Radiographic Evaluation of Marginal Bone Level Around Implants with Different Neck Designs After 1 Year

Young-Kyu Shin, DDS[1]/Chong-Hyun Han, DDS, MSD, PhD[2]/Seong-Joo Heo, DDS, MSD, PhD[3]/Sunjai Kim, DDS, MS[4]/Heoung-Jae Chun, PhD[5]

Purpose: *To evaluate the influence of macro- and microstructure of the implant surface at the marginal bone level after functional loading.* ***Materials and Methods:*** *Sixty-eight patients were randomly assigned to 1 of 3 groups. The first group received 35 implants with a machined neck (Ankylos); the second group, 34 implants with a rough-surfaced neck (Stage 1); and the third, 38 implants with a rough-surfaced neck with microthreads (Oneplant). Clinical and radiographic examinations were conducted at baseline (implant loading) and 3, 6, and 12 months postloading. Two-way repeated analysis of variance (ANOVA) was used to test the significance of marginal bone change of each tested group at baseline, 3, 6, and 12 month follow-ups and 1-way ANOVA was also used to compare the bone loss of each time interval within the same implant group (P < .05).* ***Results:*** *At 12 months, significant differences were noted in the amount of alveolar bone loss recorded for the 3 groups (P < .05). The group with the rough-surfaced microthreaded neck had a mean crestal bone loss of 0.18 ± 0.16 mm; the group with the rough-surfaced neck, 0.76 ± 0.21 mm; and the group with the machined neck, 1.32 ± 0.27 mm. In the rough-surfaced group and the rough-surfaced microthreaded group, no statistically significant changes were observed after 3 months, whereas the machined-surface group showed significant bone loss for every interval (P < .05).* ***Discussion:*** *To minimize marginal bone loss, in addition to the use of a rough surface at the marginal bone level, a macroscopic modification such as the addition of microthreads could be recommended. A rough surface and microthreads at the implant neck not only reduce crestal bone loss but also help with early biomechanical adaptation against loading in comparison to the machined neck design.* ***Conclusion:*** *A rough surface with microthreads at the implant neck was the most effective design to maintain the marginal bone level against functional loading.* (Comparative Cohort) INT J ORAL MAXILLOFAC IMPLANTS 2006;20:789–794

Key words: *machined neck, marginal bone level, microthreads, rough surface*

According to established criteria for the assessment of implant survival and success, marginal bone level change in the first year should be less than 1.5 mm, and ongoing annual bone loss should be less than 0.2 mm.[1] Adell and associates reported a bone loss of 1.2 mm using Brånemark implants for the first year in their 15-year study.[2] It was suggested that the initial marginal bone level change occurred as an adaptation of the peri-implant bone to the occlusal load. Jung and associates also reported bone loss to the level of the first thread with other implant systems.[3]

"Implant design" refers to the macro- and microstructure of an implant system (eg, shape, type of implant-abutment connection, presence of thread, thread design, surface treatment). In the early 1970s, Linkow and Chercheve proposed that dental implants have smooth endosseous necks to prevent plaque accumulation,[4] and this concept has been adopted by most dental implant manufacturers. However, a number of finite element studies have demonstrated that the peak stress, especially shear

[1]Graduate Student, Department of Prosthodontics, Yongdong Severance Hospital, College of Dentistry, Yonsei University, Seoul, South Korea.
[2]Professor, Department of Prosthodontics, Yongdong Severance Hospital, College of Dentistry, Yonsei University, Seoul, South Korea.
[3]Professor, Department of Prosthodontics and Dental Research Institute, Seoul National University, Seoul, South Korea.
[4]Assistant Professor, Department of Prosthodontics, Yongdong Severance Hospital, College of Dentistry, Yonsei University, Seoul, South Korea.
[5]Professor, Department of Mechanical Engineering, College of Engineering, Yonsei University, Seoul, South Korea.

