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Marginal bone level changes in association with different vertical implant positions: a 3-year retrospective study

Yeon-Tae Kim, Gyu-Hyung Lim, Jae-Hong Lee, Seong-Nyum Jeong *

Department of Periodontology, Wonkwang University Daejeon Dental Hospital, Wonkwang University College of Dentistry, Daejeon, Korea

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***Correspondence:**
Seong-Nyum Jeong
Department of Periodontology, Wonkwang University Daejeon Dental Hospital, Wonkwang University School of Dentistry, 77 Dunsan-ro, Seo-gu, Daejeon 35233, Korea.
E-mail: seongnyum@wonkwang.ac.kr
Tel: +82-42-366-1141
Fax: +82-42-366-1115

ORCID iDs
Yeon-Tae Kim
https://orcid.org/0000-0001-7209-3208
Gyu-Hyung Lim
https://orcid.org/0000-0001-5758-5765
Jae-Hong Lee
https://orcid.org/0000-0002-2375-0141
Seong-Nyum Jeong
https://orcid.org/0000-0003-4890-989X

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Author Contributions
Conceptualization: Gyu-Hyung Lim, Seong-Nyum Jeong; Investigation: Yeon-Tae Kim, Gyu-Hyung Lim, Seong-Nyum Jeong; Methodology: Yeon-Tae Kim, Gyu-Hyung Lim, Jae-Hong Lee, Seong-Nyum Jeong; Project administration: Seong-Nyum Jeong; Writing

ABSTRACT

Purpose: To retrospectively evaluate the relationship between the vertical position of the implant-abutment interface and marginal bone loss over 3 years using radiological analysis.
Methods: In total, 286 implant surfaces of 143 implants from 61 patients were analyzed. Panoramic radiographic images were taken immediately after implant installation and at 6, 12, and 36 months after loading. The implants were classified into 3 groups based on the vertical position of the implant-abutment interface: group A (above bone level), group B (at bone level), and group C (below bone level). The radiographs were analyzed by a single examiner.
Results: Changes in marginal bone levels of 0.99±1.45, 1.13±0.91, and 1.76±0.78 mm were observed at 36 months after loading in groups A, B, and C, respectively, and bone loss was significantly greater in group C than in groups A and B.
Conclusions: The vertical position of the implant-abutment interface may affect marginal bone level change. Marginal bone loss was significantly greater in cases where the implant-abutment interface was positioned below the marginal bone. Further long-term study is required to validate our results.

Keywords: Alveolar bone loss; Bone-implant interface; Dental implants

INTRODUCTION

Since Brånemark introduced the concept of osseointegration, the titanium implant has become one of the most preferred treatments for partially edentulous patients. A number of recent studies have reported high success rates, low morbidity, and long-term implant stability in restoration procedures in various patient populations [1-3].

However, many studies of 2-stage surgery implants have reported that marginal bone loss occurred when the load was applied to the implant following the second-stage implant surgery [4-6]. It was reported that marginal bone loss around implants was common following implant placement, with losses of 1.0–1.5 mm during the first year and 0.1–0.2 mm every subsequent year [4,7]. Since marginal bone loss is generally irreversible, its prevention is critical. Although the exact mechanism of marginal bone loss around implants has not

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

been determined, Oh et al. [8] suggested the following 6 plausible causes for early bone loss: presence of a microgap, surgical trauma, establishment of biologic width, peri-implantitis, occlusal overload, and an implant crest module.

The microgap or implant-abutment interface indicates the microspace between an abutment and an implant fixture and has been considered a reservoir for bacterial colonization. Quirynen and van Steenberghe [9] reported the presence of a substantial amount of microorganisms in the inner thread of the fixture of a Brånemark system, and they suggested that microbial leakage at the implant-abutment interface was the most probable origin for thread contamination. Several studies have assumed the zone where inflammatory cell infiltrate (ICT) is present around the implant-abutment interface (abutment ICT) to be 1.5 mm (0.75 mm of coronal space and 0.75 mm of apical space) [10,11]. It is a zone similar to that of previously reported plaque-associated infiltrate in the gingiva of natural teeth [12,13]. These studies that the establishment of abutment ICT might explain an average of 1 mm of bone loss around fixtures during the first year after implant installation. Broggini et al. [14] demonstrated a peak of inflammatory cells approximately 0.50 mm coronal to the microgap and greater bone loss for 2-piece abutment implant system than with 1-piece abutment implant system. They insisted that the absence of an implant-abutment interface at the bone crest was associated with minimal bone loss. Therefore, they recommended that implants should be placed on a shoulder above the alveolar crest or that 1-piece abutment implant system should be used.

