Research Article

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Effect of microthreads on removal torque and bone-to-implant contact: an experimental study in miniature pigs

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Purpose: The objective of this study was to evaluate the effect of microthreads on removal torque and bone-to-implant contact (BIC).
Methods: Twelve miniature pigs for each experiment, a total of 24 animals, were used. In the removal torque analysis, each animal received 2 types of implants in each tibia, which were treated with sandblasting and acid etching but with or without microthreads at the marginal portion. The animals were sacrificed after 4, 8, or 12 weeks of healing. Each subgroup consisted of 4 animals, and the tibias were extracted and removal torque was measured. In the BIC analysis, each animal received 3 types of implants. Two types of implants were used for the removal torque test and another type of implant served as the control. The BIC experiment was conducted in the mandible of the animals. The P1–M1 teeth were extracted, and after a 4-month healing period, 3 each of the 2 types of implants were placed, with one type on each side of the mandible, for a total of 6 implants per animal. The animals were sacrificed after a 2-, 4-, or 8-week healing period. Each subgroup consisted of 4 animals. The mandibles were extracted, specimens were processed, and BIC was analyzed.
Results: No significant difference in removal torque value or BIC was found between implants with and without microthreads. The removal torque value increased between 4 and 8 weeks of healing for both types of implants, but there was no significant difference between 8 and 12 weeks. The percentage of BIC increased between 2 and 4 weeks for all types of implants, but there was no significant difference between 4 and 8 weeks.
Conclusions: The existence of microthreads was not a significant factor in mechanical and histological stability.

Keywords: Biomechanics, Dental implants, Osseointegration, Torque.

INTRODUCTION

Osseointegration and stability of the implant are critical factors to the success of dental implants. Removal torque and bone-to-implant contact (BIC) are two important measures that indicate the degree of stability and osseointegration [1].

Geometry and surface roughness of the implant are thought to be important factors that influence osseointegration and stability. Many previous studies regarding the surface roughness and its effect on osseointegration have demonstrated that rough surfaces show higher biomechanical and histomorphometric properties than smooth surfaces [2,3].

Also important is the geometry of the implants, especially the thread patterns affecting osseointegration and stability of dental implants. The effects of thread shape, pitch, depth, and width on BIC, stress distribution, and marginal bone loss

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can be speculated.

More specifically, microthreads have been suggested to increase the implant surface area. The smaller thread pitch of microthreads makes a larger number of threads possible within the limited length of the fixture leading to a greater surface area. Thus, the increased surface area of the microthreads provides a more favorable stress distribution and makes the implant stable. Previous research regarding microthreads seems to support this rationale. Implants designed with microthreads at the marginal portion are reported to show less marginal bone loss [4] and higher BIC [5]. However, there is lack of research related to microthreads and their effect on biomechanical stability.

In this study, implants with and without microthreads were used to evaluate the effect of microthread design of implants on removal torque and BIC.

MATERIALS AND METHODS

Animals and preparation

The protocol of this study was approved by the Medikinetics Institutional Animal Care and Use Committee (Medikinetics-IACUC: 100125-001). Twelve adult male miniature pigs (Medi Kinetics Micropigs, Medi Kinetics Co., Busan, Korea) were used in the experiment. The removal torque was measured in the tibia of miniature pigs and histomorphometric analysis was conducted in the mandible of the miniature pigs.

The animals were premedicated with atropine (0.05 mg/kg). Zoletil (Virbac Laboratories, Carros, France) and xylazine (Narcosyl, Intervet Korea, Seoul, Korea) were used to induce anesthesia. Isoflurane (Ifran, Hana Pharm Co., Seoul, Korea) with oxygen in a 1:1 ratio (5–10 mL/kg/min) were used to maintain anesthesia during the experiment.

Implants

Two types of implants (Osstem Implant Co., Seoul, Korea) with the same diameter and length were used (ø3.7×8.5 mm) in the removal torque test. Both types of implants were treated with alumina sandblasting and acid etching of the surface and the only difference between the two types was the presence or absence of microthreads at the marginal portion. Group A had microthreads while group B did not.

