Comparative analysis of peri-implant marginal bone loss based on micro-thread location: a 1-year prospective study after loading

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감사의 글

본 논문이 완성되기까지 지속적인 지도와 세심한 배려를 아끼지 않으시고, 제 인생의 귀감이 되어주시는 문익상 교수님께 고개 숙여 깊이 감사드립니다. 그리고 바쁘신 가운데서도 논문 작성과 심사에 많은 조언과 도움을 주신 김종관 교수님, 박광호 교수님, 이동원 교수님께도 깊은 감사를 드립니다.

또한 수련기간 동안 희로애락을 함께하며 격려를 아끼지 않은 김태형 선생님, 김정주 선생님, 강영일 선생님, 이은경 선생님, 이동원 선생님, 남대호 선생님의 앞날에도 무궁한 영광이 깃들기를 기원합니다.

지금껏 절대적인 사랑으로 저를 보살펴주신 아버지와 어머니, 두 분의 사랑이 있었기에 지금의 제가 있을 수 있었습니다. 두 분 사랑하고 존경합니다. 그리고 자상하고 든든한 큰 누나와 매형, 다정한 작은 누나에게도 고마움을 표하며, 부족한 저를 믿고 지지해주시는 장인어른, 장모님, 친형처럼 잘 따라주는 처남에게도 감사의 말씀을 전합니다. 또한 영어에 있어서 많은 조언을 해준 친구 한동희에게도 고맙다는 말을 전하고 싶습니다.

그리고 언제나 나의 마음의 안식처가 되어주는 사랑하는 나의 아내 김소희와 아빠 논문 잘 쓰라고 밤에 잘 자준 우리 집 든든한 기둥 예준아 고맙고 사랑한다.

마지막으로 늘 저를 지켜주시고 올바른 길로 인도해주시는 하나님께 이 영광을 돌리며, 저를 생각해 주시는 제 주변의 모든 분들께도 감사의 마음을 전합니다.

감사합니다.

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송 동 욱

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Abstract

Comparative analysis of peri-implant marginal bone loss based on micro-thread location: a 1-year prospective study after loading

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The purpose of the present study was to investigate the effects of micro-thread location on peri-implant marginal bone levels.

Two types of implants, one with micro-threads placed at the implant top (Top) and the other with micro-threads placed 0.5 mm below the implant top (Below-top), were placed adjacent to each other in the partially edentulous areas of each of 20 patients. Bone loss around each implant was analyzed after one year of functional loading, and gingival parameters (modified plaque index and modified mucosal index) of the peri-implant soft tissue were evaluated. Bone loss after loading and gingival parameters were compared using the Wilcoxon signed-rank test.

The average bone loss in the Top group was 0.16 ± 0.19 mm, and in the Below-top group was 0.30 ± 0.22 mm, after 1-year of functional loading. The Wilcoxon signed-rank test revealed a significant difference in crestal bone loss between the Top and Below-top groups in individual patients (p = 0.002). No significant differences were found between the two groups for the gingival parameters.

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

Key words: micro-thread location, marginal bone level, prospective comparative study

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I. Introduction

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 biological width. Researches were conducted on the design and surface treatment of implants to minimize this problem.[2-6] A 4-year radiographic study[7] on micro-threaded Astra Tech 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 has also been stated that the implant-abutment interface design profoundly effects the stress distribution in marginal bone, and that 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 micro-threads at the implant neck are necessary to preserve and maintain the peri-implant marginal bone. Placing micro-threads at the implant neck greatly increases the ability of an implant to resist axial loads, and the mechanical stimulus provided by the micro-threads helps to preserve peri-implant marginal bone.[10] In animal experiments,[11] Astra Tech implants with Microthread™ at the implant neck had a higher degree of bone-to-implant contact than Brånemark implants. Furthermore, clinical studies[7,12] have shown minimal bone resorption and stable peri-implant marginal bone in Astra Tech implants with Microthread™ at the implant neck. A three-year clinical study[13] conducted by our group, which compared peri-implant marginal bone loss in micro-threaded and non-micro-threaded Astra Tech implants found that micro-threads at the implant neck were associated with less peri-implant marginal bone loss.

