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Comparative Analysis of Peri-Implant Marginal Bone Loss Based on Microthread Location: A 1-Year Prospective Study After Loading

Dong-Wook Song,* Dong-Won Lee,* Chong-Kwan Kim,† Kwang-Ho Park,‡ and Ik-Sang Moon*

Background: The purpose of the present study was to investigate the short-term effects of microthread location on peri-implant marginal bone levels.

Methods: Two types of implants, one with microthreads placed at the implant top (group A) and the other with microthreads placed 0.5 mm below the implant top (group B), were placed adjacent to each other in the partially edentulous areas of 20 patients. In total, 40 implants were placed. Bone loss around each implant was analyzed after 1 year of functional loading, and gingival parameters (modified plaque index and modified sulcus bleeding index) of the peri-implant soft tissue were evaluated. Bone losses after loading and gingival parameters were compared using the paired *t* test.

Results: The average bone loss was 0.16 (SD: 0.19) mm in group A and 0.30 (SD: 0.22) mm in group B after 1-year of functional loading. The paired *t* test revealed a significant difference in crestal bone loss between groups A and B in individual patients ($P = 0.004$). No significant differences were found between the two groups for the gingival parameters.

Conclusions: Less peri-implant bone loss was observed around implants with microthreads placed at the implant top (group A) compared to those in which microthreads were placed below the top (group B). These results indicated that the microthreads acted to stabilize the peri-implant marginal bone, and their locations played an important role in the stabilization process. *J Periodontol 2009;80:1937-1944.*

KEY WORDS

Alveolar bone loss; dental implants; dental radiography; prospective studies.

With the establishment of evaluation criteria for implant success and survival,[1] the importance of the marginal bone level in assessing the dental implant response to loading has come into focus. Marginal bone loss can result from surgical trauma during implant placement, overloading, or establishment of biologic width. Studies[2-6] were conducted on the design and surface treatment of implants to minimize this problem. A 4-year radiographic study[7] on microthreaded implants revealed that surface texture, retentive elements at the implant neck, and the implant–abutment interface design play crucial roles in maintaining peri-implant marginal bone. It was also stated that the implant–abutment interface design profoundly affects the stress distribution in marginal bone, and a conical interface design decreases the peak bone–implant interfacial shear stress compared to a flat-top interface.[8]

Surface roughness may also increase resistance to shear stress at the implant–bone interface, affecting the implant "holding power."[9] Additionally, retentive elements such as microthreads at the implant neck are necessary to preserve and maintain the peri-implant marginal bone.[7,10-13] Placing microthreads at the implant neck greatly increases the ability of an implant to resist axial loads, and the

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* Department of Periodontology, Gangnam Severance Dental Hospital, College of Dentistry, Yonsei University, Seoul, Korea.
† Department of Periodontology, College of Dentistry, Yonsei University.
‡ Department of Oral and Maxillofacial Surgery, Gangnam Severance Dental Hospital, College of Dentistry, Yonsei University.

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mechanical stimulus provided by the microthreads helps to preserve peri-implant marginal bone.[10] In animal experiments, implants with microthreads at the implant neck had a higher degree of bone-to-implant contact.[11] Furthermore, clinical studies[7,12] showed minimal bone resorption and stable peri-implant marginal bone around implants with microthreads at the implant neck. A 3-year clinical study[13] conducted by our group, which compared peri-implant marginal bone loss in microthreaded and non-microthreaded implants, found that microthreads at the implant neck were associated with less peri-implant marginal bone loss.