There is still controversy regarding the clinical effectiveness of the implant-abutment interface. According to a systematic review of 13 recent studies, the supracrestal location of the implant-abutment interface may inhibit marginal bone loss after implantation [15]. Yi et al. [16] also reported that supracrestal positioning of the implant-abutment interface is associated with less marginal bone loss. Many studies have investigated the relationship between the vertical position of the implant and marginal bone loss, but there are only a limited number of studies in the current literature with human subjects who were followed up for longer than 1 year. Therefore, the purpose of this study was to retrospectively evaluate the relationship between the vertical position of the implant-abutment interface and marginal bone loss over 3 years using radiological analysis.

MATERIALS AND METHODS

Subjects

In this retrospective study, we included patients admitted to Wonkwang University Daejeon Dental Hospital who received implants between January 2007 and December 2008. The following inclusion criteria were applied: 1) patients who had implants at the delayed stage; 2) patients who underwent 2-stage implant surgery; 3) patients who had follow-up records for at least 3 years after implantation, including radiographic images obtained immediately after implantation and at 6, 12, and 36 months after loading; and 4) patients who maintained oral hygiene through the follow-up period. In total, 367 patients initially met the inclusion criteria for the study. We then excluded the following: 1) 31 heavy smokers (those who smoked >1 pack per day); 2) 33 patients with a wasting disease, such as diabetes, or who took systemic antibiotics other than those prescribed immediately after implant surgery; 3) 50 patients whose radiographic images were uninterpretable; 4) 49 patients who received immediate implant surgery; 5) 63 patients with an implant in the anterior region; 6) 52

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patients who received immediate loading; and 7) 28 patients who received platform-switched implants. After excluding these 306 patients, 61 patients, with 286 implant-abutment interfaces of 143 implants, remained in the study. The study protocol was approved by the Wonkwang University Daejeon Dental Hospital Institutional Review Board (W1412/001-001).

Implant procedure

The following 3 types of implants were applied: TiUnite surface implants (Brånemark System MkIII TiUnite, Nobel Biocare AB, Göteborg, Sweden), sand-blasted with alumina and acid-etching (SA) surface implants (OsstemUSII, Osstem Implant Co., Seoul, Korea), and calcium phosphate (CP)-coated implants (Pitt-easy FBR, Oraltronics Dental Implant Technology GmbH, Bremen, Germany). All the implants were placed using a submerged approach, according to the manufacturers' protocols. Immediately placed implants with an implant position that was difficult to assess were excluded from the study. The second-stage implant surgery was performed a minimum of 3 months after the first-stage implant surgery, and a temporary healing abutment was connected. The prosthetic procedure was conducted in the Department of Prosthodontics.

Classification of the experimental groups

Based on studies by Ericsson et al. [10] and Abrahamsson et al. [11], it was assumed that a 1.5-mm abutment ICT zone was present around the implant-abutment interface in the peri-implant soft tissue (0.75 mm above the implant-abutment interface and 0.75 mm below the implant-abutment interface). Therefore, 0.75 mm was used as the standard for dividing the experimental groups for the present study. In total, 143 implants (286 interfaces) were classified into 3 groups based on the vertical position of the implant-abutment interface (Figure 1).

Group A (above bone level)

Group A included implant-abutment interfaces that were positioned more than 0.75 mm above the marginal bone. For this group, it was assumed that neither the implant-abutment interface nor the resulting abutment ICT zone not affected the marginal bone levels.

Group B (at bone level)

Group B included implant-abutment interfaces that were positioned at the marginal bone level, within 0.75 mm above the marginal bone. For this group, it was assumed that the implant-abutment interface did not directly affect marginal bone levels and that the abutment ICT zone indirectly affected the marginal bone levels.

Figure 1. Experimental group classification. (A) Group A; (B) Group B; and (C) Group C.
Group A: implant-abutment interface positioned above the marginal bone, Group B: implant-abutment interface positioned at the marginal bone level, Group C: implant-abutment interface positioned below the marginal bone.

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Group C (below bone level)

Group C included implant-abutment interfaces that were positioned below the marginal bone. For this group, it was assumed that the implant-abutment interface directly affected the marginal bone levels.

