Original Article

Effects of predrilling on the osseointegration potential of mini-implants

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ABSTRACT

Objectives: To determine a reliable method of drilling a pilot hole when using a self-tapping surface-treated mini-implant and to evaluate stability after placement.

Materials and Methods: Implant sites were predrilled in 12 rabbits with two devices: a conventional motor-driven handpiece and a newly developed hand drill. Mini-implants were then inserted in a complete random block design. Samples were divided into 1-week and 6-week groups to investigate osseointegration capacity in relation to the two time intervals. Mechanical and histomorphometric assessments were performed.

Results: Mechanical analysis revealed no difference in maximum removal torque or total removal energy between the motor-driven predrilling group and the hand-drilling group. No difference was found between the 1-week group and the 6-week group. Histomorphometric evaluation showed no difference in the bone-implant contact (BIC) ratio or the bone volume (BV) area. For the time interval, a statistically significant increase in BIC and BV area was found in the 6-week group when compared to the 1-week group.

Conclusions: The osseointegration potential of the motor-driven predrilling method was not different from that of the manual predrilling method with the newly developed hand drill. Hand drilling may be an attractive predrilling method in preference to the conventional motor-driven pilot drilling. (*Angle Orthod.* 2012;82:1008–1013.)

KEY WORDS: Anchorage; Removal torque value; Bone implant contact; Orthodontic mini-implant

INTRODUCTION

Orthodontic mini-implants have been widely used to provide skeletal anchorage for tooth movement because the method is less dependent on the patient's cooperation and because of the simplified treatment procedures.[1–3] However, mini-implants sometimes fail for a variety of reasons. Studies have identified many factors associated with the mini-implant success: age, sex, skeletal morphology, location in the jaw, length of waiting period until orthodontic force was applied, mini-implant size, insertion angulation, insertion torque, contact surface between bone and mini-implant, thickness and quality of cortical bone, degree of peri-implant inflammation, soft-tissue thickness, mobility, and root proximity. Experience and meticulous procedure helps prevent failure.[4–8]

The ideal orthodontic mini-implant can resist forces in any direction—constant, dynamic, or even rotational. Surface treatment has been shown to improve the success rate of mini-implants or prosthetic implants by inducing osseointegration between bone and implant surface.[9] Osseointegration is typically maintained under functional load. Sandblasted, large-grit, and acid-etched (SLA) surface-treated mini-implants are

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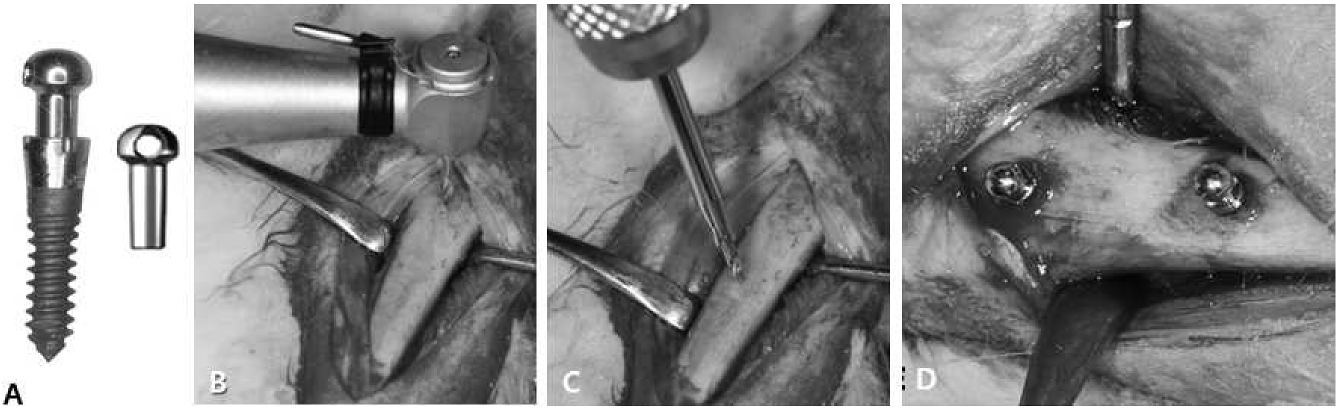

Figure 1. Methods for mechanical and histomorphometric analysis of mini-implants by different predrilling methods. (A) C-implant and a head part. (B) Predrilling using a motor-driven handpiece. (C) Predrilling using a manual hand drill. (D) After predrilling procedure, two mini-implants were inserted at each tibia.

prepared with biologically inert large-grit Al_2O_3 to form microporosity on the implant surface. SLA surface-treated mini-implants have gained popularity thanks to improved cell adhesion and proliferation, high osseointegration potential, and low failure rate.[10]

The surface treatment prevents the screw threads from having the sharp cutting edge found on a machined surface mini-screw. For this reason, predrilling is essential to enable the self-tapping feature of an SLA surface-treated mini-implant.[9] Implant sites are predrilled through the cortical bone with a low-speed handpiece. This predrilling procedure puts pressure on both clinicians and patients. Clinicians experience stress from using the engine twice, once at predrilling and once at mini-implant placement. Patients experience vibration and discomfort from the high rotational speed of drilling. Consequently, placement of mini-implants is often referred to a periodontist or an oral surgeon. The U.S. Centers for Disease Control and Prevention defines mini-implant placement using motorized predrilling as an oral surgery procedure.[11] Manual predrilling with a hand-drill can be an alternative way to lessen the complexity of the predrilling procedure.