Previously published studies[11,13] have focused on the presence or absence of micro-threads, and thus do not provide insight into the effect of the micro-thread location on peri-implant marginal bone. In a clinical study[14] using implants with different thread locations, Jung et al. demonstrated that bone loss occurs differently depending on the thread location, and that peri-implant marginal bone levels stabilized at the level of the first thread. It could therefore be speculated that the micro-thread location could also have the same effect on the stabilization of marginal bone levels. The present study was conducted to investigate this relationship.

II. Materials and Methods

1. Materials

1) Implants

The implants (Implantium, Dentium®, Seoul, Korea) that were used in the present study are screw-shaped, threaded implants made of commercially pure titanium with SLA (sand-blasted, large grit, acid-etched) surface. The point on the implant neck at which surface treatment began was designated as the top of the fixture (Figure 1). Originally, the most coronal location of the micro-threads were 0.5 mm below the top of the fixture (Below-top; Figure 1, B). However, the design of the implant was changed: the location of the micro-threads were moved up to the top of the fixture (Top; Figure 1, A). Other than the location of the micro-thread, all the other designs were identical between Top and Below-top implants, and they were both available when the clinical research was performed.

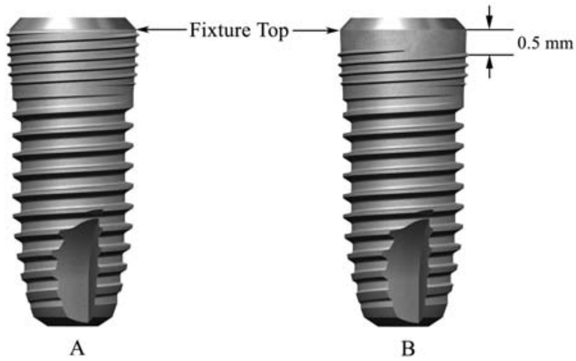

Figure 1. Schematic presentation of the implants. A, Top implant; B, Below-top implant

2) Patient selection

A pilot study was conducted prior to this investigation to determine the appropriate number of cases for statistically significant results. Twenty Below-top and Top implants each were arbitrarily chosen from independent patients not involved in the current research, and marginal bone loss after one year of functional loading was measured. A sample calculation revealed that 18 cases were necessary to obtain statistically significant results (Difference between mean of Top and Below-top = 0.20, Standard deviation 1 = 0.19, Standard deviation 2 = 0.23, α = 0.05, β = 0.20). Twenty cases were selected with an anticipated drop-out rate of 10% (MedCalc for Windows, version 10.3.0, MedCalc Software, Mariakerke, Belgium).

Patients who had undergone periodontal and implant treatment between March 2006 and July 2007 at Gangnam Severance Hospital (Department of Periodontology, College of Dentistry, Yonsei University, Seoul, Korea) 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, eleven males and nine females participated in the study, with a mean age of 53.7 years and a range of 37-78 years.

2. Methods

1) Treatment procedure

All surgeries were performed using a two-stage method. The Top and Below-top implants were placed adjacent to each other in the partially edentulous area of each patient. The mesiodistal location of each implant was randomly determined (Table 1). The second surgery was performed six and three months later for maxillary and mandibular implants, respectively. The prostheses were delivered three weeks after the second surgery. Prosthesis were mostly 2-unit bridges, except in the two patients (Table 1). Patients were recalled every three months for oral hygiene evaluation, professional plaque control, and review of self-performed oral hygiene instruction.

Table 1. Distribution of the installed implants according to jaw and fixture

Jaw	Fixture	Placed site														Total
		7	6	5	4	3	2	1	1	2	3	4	5	6	7	
Mx.	Top	3*	2		1				1			1	1		1	10
	Below-top		2	3*		1				1		1	1	1		10
Mn.	Top		2	2		1	1*							2	2	10
	Below-top	1	2	1	1					1*			1	2	1	10
Total		4	8	6	2	2	1		1	2		2	3	5	4	40

*In two patients, the Top and Below-top implants were not placed immediately adjacent to each other, and were splinted to fabricate 3- or 4-unit bridges.