Correspondence to: Dr Chong-Hyun Han, Department of Prosthodontics, Yongdong Severance Hospital, Dogokdong, Seoul, Korea. Fax: +82 2 3461 9082. E-mail: yongdong@empal.com

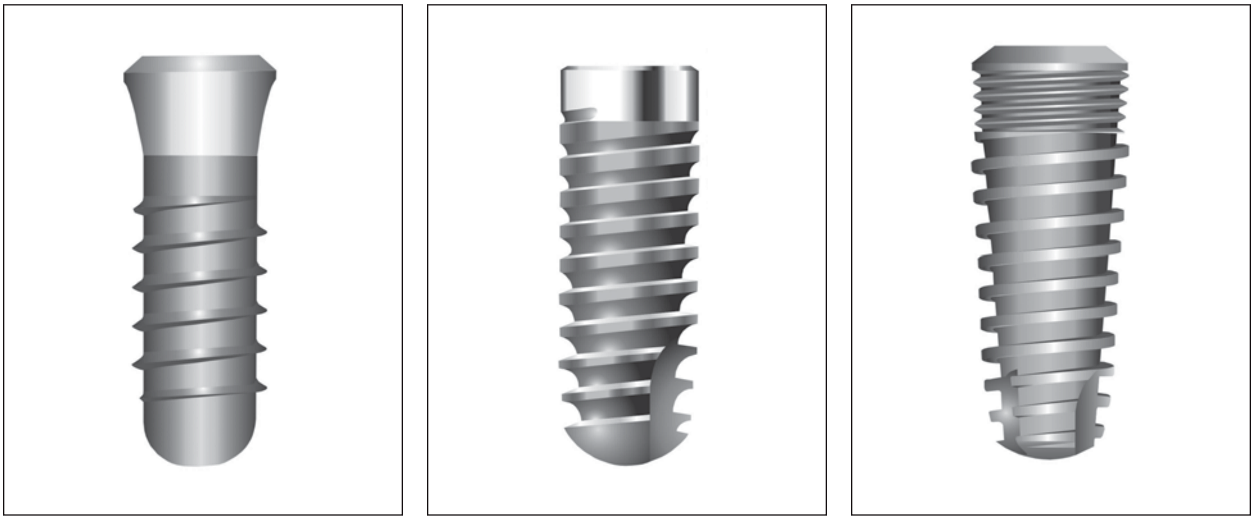

Fig 1 Stage-1 *(left)*, Ankylos *(middle)*, and Oneplant *(right)* implant systems were used in the study.

stress, was concentrated at the crestal bone area around the machined neck.[5,6] Since the cortical bone is 65% more susceptible to shear forces compared to compressive forces,[7] it can be speculated that this bone loss may be attributed to the lack of effective mechanical stress distribution between the machined coronal region of the implant and the surrounding bone.[8]

In a finite element analysis, Hansson described a positive correlation between surface roughness parameters and interfacial shear strength and suggested that retentive elements such as microthreads at implant neck may counteract marginal bone resorption.[9] Zechner and coworkers compared the amount of marginal bone loss between machined and rough-surfaced implants and concluded that significantly less bone loss was observed for rough-surfaced implants.[10] Furthermore, Norton reported a low amount of crestal bone loss for both dental implants with a rough surface and a microthread at the implant neck.[11]

The aim of this clinical study was to evaluate the influence of the macro- and microstructures of implants by analyzing the amount of marginal bone loss observed with 3 implant systems with different neck designs: machined, rough-surfaced, and rough-surfaced with microthreads.

MATERIALS AND METHODS

Patients and Implants

Subjects were selected from patients referred to the Department of Prosthodontics, Yongdong Severance Hospital, Seoul, Korea, between October 2002 and December 2003. Patients were randomized in blocks and had an equal probability of receiving an implant system with a rough-surfaced neck (Stage-1; Lifecore, Chaska, MN), one with a machined neck (Ankylos; Friadent, Mannheim, Germany), or one with a rough surface with microthreads (Oneplant; Warantec, Seoul, Korea) (Fig 1). The surface of the Stage-1 implant is roughened by blasting with calcium phosphate ceramics; it has a highly polished shoulder for soft tissue adaptation. The Ankylos implant has a machined surface in the implant neck and a rough-surfaced body with a progressive thread design, and the Oneplant implant has a sandblasted and acid-etched surface and microthreads in the implant neck. Patients were consecutively enrolled in the study according to predefined inclusion criteria. The inclusion criteria were

- Sufficient bone height to place implants according to the guidelines given by the manufacturers
- Sufficient bone width to prevent any dehiscence during implant placement
- Complete healing of the extraction site (implants had to be placed at least 3 months after extraction)
- One or 2 missing posterior teeth of the maxilla and mandible

Patients who were bruxers or who required the use of bone grafting or a membrane were excluded from the study. Implants were considered failures if pain, infection, or implant mobility were found.