The group B threads had a 0.8 mm pitch and 0.25 mm depth. On the other hand, group A had microthreads at the marginal portion with 0.4 mm thread pitch and 0.25 mm depth, and the threads with the same dimension as in group B at the apical portion. For the BIC experiment, in addition to group A and B, group C (ø3.5×8.0 mm; Astra Tech AB, Molndal, Sweden) was used to serve as a representative control (Fig. 1).

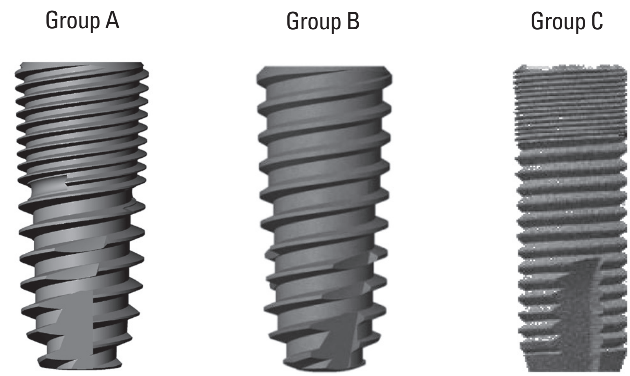

Figure 1. Design of implants used in the experiment.

Removal torque test

At both tibias in the 12 miniature pigs, implants representing group A and group B were placed, respectively. Each miniature pig received 4 implants, 2 on each side of the tibia and the position for each implant was rotated for each animal. Thus, 24 of each type of implant were placed making the total number of implants 48.

After disinfecting the surgical area with Betadine and ethanol, only the surgical area was exposed. Following initial drilling with a 2 mm twist drill, 2.0 mm and 3.3 mm diameter drills were used for drilling and implants were placed.

The miniature pigs were sacrificed after healing periods of 4, 8, or 12 weeks. Each subgroup consisted of 4 miniature pigs. The tibias of the sacrificed miniature pigs were extracted, followed by soft tissue removal and cover screw removal. In order to measure removal torque, a digital torque gauge (Kanon DTDK-N5EXL, Nakamura Mfg. Co., Tokyo, Japan) was connected to the fixture driver and the fixture driver was then connected to the fixture. The removal torque was measured by rotating the osseointegrated fixture counterclockwise. The maximum torque limit between the fixture and fixture driver was 260 Ncm. Implants that showed higher removal torque than the threshold had a tendency to slip and it was impossible to remove them from the tibia. In this case, the torque at the time of slipping was measured.

BIC analysis

A total of 12 miniature pigs were used. In each animal, P1–M1 on both sides of the mandible were extracted, and after 4 months of healing, 3 implants were placed at the 1 mm subcrestal level. The position of each implant was rotated for each animal. Seventy-two implants in total, with 24 implants each in groups A, B, and C were placed.

After disinfecting the oral cavity with 0.1% chlorhexidine, mucoperiosteal flaps were raised to expose the surgical site. Initial drilling was performed followed by drilling with diam-