2) Radiographic examination

Periapical radiographs (Kodak Insight, film speed F, Rochester, NY, USA) were taken one day after implant placement, immediately after the second surgery, immediately after prosthesis delivery, and one year after functional loading. Radiographs were taken with an XCP device (XCP Kit, Rinn, Elgin, IL, USA) using the parallel cone technique (70 kV, 8 mA, 0.250 s). A 5.5 mm spherical metal bearing (X-ray Distortion Markers, Salvin Dental Specialties, Charlotte, NC, USA) was placed to aid length measurement. All films were developed using the same automatic processor (Periomat, Durr Dental, Bietigheim-Bissingen, Germany) following the manufacturer's instructions. Films were digitized using a digital scanner (EPSON GT-12000, EPSON, Nagano, Japan) at an input resolution of 2400 dpi with 256 gray scale.

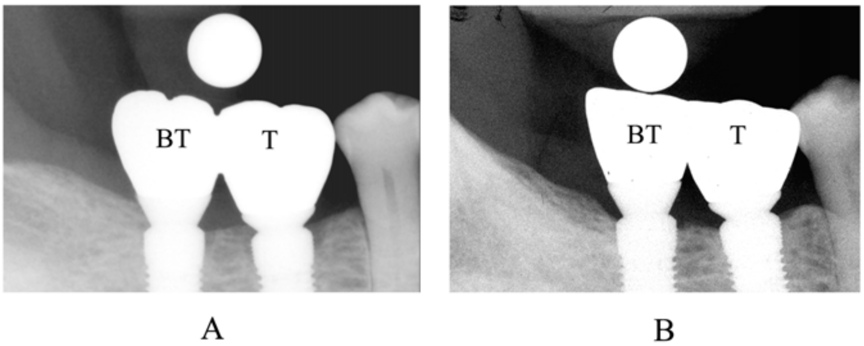

Figure 2. Intra-oral radiographs of implants
(T, Top implant; BT, Below-top implant).
A, At prosthesis delivery; B, One year after functional loading.

3) Measurement of marginal bone level change

Following digitization, all images were transferred to a personal computer (Processor, Intel Celeron D, Santa Clara, CA, USA; operating system, Windows XP Professional 2002, Redmond, WA, USA). The same monitor (Flatron 775FT Plus, LG, Seoul, Korea), set to a resolution of 1024 x 768, was used to examine the digitized radiographs. The room was kept dark throughout the computer-assisted radiographic measurement process.[15]

Bone loss was measured by comparing the radiographs taken immediately after prosthesis delivery to those taken one year after functional loading (Figure 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 (UTHSCSA Image Tool, Version 3.00, University of Texas Health Science Center in San Antonio). Because only vertical bone loss was measured, coronal bone gain was considered zero vertical bone loss. 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 (D-W-S). To test intra-observer variability, the marginal bone loss on 40 randomly selected radiographs was measured twice with a one-week interval. The statistical significance of the differences between the first and second measurements was assessed using a paired t-test. Pearson's 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's correlation coefficient of 0.97 (p < 0.0001, 95% confidence interval 0.93 to 0.98).

4) 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 mucosal index (mMI) were measured at four aspects around each implant.[16] Averages of the four obtained plaque and mucosal index values were calculated to represent the respective values for each implant.

5) Statistical analysis

The null hypothesis (H0) was defined as: (1) no difference between the medians of the marginal bone loss of the Top and Below-top groups during the examination period, (2) no difference between the medians of the plaque and gingival index of the Top and Below-top groups. The Kolmogorov-Smirnov test was used to test the normality of the distribution. The Wilcoxon's signed-rank test was used to analyze differences in peri-implant marginal bone loss and gingival parameters between the two groups. A computer software (SPSS for Windows, release 13.0, SPSS Inc., Chicago, IL, USA) was used to process the data. Values were deemed statistically significant for $p < 0.05$.