Implant Treatments

A 1-stage surgical procedure was performed, and implants were placed at the depth recommended in the guidelines given by the manufacturers (Fig 2). Single crowns or 2-unit splinted crowns were placed

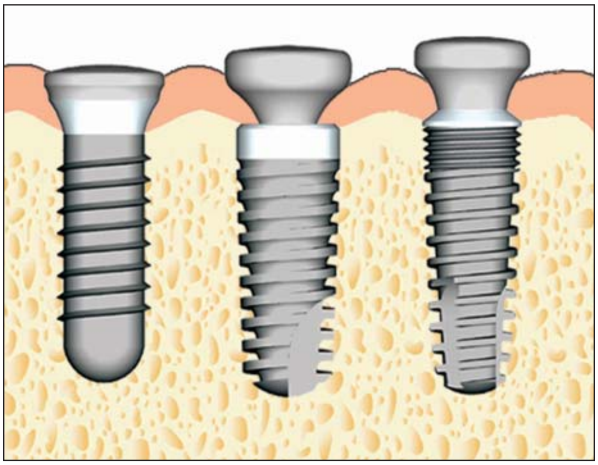

Fig 2 Single-stage surgical procedures were performed; implant depth was determined using the manufacturer's guidelines.

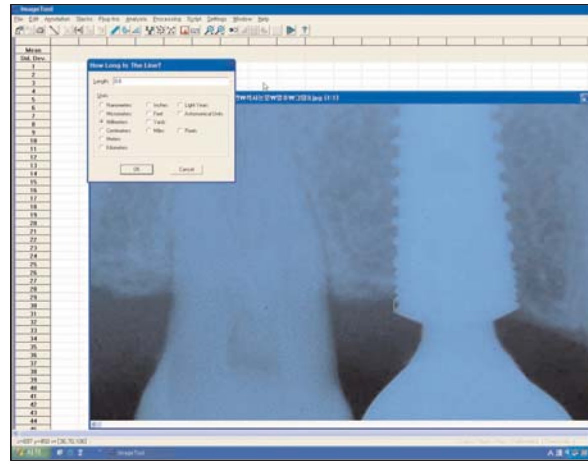

Fig 3 Digital processing of a radiographic image using UTHSCSA Image Tool software.

after 2 months for the mandible and 3 months for the maxilla. All surgical and prosthetic procedures were performed by the same clinician.

Follow-up

Clinical and radiographic examinations were conducted at baseline (loading of the implants) and at 3, 6, and 12 months postloading.

Complications such as signs of infection, abscess, abnormal hematoma, paresthesia, and mobility, if observed, were recorded at the 3 follow-up visits after implant placement. The prosthodontic results were recorded as successful if the implant-retained prosthesis remained in place and no complications were reported.

Intraoral radiographs were obtained using a paralleling technique. The radiographs were digitalized using a computerized scanner (UMAX, Astra 4000U, Korea]) at 600 dpi, 256 gray scales.

Using the most coronal point of the implant as the reference point and the lowest point of marginal bone around the implant as the bone level, the distance was measured to the nearest 0.01 mm with the UTHSCSA Image Tool (version 3.00 for Windows, University of Texas Health Science Center in San Antonio, TX; Figs 3 and 4). Bone loss was measured on the mesial and distal sides of the implants, and the average value was used.

Statistical Analysis

SPSS 10.0 (SPSS, Chicago, IL) was used for statistical analysis. Two-way repeated analysis of variance (ANOVA) was used to test the significance of marginal bone change of each tested group at baseline and each follow-up. One-way ANOVA was also used to compare the bone loss of each time interval within the same implant group. Fisher's least significant difference (LSD) was carried out for the multiple comparison tests. Statistical significance for all tests was set at $P < .05$.

