assessment of marginal bone level. *Swed Dent J*. 1991;78:1–129.

67. Persson RE, Tzannetou S, Feloutzis AG, Brägger U, Persson GR, Lang NP. Comparison between panoramic and intraoral radiographs for the assessment of alveolar bone levels in a periodontal maintenance population. *J Clin Periodontol*. 2003;30:833–839.

68. Kullman L, Al Asfour A, Zetterqvist L, Andersson L. Comparison of radiographic bone height assessments in panoramic and intraoral radiographs of

implant patients. *Int J Oral Maxillofac Implants*. 2007;22: 96–100.

69. Molander B, Ahlqwist M, Gröndahl HG, Hollender L. Agreement between panoramic and intra-oral radiography in the assessment of marginal bone height. *Dentomaxillofac Radiol*. 1991;20:155–160.

70. Pikner SS. Radiographic follow-up analysis of Branemark dental implants. *Swed Dent J*. 2008;194:5–69.