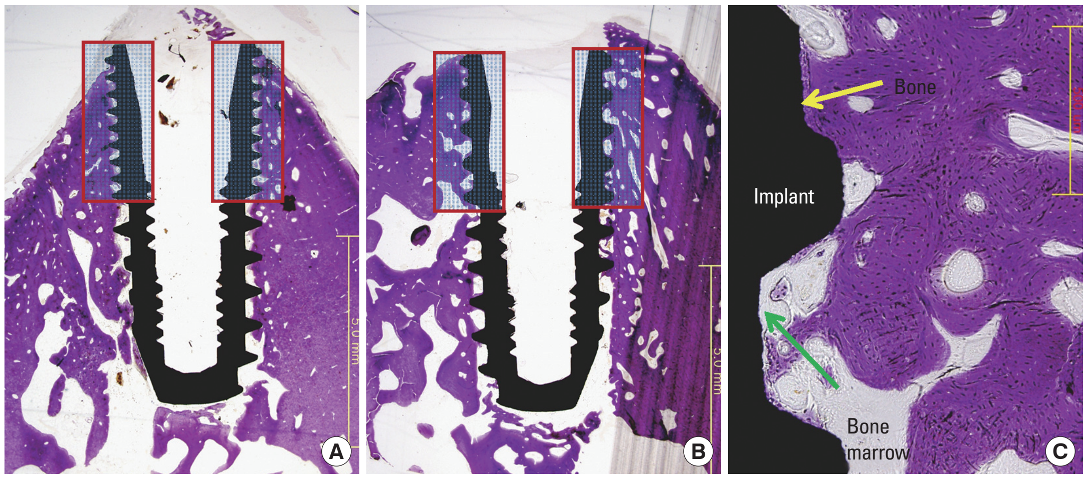

Figure 2. Cross section of implant in mandible A. (A) Implant group A. The red square indicates the region where the bone-to-implant contact (BIC) measurement was performed (H&E, ×10). (B) Implant group B. The red square indicates the region where the BIC measurement was performed (H&E, ×10). (C) Larger magnification of the marginal portion where the BIC measurement was performed. The region stained in purple indicates bone. Osseointegration can be observed at the implant-bone interface (H&E, ×100).

eters of 2.0, 3.0, and 3.6 mm and the placement of the implant fixtures. For the Astra implant (control) group, the fixtures were placed following the drilling sequence of 2.0, 3.0, and 3.4 mm drills, respectively.

The animals were sacrificed after 2, 4, and 8 weeks. Each subgroup consisted of 4 miniature pigs. The specimens were collected to include the implant fixture and the peripheral bone tissue. Each specimen was fixed with 10% phosphate buffered formalin, consecutively dehydrated using alcohol, and embedded with resin (Technovit 7210 VLC, Heraeus Kulzer GmbH, Wehrheim, Germany).

The embedded blocks were severed in the bucco-lingual direction using a diamond band cutting system (Exakt CP, Exakt Apparatebau, Norderstedt, Germany), ground to a 30-40 μm thickness using a micro grinding system (Exakt 400CS, Exakt Apparatebau, Norderstedt, Germany), and hematoxylin and eosin stained.

Light microscopy (BX51, Olympus Co., Tokyo, Japan), a digital camera (DP71, Olympus Co.) and image analysis software (Image-Pro Plus, Media Cybernetics Inc., Silver Spring, MD, USA) were used in histological and histomorphometric analysis with a ×100 magnification.

BIC analysis was performed in the portion with the microthreads and the corresponding portions of each type of implant (Fig. 2). Samples with errors in processing the specimens were excluded.

Statistical analysis

Mean and standard deviation values were calculated for each type of implant according to the different healing periods in both the removal torque and BIC experiments. Due to the small number of implants used in the experiment, the normality assumption could not be made and the *t*-test could not be applied. Instead, nonparametric methods were used to test the difference between each implant type. In this case, a Mann-Whitney *U* test was used to investigate the differences between each implant type. *P*-values < 0.05 were considered significant. Statistical analysis was performed using the IBM SPSS ver. 19.0 (IBM Co., Armonk, NY, USA).

RESULTS

Clinical observation

No remarkable complications were found during the healing period for either experiment. There were no open wounds, infections, fractures, or lost implants. At sacrifice, all 48 implants were considered successfully integrated at the time of the removal torque experiment. For the BIC experiment, 2 out of 72 implants showed an inadequate level of bone regeneration and showed mobility at sacrifice. These sites were excluded from the analysis.

Removal torque

The mean and standard deviation of removal torque is illustrated in Table 1 and Fig. 3. There was no significant difference between group A and B at each healing interval. The removal torque values of both types of implants increased between 4 and 8 weeks, but there were no significant differences between 8 and 12 weeks for both types of implants.