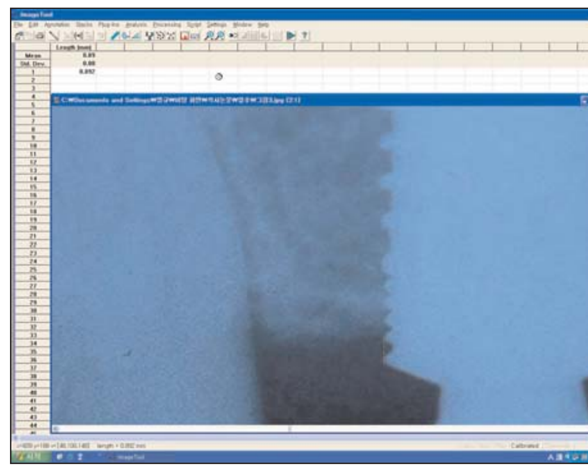

Fig 4 Measurement of crestal bone loss on a magnified radiographic image using UTHSCSA Image Tool software.

RESULTS

The test group comprised 107 implants in 68 patients, 29 women and 39 men, with a mean age of 48 years. Thirty-five implants with machined necks, rough necks, and rough necks with microthreads were examined (Table 1, Fig 1). In all patients initial implant stability was achieved.

No remarkable complications were experienced over the course of the study. No patient reported suffering from pain, and no mobility or prosthetic complications were detected.

Table 1 Distribution of the Implants

	Neck surface: Machined	Rough	Rough with microthreads	Total
Jaw				
Maxilla	13	14	17	44
Mandible	22	20	21	63
Patient sex				
Male	12	12	15	39
Female	23	22	23	68

Table 2 Crestal Bone Level Changes Measured from the Bone Level at Baseline

Neck surface	Follow-up: 3-month Mean	3-month SD	6-month Mean	6-month SD	12-month Mean	12-month SD
Machined	0.98	0.32*	1.24	0.23	1.32	0.27
Rough	0.58	0.13*	0.70	0.18	0.76	0.21
Rough with microthreads	0.15	0.05*	0.18	0.07	0.18	0.16

*$P < .05$.

Table 3 Crestal Bone Level Changes Between Implants for Different Time Intervals

Neck surface	Follow-up: 0 to 3 mo Mean	0 to 3 mo SEM	3 to 6 mo Mean	3 to 6 mo SEM	6 to 12 mo Mean	6 to 12 mo SEM
Machined	0.98	0.32*	0.26	0.18*	0.09	0.12*
Rough	0.58	0.13*	0.12	0.08	0.05	0.06
Rough with microthreads	0.15	0.05*	0.03	0.05	0.01	0.11

*$P < .05$.

In 1 patient with rough-necked implants, a slight soft tissue inflammation was diagnosed at the 3-month follow-up. After a decontamination procedure and an antibiotic treatment, the inflammation ceased.

Marginal Bone Level Changes

Marginal bone loss for each type of implant are illustrated in Table 2. The changes in bone level between systems were analyzed using 2-way repeated ANOVA, and significant differences were detected among the 3 systems ($P < .05$).

The group with the rough-surfaced microthreaded implant neck showed the least amount of bone loss (mean, 0.18 ± 0.16 mm), and the group with machined neck showed the greatest amount of bone loss (mean, 1.32 ± 0.27 mm) after 1 year of functional loading.

Table 3 shows the changes in bone loss for each interval and system. The majority of the bone loss occurred during the first 3 months of loading in all systems. There was a statistically significant decrease after 3 months with all systems ($P < .05$). However, after 3 months, neither implants with a rough neck nor those with a rough-surfaced microthreaded neck underwent significant bone loss. In comparison, for the machined-neck group, significant bone loss was found at every follow-up ($P < .05$).

DISCUSSION

The implants used in the current study have some differences in the macro- and microdesign of their neck areas. Ankylos has a machined surface, Stage-1 has a rough surface, and Oneplant has both a rough surface and a microthread. The results of the current study demonstrated that the amount of marginal bone loss at 12 months of functional loading was significantly different among the 3 groups ($P < .05$). After 1 year of functional loading, the group with the rough-surfaced microthreaded neck showed the least amount of bone loss, whereas the group with machined neck design showed the greatest amount of bone loss.