III. Results

1. 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. Complications associated with the prostheses were also not found.

2. 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. The average bone loss in the Top group was 0.16 ± 0.19 mm and 0.30 ± 0.22 mm in the Below-top group, showing a statistically significant difference (p = 0.002). A box plot of the marginal bone loss around Top and Below-top implants is illustrated in Figure 3.

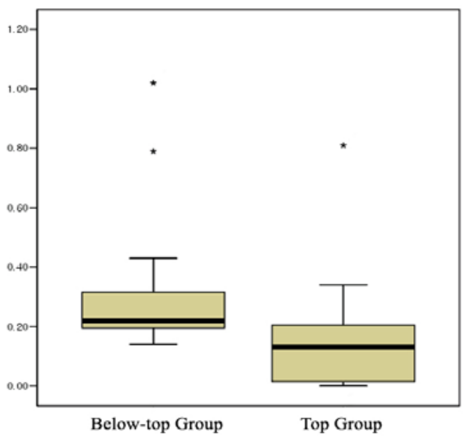

Figure 3. Box plot of the marginal bone loss around Top and Below-top implants.

Table 2. Marginal bone loss of Top and Below-top implants

Subject	Type of implants	
	Top	**Below-top**
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**
Standard deviation	**0.19**	**0.22**
Median	**0.13**	**0.22**

* $p = 0.002$, significantly different

3. Evaluation of peri-implants soft tissue

The peri-implant soft tissues revealed little tendency to bleed following probing and were clinically healthy. The average plaque index of the Top group was 0.69, while the average of the Below-top group was 0.65. The average mucosal index was 0.56 and 0.53 for the Top and Below-top group, respectively. The mPI and mMI for each type of implant is illustrated in Table 3, 4. No significant differences were found between the two groups for either the plaque or mucosal index (mPI; $p = 0.41$, mMI; $p = 0.18$).

Table 3. Modified plaque index of Top and Below-top implants

Subject	Type of implants	
	Top	Below-top
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**
Standard deviation	**0.30**	**0.29**
Median	**0.75**	**0.75**

* $p = 0.41$, Not significantly different

Table 4. Modified mucosal index of Top and Below-top implants

Subject	Type of implants	
	Top	**Below-top**
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**
Standard deviation	**0.34**	**0.34**
Median	**0.63**	**0.50**

* p = 0.18, Not significantly different

IV. Discussion

This prospective study investigated whether the micro-thread location at the implant neck affects the peri-implant marginal bone level. To minimize variability from load or bone quality, Top and Below-top implants 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 one year after functional loading to study the influence of micro-threads on changes in marginal bone under load.[17] Less bone loss was observed in the Top group than in the Below-top group (0.16 ± 0.19 mm vs. 0.30 ± 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 were within the success criteria established by Albrektsson et al.[1]

Allowing sliding movement between an implant and the bone may help the marginal bone resist horizontal forces, which argues the use of implants with a smooth neck.[18,19] However, numerous animal experiments[20,21] and clinical studies[22-26] have 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 micro-threads at the implant neck are necessary to avoid such problems.[10] In a clinical study[14] involving various implant systems, bone loss usually occurred to 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.

A photoelastic study[27] demonstrated that threads generate compressive stresses in the supporting tissues, and that the thread location on the implant body affects the pattern of load transfer. A literature review on peri-implant marginal bone loss indicated that the first thread converts the shear force placed on the implant into a compressive force.[28] According to one study,[29] 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.

The reported marginal bone loss around Astra Tech implants after one year of functional loading are varied, and range from 0.05 to 0.6 mm.[7,12,30,31] Here, the average bone loss around implants with micro-threads placed 0.5 mm below the top of the neck (Below-top) was 0.30 ± 0.22 mm, greater than that observed around implants in which the micro-threads were placed at the neck top (Top). Below-top implants lack retentive features above the micro-thread level, and therefore lack the ability to distribute stress concentrated at the implant neck. They thus transfer this stress to the peri-implant marginal bone. If such stress exceeds the threshold that the peri-implant marginal bone can withstand, compensatory modeling and remodeling occurs, eventually resulting in bone resorption.[32] Therefore, it could be said that micro-threads, which act to distribute stress, placed at the level of the marginal bone exert optimal effects for maintaining peri-implant marginal bone stability.