Bone-to-implant contact

The mean and standard deviation of BIC is illustrated in

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Table 2 and Fig. 4. At every healing period, there was no significant difference between groups A and B. There was also no significant difference between groups A and C and between groups B and C for every healing period. BIC values increased between 2 and 4 weeks for every type of implant including group C, but there were no significant differences between 4 and 8 weeks for any of the types of implants.

DISCUSSION

The purpose of the present study was to investigate the effect of microthreads at the crestal portion of the implants on biomechanical and histological stability.

It has been suggested that microthreads in the crestal portion maintain marginal bone and soft tissues around the implants. Many studies evaluating microthreads at the neck of the implant fixture and their effect on marginal bone loss have demonstrated less marginal bone loss on long-term follow-up [4]. In addition, histological evaluation in a previous investigation demonstrated higher BIC values in microthreaded implants [5]. This finding of higher BIC and less marginal bone loss may be related to the small thread pitch of the microthreads. The pitch is considered to have a significant effect among implant design variables because of its effect on surface area [6]. As the thread pitch decreases, surface area increases to produce more favorable stress distribution. Microthreads in the crestal portion create greater surface area at the marginal portion to transfer vertical load into a more compressive interface, creating less shear stresses at the bone-implant interface [7]. On the other hand, implants with a smooth neck transmit negligible forces to the marginal bone, leading to more resorption. These effects of microthreads, preventing marginal bone loss and increasing BIC

Table 1. Mean and standard deviation of removal torque (Ncm) by implant type and healing period.

Healing period (week)	Group A	Group B	*P*-value
4	169.1±40.3	145.7±56.5	0.694
8	265.0±9.9[a)]	243.8±25.9[a)]	0.2
12	267.6±28.6[b)]	274.4±25.4[b)]	0.694

Values are presented as mean±standard deviation.
$P<0.05$ was considered statistically significant.
a)Statistically significant between 4 weeks and 8 weeks.
b)Statistically not significant between 8 weeks and 12 weeks.

Table 2. Mean and standard deviation of bone-to-implant contact (%) for implant types and healing period.

Healing periods (week)	Group A	Group B	Group C	*P*-value		
				Group A/B	Group A/C	Group B/C
2	33.3±17.0	46.0±20.8	40.9±8.6	0.281	0.368	0.927
4	75.9±5.5[a)]	81.0±7.7[a)]	73.2±15.5[a)]	0.259	0.534	0.181
8	75.0±9.0[b)]	77.6±14.3[b)]	78.9±11.7[b)]	0.383	0.397	0.867

Values are presented as mean±standard deviation.
$P<0.05$ was considered statistically significant.
a)Statistically significant between 2 weeks and 4 weeks.
b)Statistically not significant between 4 weeks and 8 weeks.

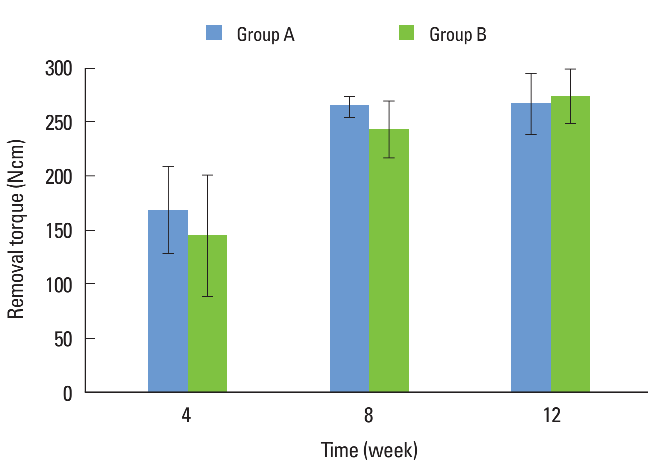

Figure 3. Mean and standard deviation of removal torque (Ncm) at each healing period.