Until the early 1990s, the neck portion of most endosseous dental implants had a smooth machined surface, originating with the Brånemark System, and this was regarded as an effective design to prevent plaque accumulation when an implant was exposed to oral cavity because of loss of the alveolar bone.[12] However, this machined neck is not an effective design for the distribution of occlusal force. Many longitudinal studies have shown the marginal bone level to be resorbed to the first thread of machined implants after a year of function.[3,8] Bone growth over the cover screw is often discovered at second-stage surgery, but after functional loading, bone loss down to the first thread has been noted.[2,3,13] This phenomenon could be explained by the biomechanical adaptation of bone to occlusal loads.[14]

There have been many reports on the influence of surface roughness on the bone-implant interface with respect to marginal bone loss. In 1990 Wilke and associates reported an increased resistance to interfacial shear strength between implant and bone when the surface of the implant was roughened in some way,[15] and Hansson and Norton utilized a mathematical model to determine the ideal surface roughness.[16] However, in the present study, the surface roughness was found somewhat insufficient to hold the crestal bone level. This finding is supported by an earlier study by Bragger and colleagues.[17] In that study, Straumann implants were placed supracrestally to eliminate the possible influence of the smooth surface, and bone loss was investigated 1 year after surgery. Although the rough-smooth surface border was far away from the marginal bone, a mean crestal bone loss of 0.78 mm was reported, suggesting the insufficiency of the rough surface to maintain a steady bone level.

The present study also examined implants with a rough-surfaced microthreaded neck. Many clinical studies have been conducted on the effect of the microthread on crestal bone loss.[11,18] Norton evaluated 33 single-tooth implants radiographically for up to 4 years and reported bone loss of 0.32 mm mesially and 0.34 mm distally.[11] Palmer and coworkers reported no important bone loss in their observation of Astra Tech implants.[18] These clinical reports could be explained by finite element analysis. Hansson found that the microthreads at the implant neck decrease the peak interfacial shear stress on the cortical bone.[9]

In the present study, the majority of the bone loss occurred early in the loading period for all systems, and the amount of marginal bone loss after 3 months of functional loading was not significant in the rough-surfaced and rough-surfaced microthreaded groups ($P > .05$). However, the implants with machined necks showed significant bone loss in every interval, which could be interpreted as progressive bone loss. Furthermore, bone loss for this group did not become stabilized (ie, reach a "steady state," defined by Albrektsson and associates as bone loss of 0.2 mm or less) until 6 months postloading.[1] It is important to know when bone resorption around implants reaches a steady state because the preservation of bone support is essential for soft tissue esthetics. When soft tissue esthetics are crucial to the implant success, it is advisable to wait until 6 months of functional loading to deliver the final prosthesis if implants with a machined neck were placed.

Although the present study focused on differences in crestal bone loss caused by biomechanical aspects, especially functional load, biologic aspects, such as the concept of crestal bone loss due to the formation of a biologic width around the implant, should not be ignored. Grunder and associates suggested that crestal bone loss caused by "platform switching" could be reduced by moving the implant-abutment junction toward the center of the implant, away from the surrounding bone.[19] This hypothesis is based on research that demonstrated that bacterial contamination of the implant-abutment interface appears to provoke the inflammatory response.[20,21] Two of the implants used in the present study, the implant with the machined neck and the one with the rough neck with microthreads, were placed with the implant-abutment junction away from the crestal bone. However, the implants with machined necks showed the greatest amount of bone loss in this study. Based on these results, it could be concluded that moving the microgap away from the crestal bone alone was not sufficient to reduce bone loss, and additional design changes such as the use of microthreads and a rough surface should be considered for the implant neck.

The causes of crestal bone loss around implants are not fully understood. Since the present study had a relatively small sample size, and the implants studied had differences other than neck configuration that may have influenced the results, further studies are needed to clarify the relationship between implant neck design and crestal bone loss.

CONCLUSION

Within the limits of these clinical results, it can be concluded that the use of a rough surface with microthreads on implants at the crest region was the most effective design to maintain the marginal bone level after functional loading.

ACKNOWLEDGMENTS

This study was supported by a grant of the Korea Health 21 Project, Ministry of Health and Welfare, Republic of Korea [01-PJ5-PG1-01CH12-0002] and by the Brain Korea 21 Project for Medical Science, Yonsei University.