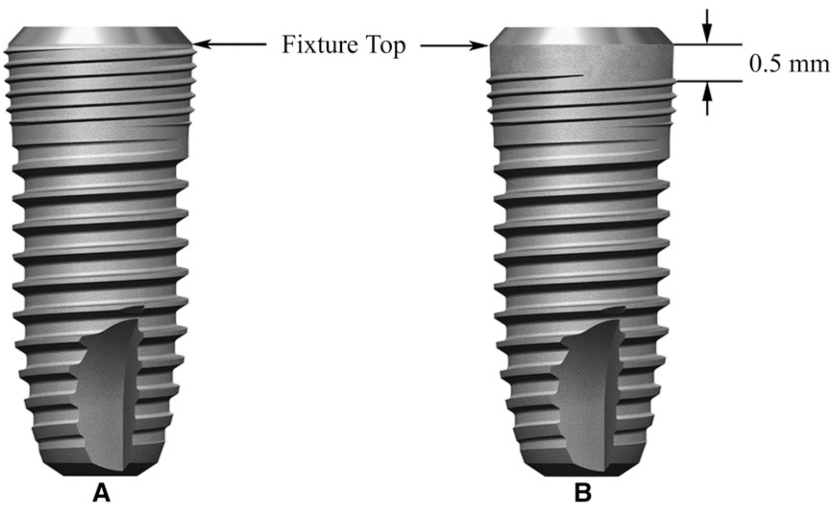

Figure 1.
Schematic presentation of implants. ***A)*** *Implants in group A.* ***B)*** *Implants in group B.*

Previously published studies[11,13] focused on the presence or absence of microthreads and, thus, did not provide insight into the effect of the microthread location on peri-implant marginal bone. In a clinical study using implants with different thread locations, Jung et al.[14] demonstrated that bone loss occurred differently depending on the thread location, and peri-implant marginal bone levels stabilized at the level of the first thread. Therefore, it is possible that the microthread location might also have the same effect on the stabilization of marginal bone levels. The present study was conducted to investigate this relationship.

MATERIALS AND METHODS

This study was approved by the Institutional Review Board of Yonsei University. Patients were informed of the study procedures, and all provided written informed consent.

Implants

The implants[§] used in this study were screw-shaped, threaded implants made of commercially pure titanium with a sand-blasted, large grit, acid-etched (SLA) surface. The point on the implant neck at which surface treatment began was designated as the top of the fixture (Figs. 1A and 1B). Originally, the most coronal location of the microthreads was 0.5 mm below the top of the fixture (group B; Fig. 1B). However, the design of the implant was changed: the location of the microthreads was moved up to the top of the fixture (group A; Fig. 1A). Other than the location of the microthreads, all other designs were identical between the two types of implants, and they were both available when the clinical research was performed.

Patient Selection

A pilot study was conducted prior to this investigation to determine the appropriate number of cases for statistically significant results. Twenty implants of each group were arbitrarily chosen from independent patients not involved in the current research, and marginal bone loss after 1 year of functional loading was measured. A sample calculation revealed that 18 cases were necessary to obtain statistically significant results (the difference between the mean of groups A and B = 0.20; SD 1 = 0.19; SD 2 = 0.23; $\alpha = 0.05$; $\beta = 0.20$). Twenty cases were selected with an anticipated dropout rate of 10%.[‖]

Patients who required implant therapy were recruited between March 2006 and July 2007 to the Department of Periodontology, Gangnam Severance Hospital, and were selected as subjects for this study. Most patients were in good general health, and the two patients who had diabetes and hypertension were well controlled with medication. In total, 11 males and nine females (mean age: 53.7 years; age range: 37 to 78 years) participated in the study.

Treatment Procedure

All surgeries were performed using a two-stage method. Implants from each group were placed adjacent to each other in the partially edentulous area of each patient. The implants were placed 0.5 mm subcrestally per the manufacturer's guidelines, and special attention was paid to ensure that there was ≥1 mm of bone remaining both buccally and lingually. The mesio-distal location of each implant was randomly determined. The location and characteristics of each type of implant are illustrated in Table 1. The second surgery was performed 3 and 6 months later for mandibular and maxillary implants, respectively. The prostheses were delivered 3 weeks after the second

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[§] Implantium, Dentium, Seoul, Korea.
[‖] MedCalc for Windows, version 10.3.0, MedCalc Software, Mariakerke, Belgium.

Table 1.

Distribution of the Locations and Dimensions of Implants

Subject	Group	Tooth #	Fixture Diameter/ Length (mm)
1	A	19	4.3/8
	B	20	4.3/8
2	A	27	3.8/8
	B	28	4.3/8
3	A	29	4.3/8
	B	30	4.3/8
4	A	30	4.3/10
	B	31	4.3/10
5	A	19	4.3/10
	B	18	4.3/10
6	A	29	4.3/12
	B	30	4.3/10
7	A	2	4.3/8
	B	3	4.3/8
8	A	5	4.3/8
	B	6	4.3/8
9	A	9	4.3/8
	B	10	4.3/10
10*	A	26	3.8/10
	B	23	3.8/10
11	A	13	4.3/10
	B	12	4.3/10
12	A	3	4.3/10
	B	4	4.3/10
13*	A	2	4.3/10
	B	4	3.8/10
14	A	2	4.8/8
	B	3	4.3/12
15	A	30	4.8/10
	B	29	4.3/8
16	A	13	4.3/10
	B	14	4.3/10
17	A	15	4.3/8
	B	14	4.3/10
18	A	18	4.3/8
	B	19	4.3/10
19	A	3	4.3/10
	B	4	4.3/10
20	A	18	4.3/10
	B	19	4.3/12