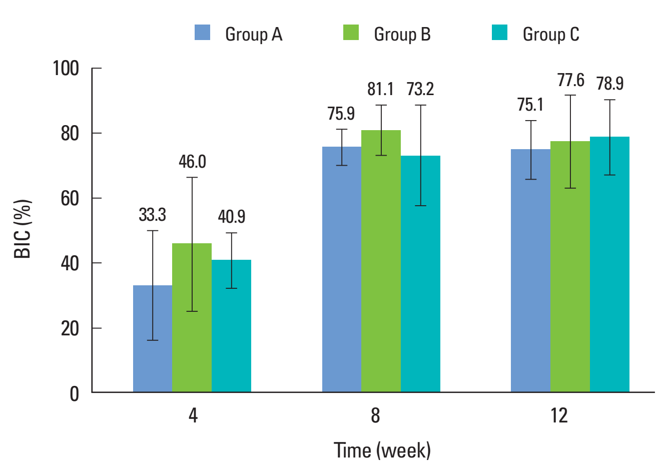

Figure 4. Mean and standard deviation of BIC (%) at each healing period. BIC: bone-to-implant contact.

are thought not only to preserve marginal bone and soft tissue around the implants but also to increase biomechanical stability as well.

In the present study, the removal torque was measured in the tibia of miniature pigs to estimate the effect of microthreads on biomechanical stabilization. The removal torque values showed no significant difference between the implants with or without microthreads. This result implies that placement of microthreads at the crestal portion alone does not contribute to biomechanical stability and does not provide a significant mechanical interlocking effect at the bone-implant interface. The removal torque values of the 3 groups increased between 4 and 8 weeks, but there was no significant difference between 8 and 12 weeks. Furthermore, the BIC values of all 3 groups increased between 2 and 4 weeks, but there was no significant difference between 4 and 8 weeks. This result indicates that the dynamic healing process and osseointegration is completed within 8 and 4 weeks for the tibia and the mandible of miniature pigs, respectively.

BIC was measured in the mandible of miniature pigs, and showed minimal differences, contradicting previous studies that showed microthreaded implants or smaller thread pitch to have higher BIC values [5,8]. This phenomenon of higher BIC may be due to the fact that previous studies compared microthread implants against smooth neck implants where threads are absent at the marginal portion. The smooth portion of implants is known to create more shear stress, which elicits a negative effect on bone regeneration [9]. Therefore, considering that BIC in the present study was compared between microthreaded implants and implants without microthreads but larger threads at the crestal portion, shear stresses may have decreased by the implant design in both groups. The magnitude and direction of the stresses that are transformed from the vertical load into compressive and shear stresses by each thread are critical factors for the BIC in this case.

Studies pertaining to thread pitch and its effect on crestal bone loss level [10], resistance to vertical load [11], and stress distribution [12] have been reported. These studies demonstrated lower thread pitch to have favorable resistance and stress distribution and less crestal bone loss. However, this appears insufficient to verify the simple linear correlation between smaller pitches such as microthreads and higher histological and biomechanical stabilization. On the other hand, Kong et al. [13] suggested 0.8 mm as the optimal thread pitch for achieving primary stability and optimum stress distribution in cylindrical implants with V-shaped threads using finite element analysis. In the present study, the thread pitch of microthreads was 0.4 mm and the thread pitch of corresponding nonmicrothreaded implants was 0.8 mm. Although it may not be legitimate to compare the previous result by Kong et al. [13] because of the different implant shape (tapered) used in our study, this suggests interesting insights and requires further studies to validate the effect of microthreads and their thread pitch on biomechanical features and their overall effect on bone reaction. Also, a search for the optimal thread pitch and implant design to achieve the highest biomechanical and histological stabilization and osseointegration is needed as well.

CONFLICT OF INTEREST

Authors In Hee Cho, Myung Duk Kim, and Tae Gwan Eom are researchers employed under Osstem Implant Co. (Seoul, Korea).

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