Radiographic analysis

Panoramic radiographic images were taken immediately after implant installation and at 6, 12, and 36 months after loading. Prior to imaging, the laser positioning beam was fixed at the Frankfort horizontal plane (porion to orbitale) and the oral commissure. Images were magnified 400% using Adobe Photoshop CS5 (Adobe Systems Inc., San Jose, CA, USA), and the contrast was increased to ensure that all structures could be clearly distinguished. The number of vertical pixels of the implant image was then recorded. Since the actual length of the implant could be obtained from previous medical records, the actual length associated with one pixel could be determined for the magnified panoramic images.

Marginal bone level was defined as the maximum distance from the implant-abutment interface on the implant side to the marginal bone. Marginal bone level was measured from the mesial and distal sides in one implant in pixels, which was then converted to millimeters based on the length of the implant recorded in the previous medical records. Only the vertical marginal bone level was measured; the horizontal level was ignored. One calibrated examiner recorded the mesial and distal aspects of each implant. The intraexaminer consistency was determined to have a kappa value of 0.96, indicating a high level of reliability.

Statistical analysis

SPSS (PASW Statistics for Windows, version 18.0, SPSS Inc., Chicago, IL, USA) was used to perform the statistical analyses. Data are presented as mean±standard deviation. The homogeneity of the variance was verified using the Levene test. Bony changes within the groups were analyzed using the paired *t*-test, and the comparison between the groups at each stage (baseline and at 6, 12, and 36 months) was analyzed using analysis of variance and the *post hoc* Tukey test, at a level of significance of $P<0.05$.

RESULTS

In total, 286 implant surfaces of 143 implants from 61 patients were analyzed. The mean age of the patients was 51.4 years, and 63.9% were male. The number of implant-abutment interfaces was 73 in group A, 177 in group B, and 36 in group C, with group B accounting for 61.89% of the total. The distribution of implant surfaces for each group is summarized in Table 1.

Changes in marginal bone levels are shown in Table 2. In groups A and B, the mean distance between the implant-abutment interface and the marginal bone immediately after

Table 1. Distribution of implants by surface type

Group	No. of surfaces (%)		
	SA	TU	CP
A	34 (46.58)	3 (4.11)	36 (49.31)
B	53 (29.94)	44 (24.86)	80 (45.20)
C	9 (25.00)	9 (25.00)	18 (50.00)

SA: sand-blasted with alumina and acid-etching, TU: TiUnite, CP: calcium phosphate, group A: implant-abutment interface positioned above the marginal bone, group B: implant-abutment interface positioned at the marginal bone level, group C: implant-abutment interface positioned below the marginal bone.

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Table 2. Change in marginal bone level over time (n=286)

Group	Baseline	6 mon	12 mon	36 mon
A (n=73)	−1.43±0.77	−1.99±0.76	−2.14±0.84	−2.42±1.49
B (n=177)	−0.21±0.24	−0.90±0.64	−1.14±0.65	−1.34±0.91
C (n=36)	0.61±0.29	−0.56±0.52	−0.86±0.61	−1.14±0.80
P value	<0.001	<0.001	<0.001	<0.001

Values are presented as mean±standard deviation (mm).
Group A: implant-abutment interface positioned above the marginal bone, group B: implant-abutment interface positioned at the marginal bone level, group C: implant-abutment interface positioned below the marginal bone, n: number of surfaces.

implantation (baseline) were 1.43±0.77 mm and 0.21±0.24 mm, respectively; the marginal bone was located below the implant-abutment interface in both groups. In group C, the marginal bone was located above the implant-abutment interface, with a mean distance of 0.61±0.29 mm at baseline.

At 6 months after loading, marginal bone loss was 0.56±0.71 mm in group A, 0.69±0.62 mm in group B, and 1.18±0.53 mm in group C (Table 3). The amount of marginal bone loss was significantly greater in group C than in the other 2 groups ($P<0.05$). At 36 months after loading, the amount of marginal bone loss was 0.99±1.45 mm, 1.13±0.91 mm, and 1.76±0.78 mm in groups A, B, and C, respectively, and the amount of bone loss from the baseline was significantly greater in group C than in groups A and B ($P<0.05$).