The objective of this study was to investigate the effects of newly developed hand-driven predrilling on stability of self-tapping mini-implant system at placement and removal in rabbit bone.

MATERIALS AND METHODS

Mini-implants used in this study were SLA surface-treated mini-implants (C-implant, Cimplant Co, Seoul, Korea) with a diameter of 1.8 mm and a length of 8.5 mm (threaded portion of 6.5 mm). It is a two-component system composed of a screw and a head portion (Figure 1A). After inserting the threaded portion into the bone, the head portion is tapped into place and held by friction.[12]

This study was conducted with the approval (KHMC-IACUC 10-065) of the Institutional Animal Care and Use Committee.

Twelve female New Zealand white rabbits (body weight 3.0–3.5 kg) were used. Implant sites were predrilled with two devices, a conventional motor-driven handpiece and a newly developed hand-drill. After mini-implant placement, the insertion/removal torque and bone-implant contact (BIC) ratio were analyzed each for mechanical and histomorphometric changes. Comparative study between these two analyses was also conducted.

Experiment groups consisted of the handpiece predrilling (HP) group and the hand predrilling (HD) group. Implant sites were predrilled with two devices, a conventional motor-driven handpiece and a newly developed hand drill. After mini-implant placement, the insertion/removal torque and BIC ratio were each analyzed for mechanical and histomorphometric changes. A comparative study between these two analyses was also conducted.

These groups were subdivided into a 1-week group and a 6-week group to evaluate the effect of time on osseointegration. The right and left tibias of each rabbit were divided as mesial and distal. To eliminate variations among individual rabbits and insertion locations, mini-implants were placed using a complete random block design in the order of HP-HD, HD-HP, HD-HP, HP-HD. In total, 48 mini-implants were used in this study. Among the 12 animals, 8 (32 mini-implants) were used for mechanical analysis and the remaining 4 (16 mini-implants) were used for histomorphometric assessment.

Tiletamine-zolazepam (10 mg/kg, Zoletil, Virbac Korea Co, Seoul, Korea) and xylazine (2 mg/kg, Rompun, Bayer Korea, Seoul, Korea) were intramuscularly administered for general anesthesia. To obtain local anesthesia and hemostasis, 1.8 mL of local anesthetic