* In two patients, the implants were not placed immediately adjacent to each other and were splinted to fabricate three- or four-unit bridges.

surgery. Prostheses were mostly two-unit bridges, except in two patients (Table 1). Patients were recalled every 3 months for oral hygiene evaluation, professional plaque control, and a review of self-performed oral hygiene instructions.

Radiographs

The taking and measurement of radiographs followed previous protocols established by our group.[13,15-18] In brief, periapical radiographs[¶] were taken 1 day after implant placement, immediately after the second surgery, immediately after prosthesis delivery, and 1 year after functional loading. Radiographs were taken with an extension cone paralleling device[#] using the parallel cone technique (70 kV, 8 mA, and 0.250 seconds). A 5.5-mm spherical metal bearing was placed to aid length measurement. All films were developed using the same automatic processor[**] following the manufacturer's instructions. Films were digitized using a digital scanner[††] at an input resolution of 2,400 dots per inch with a 256 gray scale.

Measurement of Marginal Bone Level Change

After digitization, all images were transferred to a personal computer.[‡‡] The same monitor,[§§] set to a resolution of 1,024 × 768 pixels per inch, was used to examine the digitized radiographs. The room was kept dark throughout the computer-assisted radiographic-measurement process.

Bone loss was measured by comparing the radiographs taken immediately after prosthesis delivery to those taken 1 year after functional loading (Fig. 2). The marginal bone height was measured as the distance between the reference point and the most apical point of the marginal bone level. The reference point was the border between the polished surface and the SLA surface of the fixture. Calibration was performed using the known thread-pitch distance of the implants (1 pitch = 0.64 mm). A 5.5-mm spherical metal bearing was used for calibration when the threads were not clearly visible on the radiographs. Measurements were taken to the nearest 0.01 mm using computer software.[‖‖] Bone loss was measured at the mesial and distal peri-implant sites, and their average values were used.

Measurements were made by a single operator (DWS). To test intraobserver variability, the marginal bone loss on 40 randomly selected radiographs was measured twice, with a 1-week interval. The statistical significance of the differences between the first and

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[¶] Kodak Insight, film speed F, Kodak, Rochester, NY.
[#] Extension Cone Paralleling Kit, Rinn, Elgin, IL.
[**] Periomat, Durr Dental, Bietigheim-Bissingen, Germany.
[††] Epson GT-12000, Epson, Nagano, Japan.
[‡‡] Processor: Intel Celeron D, Intel, Santa Clara, CA; operating system: Windows XP Professional 2002, Microsoft, Redmond, WA.
[§§] Flatron 775FT Plus, LG, Seoul, Korea.
[‖‖] UTHSCSA Image Tool, Version 3.00, University of Texas Health Science Center at San Antonio, San Antonio, TX.

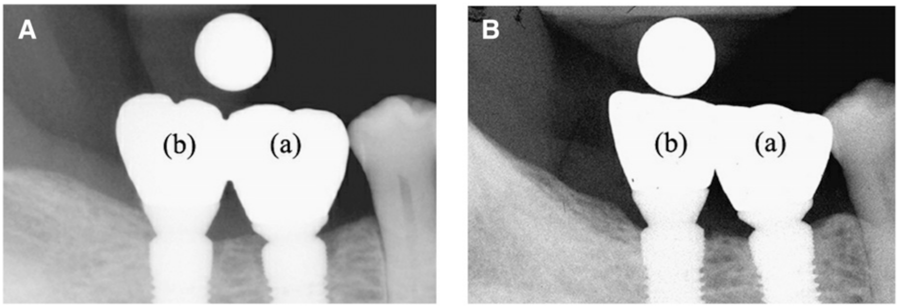

Figure 2.
Intraoral radiographs of implants in groups A (a) and B (b). ***A)*** *At prosthesis delivery.* ***B)*** *One year after functional loading.*

second measurements was assessed using the paired t test. Pearson correlation coefficients were calculated to analyze the correlation between the two sets of measurements. No significant differences were found between the first and second measurements in the paired t test ($P = 0.43$; 95% confidence interval: –0.03 to 0.01). Both showed a high correlation, with a Pearson correlation coefficient of 0.97 ($P < 0.0001$; 95% confidence interval: 0.93 to 0.98).