Changes in marginal bone levels were greatest during the period from the baseline to 6 months after loading for all 3 groups (Table 4). The loss in group C (1.18±0.53 mm) was significantly greater than that of the other 2 groups ($P<0.05$). The amount of marginal bone loss decreased after 6 months, and there were no statistically significant differences in bone loss between successive observation periods from the previous stage were detected among the 3 groups.

There was no significant difference in bone loss between the internal- and external-connection implants at the same vertical position, except for group A at 36 months after

Table 3. Comparison of marginal bone loss according to vertical implant position from the baseline

Group	6 mon[a]	12 mon[b]	36 mon[c]
A (n=73)	0.56±0.71	0.71±0.74	0.99±1.45
B (n=177)	0.69±0.62	0.93±0.65[b]	1.13±0.91
C (n=36)	1.18±0.53[b,c]	1.47±0.59[b,c]	1.76±0.78[b,c]
P value	<0.001	<0.001	0.020

Values are presented as mean±standard deviation (mm).
Group A: implant-abutment interface positioned above the marginal bone, group B: implant-abutment interface positioned at the marginal bone level, group C: implant-abutment interface positioned below the marginal bone, n: number of surfaces.
[a]Statistically significant difference compared with previous stage ($P<0.05$); [b]Statistically significant difference compared with group A ($P<0.05$); [c]Statistically significant difference compared with group B ($P<0.05$).

Table 4. Comparison of marginal bone loss between successive observation periods

Group	Baseline to 6 mon	6–12 mon	12–36 mon
A (n=73)	0.56±0.71	0.15±0.35	0.28±1.06
B (n=177)	0.69±0.62	0.24±0.37	0.20±0.61
C (n=36)	1.18±0.53[a]	0.29±0.38	0.29±0.48
P value	<0.001	0.110	0.670

Values are presented as mean±standard deviation (mm).
Group A: implant-abutment interface positioned above the marginal bone, group B: implant-abutment interface positioned at the marginal bone level, group C: implant-abutment interface positioned below the marginal bone, n: number of surfaces.
[a]Statistically significant difference compared with groups A and B ($P<0.05$).

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Table 5. Comparison of marginal bone loss according to implant connection types

Group	6 mon		12 mon		36 mon	
	Internal	External	Internal	External	Internal	External
A (n=73)	0.62±0.80	0.50±0.61	0.84±0.85	0.59±0.60	1.47±1.81[a)]	0.52±0.77
B (n=177)	0.63±0.54	0.74±0.68	0.89±0.62	0.97±0.68	1.15±0.99	1.12±0.84
C (n=36)	1.15±0.65	1.20±0.49	1.45±0.50	1.49±0.94	1.67±0.48	1.84±0.99
P value	0.006	0.001	0.004	<0.001	0.165	<0.001

Values are presented as mean±standard deviation (mm).
Group A: implant-abutment interface positioned above the marginal bone, group B: implant-abutment interface positioned at the marginal bone level, group C: implant-abutment interface positioned below the marginal bone, n: number of surfaces.
a)Statistically significant difference compared with external group ($P<0.05$).

Table 6. Comparison of marginal bone loss according to implant surface types

Implant surface group	6 mon	12 mon	36 mon
SA (n=96)	0.71±0.75	0.86±0.75	0.91±0.85
TU (n=56)	0.76±0.51	1.07±0.62	1.29±0.97
CP (n=134)	0.70±0.65	0.95±0.70	1.30±1.12[a)]
P value	0.829	0.220	0.012

Values are presented as mean±standard deviation (mm).
SA: sand-blasted with alumina and acid-etching, TU: TiUnite, CP: calcium phosphate, n: number of surfaces.
a)Statistically significant difference compared with SA group ($P<0.05$).

loading (Table 5). The amount of bone loss was greater in the subcrestal group than in the other 2 groups for both internal- and external-connection implants.

The amount of marginal bone loss in the CP-coated surface group at 36 months after loading was 1.30±1.12 mm, which was significantly different than the marginal bone loss of 0.91±0.85 mm in the SA surface group (Table 6).

DISCUSSION

This retrospective study evaluated and compared marginal bone level changes according to different vertical implant positions over 36 months after loading. In group C, in which the implant was placed below the marginal bone, significantly greater bone loss was observed at all time points from the baseline, including 36 months after loading.