REFERENCES

1. Albrektsson T, Zarb G, Worthington P, Eriksson RA. The long-term efficacy of currently used dental implants. A review and proposed criteria for success. Int J Oral Maxillofac Implants 1986;1:11–25.
2. Adell R, Lekhom U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10:387–416.

3. Jung YC, Han CH, Lee KW. A 1 year radiographic evaluation of marginal bone around dental implants. Int J Oral Maxillofac Implants 1996;11:811–818.
4. Linkow LI, Cherchève R. Theories and techniques of oral implantology. St Louis, MO: Mosby, 1970.
5. Kitoh M, Matsushita Y, Yamane S, Ikeda H, Suetsugu T. The stress distribution of the hydroxyapatite implant under the vertical load by the two-dimensional finite element method. J Oral Implantol 1988;14:65–72.
6. Meijer HJA, Starmans FJM, Steen WHA, Bosman F. A three-dimensional, finite element analysis of bone around dental implants in an edentulous human mandible. Arch Oral Biol 1993;38:491–496.
7. Guo EX. Mechanical properties of cortical bone and cancellous bone tissue. In: Cowin SC (ed). Bone Mechanics Handbook, ed 2. Boca Raton, FL: CRC Press, 2001:1–23.
8. Oh TJ, Yoon JK, Misch CE, Wang HL. The causes of early implant bone loss: Myth or science? J Peridontol 2002;73:322–333.
9. Hansson S. The implant neck: Smooth or provided with retention elements. A biomechanical approach. Clin Oral Implants Res 1999;10:394–405.
10. Zechner W, Trinkl N, Watzak G, et al. Radiologic follow-up of peri-implant bone loss around machine-surfaced and rough-surfaced interforaminal implants in the mandible functionally loaded for 3 to 7 years. Int J Oral Maxillofac Implants 2004;19:216–221.
11. Norton MR. Marginal bone levels at single tooth implants with a conical fixture design. The influence of surface macro- and microstructure. Clin Oral Implants Res 1998;9:91–99.
12. Misch CE, Bidez MW. A scientific rationale for dental implant design. In: Misch CE (ed). Contemporary Implant Dentistry, ed 2. St Louis: Mosby, 1999:329–343.
13. Jemt T, Lekhom U, Gröndahl K. A 3-year follow-up study of early single implant restoration ad modum Brånemark. Int J Periodontics Restorative Dent 1990;10:341–349.
14. Kitamura E, Stegaroiu R, Nomura S, Miyakawa O. Biomechanical aspects of marginal bone resorption around osseointegrated implants: Considerations based on a three-dimensional finite element analysis. Clin Oral Implants Res 2004;15:401–412.
15. Wilke HJ, Claes L, Steinemann S. The influence of various titanium surfaces on the interface shear strength between implants and bone. Advances in Biomaterials 1990;9:309–314.
16. Hansson S, Norton M. The relation between surface roughness and interfacial shear strength for bone anchored implants: A biomechanical approach. In: Hansson S (ed). Toward an Optimized Dental Implant and Bridge Design: A Biomechanical Approach [thesis]. Göteborg, Sweden: Chalmers University of Technology, 1997.
17. Brägger U, Häfeli U, Huber B, Hämmerle CHF, Lang NP. Evaluation of postsurgical crestal bone levels adjacent to non-submerged dental implants. Clin Oral Implants Res 1998;9:218–224.
18. Palmer RM, Smith BJ, Palmer PJ, Floyd PD. A prospective study of Astra single tooth implants. Clin Oral Implants Res 1997;8: 173–179.
19. Grunder U, Gracis S, Capelli M. Influence of 3-D bone-to-implant relationship on esthetics. Int J Periodontics Restorative Dent 2005;25:113–119.
20. Ericsson I, Nilner K, Klinge B, Glantz P-O. Radiographical and histological characteristics of submerged and nonsubmerged titanium implants 1996;7:20–26.
21. Persson LG, Lekholm U, Leonhardt A, Dahlen G, Lindhe J. Bacterial colonization on internal surfaces of Brånemark system implant components. Clin Oral Implants Res 1996;7:90–95.