Follow-Up Parameters

At the 1-year follow-up visit, implants were evaluated for pain, discomfort, and implant-related infection. An implant was deemed as surviving when it was stable, functional, and asymptomatic. To rule out the possible influence of inflammatory changes of the peri-implant tissues on the surrounding marginal bone, the modified plaque index (mPI) and modified sulcus bleeding index (mBI) were measured at four aspects around each implant.[19] Averages of the four obtained mPI and mBI values were calculated to represent the respective values for each implant.

Statistical Analyses

The null hypothesis was defined as: 1) no difference between the mean marginal bone loss of groups A and B during the examination period; and 2) no difference between the mean mPI and mBI of both groups. The Kolmogorov-Smirnov test was used to test the normality of the distribution. The paired t test was used to analyze differences in peri-implant marginal bone loss and gingival parameters between the two groups. Computer software[¶¶] was used to process the data. Values were deemed statistically significant at $P < 0.05$.

RESULTS

Clinical Examination

No remarkable complications were found during the observation period. None of the subjects complained of pain, and mobility was not observed in any of the implants. No implants were lost in this study, and complications associated with the prostheses were also not found.

Marginal Bone Level Changes

The marginal bone loss for each type of implant is illustrated in Table 2. The Kolmogorov-Smirnov test revealed a normal distribution in both groups (group A: $P = 0.064$; group B: $P = 0.377$). The average bone loss in groups A and B showed a statistically significant difference ($P = 0.\,004$). A box plot of the marginal bone loss around implants from groups A and B is illustrated in Figure 3.

Evaluation of Peri-Implant Soft Tissues

The peri-implant soft tissues revealed little tendency to bleed after probing and were clinically healthy. The mPI and mBI for each type of implant is illustrated in Tables 3 and 4, respectively. No significant differences were found between the two groups for either the mPI or mBI (mPI: $P = 0.419$; mBI: $P = 0.186$).

DISCUSSION

This prospective study investigated whether the microthread location at the implant neck affected the peri-implant marginal bone level. To minimize variability from load or bone quality, implants from groups A and B were placed adjacent to each other in the edentulous area of each patient. We used computer software to accurately and reliably analyze periapical radiographs taken immediately after prosthesis connection and 1 year after functional loading to study the influence of microthreads on changes in marginal bone under load.[20] Less bone loss was observed in group A than in group B (0.16 [SD: 0.19] mm versus 0.30 [SD: 0.22] mm), and no significant differences were found between the two groups for the gingival parameters. Bone loss at the mesial and distal peri-implant sites was within the success criteria established by Albrektsson et al.[1]

Numerous animal experiments[21,22] and clinical studies[14,23-27] demonstrated that a smooth implant neck without retentive elements facilitates significant marginal bone resorption. Such bone loss may be due to a lack of mechanical stimulus around the implant; elements such as a rough surface and microthreads at the implant neck are necessary to avoid such problems.[10] In a clinical study[14] involving various implant systems, bone loss usually occurred at the most apical point of the smooth portion of the implant neck, immediately above the first thread. At the level of the first thread, the peri-implant marginal bone remained stable.

[¶¶] SPSS for Windows, release 13.0, SPSS, Chicago, IL.

Table 2.

Marginal Bone Loss (mm) Around Implants in Groups A and B

	Type of Implant	
Subject	Group A	Group B
1	0.03	0.15
2	0.16	0.22
3	0.17	0.15
4	0.21	0.43
5	0.00	0.43
6	0.00	0.22
7	0.31	0.35
8	0.32	0.23
9	0.17	0.16
10	0.81	0.79
11	0.08	0.20
12	0.14	0.21
13	0.03	0.28
14	0.00	0.14
15	0.34	0.26
16	0.20	1.02
17	0.12	0.20
18	0.06	0.19
19	0.00	0.25
20	0.00	0.21
Average	0.16	0.30
SD	0.19	0.22
Median	0.13	0.22
95% confidence interval for the mean	0.07 to 0.25	0.20 to 0.32

A photoelastic study[28] demonstrated that threads generated compressive stresses in the supporting tissues, and the thread location on the implant body affected the pattern of load transfer. A literature review[29] on peri-implant marginal bone loss indicated that the first thread converted the shear force placed on the implant into a compressive force. According to one study,[30] bone is most resistant to compressive strength and is 30% and 65% less resistant to tensile and shear strength, respectively. This transformation of the shear stress acting on the peri-implant marginal bone to compressive strength reduces excessive stress and decreases microdamage to the marginal bone.