Many studies have reported that the implant-abutment interface, or the microgap, of 2-piece abutment implant systems is the most probable origin of thread contamination [9,10,14]. Hermann et al. [17] suggested that marginal bone loss could be influenced by the vertical position of the microgaps. It was reported that supracrestally positioned microgaps might inhibit changes in marginal bone levels [15,16,18]. In the present study, the amount of marginal bone loss at 12 months after loading was 1.47 mm for group C, 0.93 mm for group B, and 0.71 mm for group A. Group C showed the largest changes in marginal bone levels, whereas group A showed the smallest. Yi et al. [16] reported a mean change in marginal bone levels of 2.25, 1.47, and 0.89 mm at 12 months after loading for implant-abutment interfaces located below, at, and above bone level, respectively. Although the mean values are relatively large, they are in line with the results of the present study. The larger mean values likely resulted from differences in the study design. Yi et al. [16] divided their experimental groups by 0.5 mm rather than 0.75 mm, and they used different types of implants. We included implant systems with both external and internal connections, whereas Yi et al. [16] used only implant systems with external connections.

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In the present study, overall, greater marginal bone loss was detected in group B than group A, but this was not statistically significant, except at 1 year after loading. This was inconsistent with the findings of the study by van Eekeren et al. [19]. They reported that, for cases in which the implant-abutment interface was positioned above the bone, there was a statistically significant inhibition of bone loss relative to cases where the interface was positioned at bone level. This inconsistency was likely caused by differences in the position of the implant-abutment interface for the above-bone-level group: 2.5 mm for van Eekeren et al. [19] and a mean of 1.43 mm for the present study. As a result, it appears that a vertical implant position of 1.43 mm above the bone is insufficient to block the effect of the implant-abutment interface on marginal bone level changes.

Our results demonstrated that marginal bone loss occurs aggressively during the early phase of healing, from the baseline to 6 months after implant loading. In particular, the loss in group C was 1.18 mm, which was significantly different from the loss in the other 2 groups. It was shown that annual bone level changes decreased approximately 0.1–0.15 mm thereafter, which is similar to the results reported in previous studies [4,7].

Many studies have reported that implants with an external connection resulted in a greater bone loss when compared with implants with an internal connection [20,21]. Generally, for internal-connection implants, the abutment diameter is smaller than the implant diameter, allowing for some additional thickness in the horizontal soft-tissue component [11,19]. It has been proposed that the horizontal distance provided by platform switching may reduce crestal bone loss that results from the reformation of biologic width and microgaps [21,22]. However, in the present study, there was no significant difference in bone loss between internal- and external-connection implants, except for group A at 36 months after loading. However, there was a significant difference in marginal bone loss according to vertical implant position for both internal- and external-connection implants. Group C showed the largest changes in marginal bone loss among three experimental groups for both connection types. We used 3 kinds of implant systems, one of which was an internal-connection type. However, all 3 implant systems included in this study had a straight implant-abutment connection design; implants with platform-switched abutment designs were excluded. The difference in the vertical position of the implant is likely to be a key variable in marginal bone loss, as platform switching was excluded from the present study.

Three types of implants manufactured by different companies with different surface treatments were used in the present study: a SA surface, a TiUnite surface, and a CP-coated surface. With the exception of marginal bone level changes between the SA and the CP-coated surface groups at 36 months after loading, the differences were not statistically significant among the 3 surface groups. However, for some CP-coated surface implants, relatively large marginal bone level changes were observed at 36 months after loading, despite the absence of peri-implantitis; this was likely due to cohesive failure and disruption of the coating/implant interface [23,24]. CP coating as well as hydroxyapatite is advantageous for initial osseointegration due to increased osteoconductivity, but long-term observations have reported the possibility of coating degradation or dissolution [24,25].

This was a retrospective study analyzing radiographic images and, therefore, has several limitations. First, bias may have occurred when determining the patient population. Second, the sample size was relatively small. Third, we inevitably used panoramic views, which have limitations regarding accurate measurement and analysis. In addition, a causal relationship

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could not be verified for some potentially relevant variables. When the implant-abutment interface was positioned below the bone, more aggressive losses in marginal bone level were observed than in other groups, but the mechanism could not be explained in this study.

In conclusion, the vertical position of implant-abutment interfaces may affect changes in marginal bone levels. Marginal bone loss was significantly greater in cases where the implant-abutment interface was positioned below the marginal bone. Therefore, clinicians should avoid positioning implant too deeply, as this will cause early marginal bone loss. To support these results, a more precisely designed large-scale prospective clinical study is needed.

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