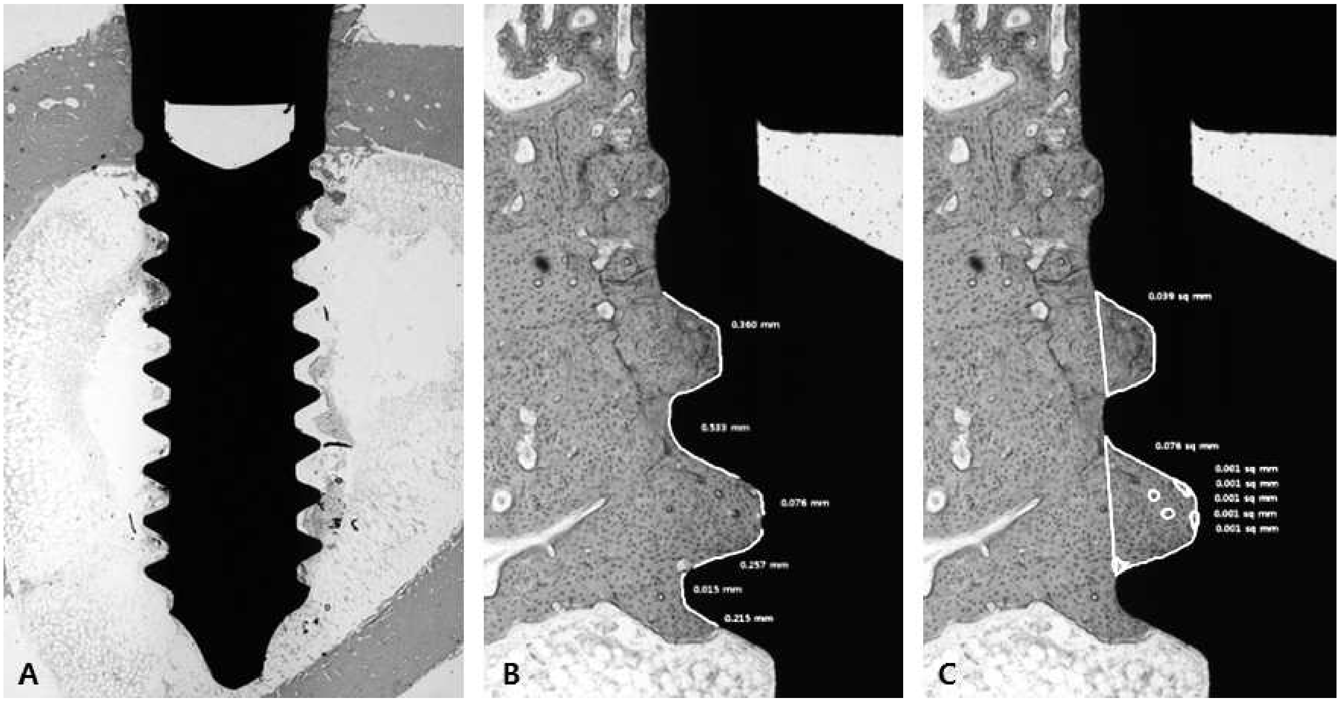

Figure 2. (A) Tissue specimen of mini-implant for histomorphometric analysis. (B) Bone-implant contact (BIC) ratio. (C) Bone volume (BV).

(2% lidocaine with 1:100,000 epinephrine) was injected in the surgical site. Analgesics and antibiotics were administered after surgery for animal welfare and prevention of infection.

Mechanical Analysis

All surgical procedures were carried out in sterile conditions. The dissection was performed with a #15 blade through the skin and subcutaneous tissue to the periosteum and fascia. A periosteum elevator was used to expose the tibia. Predrilling was carried out with a guide drill 1.5 mm in diameter and 5 mm long (Stryker Leibinger Co, Freiburg, Germany) (Figure 1B) and hand drill (Cimplant Co, Seoul, Korea) (Figure 1C). Mini-implants were placed with a surgical engine (Elcomed SA200C, W&H, Bürmoos, Austria) that could measure and record the maximum insertion torque at 1/8 second intervals and total insertion energy. Rotational speed of the motor-driven predrilling, implant insertion speed, and maximum torque were set to 2500 rpm, 30 rpm, and 50 Ncm, respectively. The drilling site was irrigated with saline to minimize bone damage from frictional heat generation. Mini-implants were placed perpendicular to the tibial surface (Figure 1D). To completely cover mini-implants with soft tissue, the fascia and skin were closed with absorbable sutures (4-0 Surgisorb, Samyang, Seoul, Korea). Implant sites were incised and exposed at 1 week and 6 weeks. Maximum removal torque and total removal energy were measured. The engine speed and maximum torque (30 rpm and 50 Ncm, respectively) were set at the same level used with the insertion procedure.

Histomorphometric Analysis

After harvesting tissue samples surrounding mini-implants at 1 week and 6 weeks after placement, the samples were fixated in buffered neutral formalin (Sigma Aldrich) for a week followed by fixation in 70% ethanol for a month. These histological specimens were dehydrated in a graded ethanol series (70%–100%) for 2 days. dehydrated tissue samples were infiltrated with a series of mixtures (3:1, 1:1, 1:3 ratio) of alcohol and Technovit 7200 resin (Exakt GmbH, Germany) for 2 weeks over the course of 6 weeks. The samples were infiltrated again with Technovit 7200 for 4 weeks and were embedded in Technovit 7200 using a light-curing system. The embedded blocks were hardened in a pyrostat at 42°C for 2 weeks and then sectioned with a M310 Diamond band micro-cutting machine (Exakt GmbH) at a thickness of 300 μm. A non-decalcified specimen with a thickness of 40–50 μm was prepared by grinding with a 410-microgrinding machine (Exakt GmbH) (Figure 2A).

To evaluate the degree of contact between mini-implant and bone, BIC was calculated as a percentage by dividing actual bone-implant contact over threaded portion of the mini-implant (Figure 2B). BIC was measured separately in the cortical bone area (cortical BIC) and cortical and spongious bone area (total BIC). Bone volume (BV) was calculated as a percentage by dividing the bone area over surface area of all threads

Table 1. Mechanical Analysis [a]

	Week	Type of Predrilling: Handpiece	Type of Predrilling: Hand Drill	Significance (P Value)
Maximum insertion torque (Ncm)	1	10.81 ± 3.29	10.50 ± 2.48	Week .624, type .330
	6	11.81 ± 2.24	10.38 ± 1.71	
Total insertion energy (J)	1	1.69 ± 0.42	1.86 ± 0.68	Week .758, type .958
	6	2.02 ± 0.84	1.83 ± 0.34	
Maximum removal torque (Ncm)	1	5.80 ± 2.26	5.71 ± 2.24	Week .229, type .506
	6	6.13 ± 2.07	7.21 ± 1.80	
Total removal energy (J)	1	1.06 ± 0.62	1.12 ± 0.59	Week .882, type .537
	6	0.98 ± 0.44	1.15 ± 0.41	

[a] A two-way analysis of variance was performed.
* $P<.05$; ** $P<.01$; *** $P<.001$.