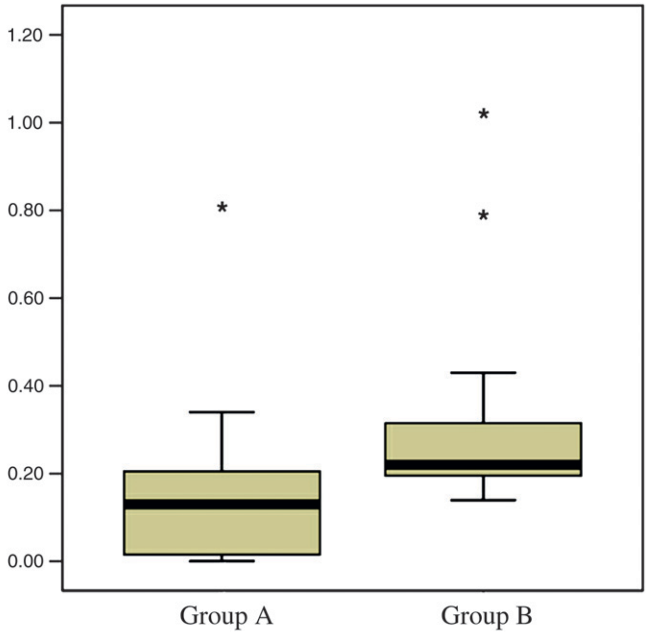

Figure 3.
Box plot of marginal bone loss around implants in groups A and B. Asterisks represent the outside value that is defined as a value larger than the upper quartile plus 1.5 times the interquartile range.

The reported marginal bone loss around microthreaded implants after 1 year of functional loading are varied and range from 0.05 to 0.6 mm.[7,12,31,32] It was speculated that the presence or absence of the microthread might be the proper explanation for the diversity in the reported bone loss.[13] In the present study, the average bone loss around implants with microthreads placed 0.5 mm below the top of the neck (group B) was greater than that observed around implants in which the microthreads were placed at the implant top (group A). One possible explanation is that implants with microthreads placed below the top lacked retentive features above the microthread level and, therefore, lacked the ability to distribute stress concentrated at the implant neck. Thus, these implants may have transferred this stress to the peri-implant marginal bone. If such stress exceeds the threshold that the peri-implant marginal bone can withstand, fatigue microdamage occurs, leading to bone resorption.[33] Therefore, microthreads, which act to distribute stress, placed at the level of the marginal bone exert optimal effects for maintaining peri-implant marginal bone stability.

The incorporation of retentive elements such as microthreads to rough-surface implants provides various advantages including increased implant-to-bone contact and improved stress distribution.[10,11,33] However,

Table 3.

mPI of Implants in Groups A and B

	Type of Implant	
Subject	Group A	Group B
1	0.75	0.50
2	0.50	0.50
3	0.75	0.75
4	1.00	1.00
5	0.75	0.50
6	0.50	0.50
7	0.25	0.50
8	1.00	0.75
9	1.00	1.00
10	1.00	0.75
11	0.50	0.25
12	0.75	0.75
13	0.50	1.00
14	0.25	0.50
15	0.75	0.75
16	1.00	1.00
17	0.50	0.25
18	1.00	1.00
19	1.00	0.75
20	0.00	0.00
Average	0.69	0.65
SD	0.30	0.29
Median	0.75	0.75
95% confidence interval for the mean	0.55 to 0.83	0.52 to 0.78

Table 4.