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 micro-thread. Also, while the aforementioned study 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, localized effects caused by any load acting on a body will dissipate or smooth out within regions that are sufficiently away from the location of the load. 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 the Below-top group, in which marginal bone resorption occurred to a level coronal to the first micro-thread, 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.

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 mMI of the implant prostheses were measured one year after functional loading.[16] 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.

It should be noted that the plaque and mucosal indices measured one 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 plaque and mucosal indices 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 instead due to differences in the micro-thread location. This study also showed that micro-threads stabilize the level of the marginal bone. Therefore, placing micro-threads as far coronally as possible along the bone-to-implant interface could help maintain the marginal bone.

V. Conclusion

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

The average bone loss in the Top group was 0.16 ± 0.19 mm, and in the Below-top group was 0.30 ± 0.22 mm, after 1-year of functional loading. The Wilcoxon signed-rank test revealed a significant difference in crestal bone loss between the Top and Below-top groups in individual patients (p = 0.002). No significant differences were found between the two groups for the gingival parameters.

Less peri-implant bone loss was observed in the Top group compared with the Below-top group. These results indicate that micro-threads act to stabilize the peri-implant marginal bone and that their location plays an important role in the stabilization process.

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국문 요약

미세나사선의 위치에 따른
임플란트 주위 변연골 소실 비교 분석:
기능적 부하 후 1년 간의 전향적 연구

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이번 연구에서는 미세나사선의 위치가 서로 다른 두 임플란트에서 기능적 부하를 가하고 1년 후의 골소실량을 비교 분석하여 미세나사선의 위치가 임플란트 주위 변연골 유지에 미치는 영향에 대하여 알아보려 하였다.

총 20명의 환자에게 미세나사선이 임플란트 최상부부터 존재하는 임플란트 (Top) 와 미세나사선이 최상부 0.5 mm 하방부터 존재하는 임플란트 (Below-top) 를 인접하여 식립하였다. 임플란트 주위 변연골에 가해지는 응력 분포에 미치는 미세나사선의 영향을 알아보기 위하여 상부 보철물 연결 시의 방사선 사진과 기능적 부하를 가하고 1년 후 방사선 사진 사이의 임플란트 주위 변연골 변화량을 조사하였다. 또한 두 임플란트에서 변연골에 미치는 염증의 영향을 조사하기 위해 기능적 부하를 가하고 1년 후 각각의 임플란트에서 치은 지수 (치태 지수, 점막 지수) 를 측정하였다.

각 임플란트의 근원심에서의 골변화량의 평균은 Top 임플란트는 0.16 ± 0.19 mm, Below-top 임플란트는 0.30 ± 0.22 mm 였으며, Wilcoxon's signed-rank test를 이용하여 분석한 결과 통계학적으로 유의한 차이를 보였다 (p = 0.002). 기

능적 부하를 가하고 1년 후 측정한 치은 지수 (치태 지수, 점막 지수) 는 두 임플란트에서 유의한 차이를 보이지 않았다 (치태 지수; $p = 0.41$, 점막 지수; $p = 0.18$).

이번 연구에서 Top 임플란트에 비해 Below-top 임플란트에서 더 많은 양의 골소실이 관찰되었으며, 두 임플란트에 가해진 염증의 영향이 동일하다고 가정할 때 미세나사선의 위치 차이가 연구 결과에 영향을 미쳤다고 할 수 있다.

본 연구 결과에 의하면 미세나사선은 임플란트 주위 변연골 유지에 기여하며, 이 과정에서 미세나사선의 위치가 중요한 역할을 한다고 할 수 있다.

핵심 되는 말: 미세나사선 위치, 변연골 소실량, 전향적 비교 연구