mBI of Implants in Groups A and B

	Type of Implant	
Subject	Group A	Group B
1	0.50	0.50
2	0.50	0.75
3	0.50	0.50
4	0.00	0.00
5	0.75	0.75
6	0.00	0.00
7	0.25	0.25
8	0.75	0.50
9	1.00	1.00
10	0.75	0.75
11	0.50	0.50
12	0.75	0.75
13	1.00	1.00
14	0.75	0.75
15	0.75	0.50
16	0.25	0.00
17	1.00	1.00
18	1.00	0.75
19	0.25	0.25
20	0.00	0.00
Average	0.56	0.53
SD	0.34	0.34
Median	0.63	0.50
95% confidence interval for the mean	0.40 to 0.72	0.36 to 0.69

the exposure of rough-surface implants to the oral environment can accelerate biofilm formation and facilitate plaque retention, increasing the risk of peri-implant mucositis and peri-implantitis.[34,35] Therefore, such potential biologic complications related to microthreads should be taken into account when formulating a treatment plan for patients with a high susceptibility to peri-implantitis.[35]

Unlike the study by Jung et al.,[14] in which marginal bone loss occurred to the level of the first thread, the present investigation showed less bone loss in most subjects, to a level slightly coronal to the first microthread. Also, whereas the aforementioned study[14] used external hex-type implants with a flat-top implant–abutment interface, the present study used implants with an internal conical seal design and a conical implant–abutment interface. According to a previous study[8] using finite-element analysis, the peak interfacial shear stress occurs at the top marginal bone in flat-top interfaces but more apically in conical interfaces. The magnitude and location of the peak stress in marginal bone is crucial. According to Saint Venant's principle, load distribution change on the end of a structure alters the stresses only near the end.[8] Thus, an implant–abutment junction that is closer to the alveolar crest will produce greater stress and strain compared to one that is farther away, which, in turn, may lead to bone loss. The bone-loss pattern of group B, in which marginal bone resorption occurred at a level coronal to the first microthread, may have been influenced by the internal conical seal design, which decreases the stress and strain on the marginal bone by axially distributing stresses applied to the implant. The effects of platform switching may also account for the lesser amount of bone loss observed. The abutments that were used in this investigation were smaller in diameter than the fixtures, and the fixtures had a horizontal offset and a bevel at the top, placing the implant–abutment interface farther from the crestal bone. This feature prevents inflammation arising from the implant–abutment interface from reaching bone, contributing to a decrease in overall alveolar bone loss.[36,37] Taken together, the bone-loss pattern observed in this study could be a result of the presence of microthreads at the implant neck and a combination of other factors such as the internal conical design and platform switching.

Inflammation of the peri-implant tissues can adversely affect the integrity of the peri-implant marginal bone. To investigate the influence of peri-implant tissues on marginal bone, the mPI and mBI of the implant prostheses were measured 1 year after functional loading. No significant differences in gingival parameters were found between the two groups. This could be explained by the study design, which involved placing the two different implant types adjacent to each other in an attempt to provide the same conditions for both groups.

The mPI and mBI measured 1 year after functional loading cannot be said to perfectly reflect the health of the peri-implant soft tissues during that time period. However, considering the similarities between the mPI and mBI of the two groups, it can be presumed that inflammation of the peri-implant tissues affected both groups to the same degree. Thus, the difference in the marginal bone loss between the two types of implants was due to differences in the microthread location. This study also showed that microthreads stabilized the level of the marginal bone. Therefore, placing microthreads as far coronally as possible along the bone-to-implant interface could help maintain the marginal bone.

CONCLUSIONS

The aim of this study was to investigate the effects of microthread location on peri-implant marginal bone levels.

The average bone loss was 0.16 (SD: 0.19) mm in group A and 0.30 (SD: 0.22) mm in group B after 1 year of functional loading. The paired *t* test revealed a significant difference in crestal bone loss between groups A and B in individual patients ($P = 0.004$). No significant differences were found between the two groups for the gingival parameters.

Less peri-implant bone loss was observed in the implants with microthreads placed at the implant top (group A) compared to those in which microthreads were placed below the top (group B). These results indicate that microthreads act to stabilize the peri-implant marginal bone, and their location plays an important role in the stabilization process.

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Drs. Song and Lee contributed equally to the research in this study. The authors report no conflicts of interest related to this study.

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Correspondence: Dr. Ik-Sang Moon, Department of Periodontology, Gangnam Severance Dental Hospital, College of Dentistry, Yonsei University, Seoul, Korea. Fax: 82-2-3463-4052; e-mail: ismoon@yuhs.ac.

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