(Figure 2C). Image analysis software (Kappa Image-Base-Metreo, Kappa Optoelectronics, Germany) was used to measure and analyze images from a microscope (Bx-51 research microscope, Olympus, Japan) taken with a digital camera (Kappa Dx30c, Kappa Optoelectronics, Gleichen, Germany).

Statistical Analysis

To eliminate variations among individual rabbits and insertion locations, the mini-implants were placed using a complete random block design. In spite of the small sample size, analysis of variance (ANOVA) could be used for histomorphometry because of the complete random block design. Statistical analysis was performed using SPSS version 12.0 for Windows (SPSS Inc, Chicago, Ill). After evaluating violation of normality and homoscedasticity, data were verified by the mixed model ANOVA, including individual animal variable and right and left mini-implant site variable. Because the effects of an individual animal variable or a right and left mini-implant site variable were not identified, two-way ANOVA was carried out excluding those two variables.

RESULTS

Mechanical Analysis

The insertion method or the postinsertion time did not affect maximum torque or total energy during insertion and removal in a statistically significant way (Table 1).

Histomorphometric Analysis

BIC and BV were not influenced by the insertion methods (Table 2), but they were affected by time. A comparison of the 1-week and 6-week data showed a statistically significant increase in values of BIC and BV.

DISCUSSION

This study evaluated an SLA surface-treated two-component mini-implant used for skeletal anchorage. SLA surface treatment increases BIC and leads to improved stability and a long-term success rate.[13] Mechanical evaluation during insertion and removal of mini-implants was conducted by measuring maximum torque and total energy. Maximum insertion and removal torque was defined as maximum torque value from the beginning to the end of insertion or removal of mini-implants. Total insertion energy (J) was defined as the amount of energy absorbed by bone from the beginning of insertion to the moment when the maximum torque value was reached. Total removal energy (J) was defined as the amount of energy absorbed by bone from the moment maximum torque value was reached to the end of removal of mini-implants.[9] No difference in maximum torque or total energy was found between the conventional motor-driven handpiece group and hand-drill group. We conclude that either of the tested insertion methods results in a similar quality of osseointegration of the C-implant.

Table 2. Histomorphometric Analysis[a]

	Week	Type of Predrilling: Handpiece	Type of Predrilling: Hand Drill	Significance (P Value)
Cortical BIC[b] (%)	1	58.51 ± 12.69	44.59 ± 24.81	Week .043*, type .064
	6	78.50 ± 10.60	60.30 ± 10.27	
Total BIC (%)	1	10.26 ± 3.08	6.43 ± 4.72	Week .043*, type .758
	6	13.40 ± 7.31	15.52 ± 5.63	
Bone volume (%)	1	40.71 ± 12.66	28.22 ± 16.01	Week >.001***, type .145
	6	74.65 ± 13.54	63.86 ± 17.06	

[a] A two-way analysis of variance was performed.
[b] BIC indicates bone-implant contact.
* $P<.05$; ** $P<.01$; *** $P<.001$.

Therefore, the clinician can choose the simpler way to make the pilot hole using a hand drill without compromising the stability of mini-implants.

To evaluate effects of time lapse, samples were divided into a 1-week group and a 6-week group. In a rabbit study, Go et al.[14] reported that the initial stability of a mini-implant was obtained by mechanical retention. After 6 weeks of inflammatory response during this bone-maturing phase, the mini-implant stability was further established by direct implant-to-bone contact through new bone remodeling. Glaucio and Liliane[15] evaluated the tissue-healing pattern around mini-implants and reported periosteal change and BIC increase in a 12-week group when compared with a 1-week and a 4-week group. Mo et al.[16] measured removal torque of immediately loaded mini-implants in rabbits and reported that removal torque decreased considerably during the first week and did not change after 6 weeks.

Based on these findings, our study divided samples into a 1-week group, which represented initial healing, and a 6-week group, which experienced a certain degree of bone healing and remodeling.

Lawes et al.[17] suggested that a high insertion torque of a tapered bone screw is associated with less loosening at the bone-implant interface. In contrast, Frost[18] stated that integrity could not be maintained if too much bone change occurred. Hansson and Werke[19] also reported that bone resorption occurs under excessive force exceeding the physiological limit. Therefore, if excessive insertion torque is applied, bone may crack or can become necrotic. Further studies are required to determine the physiological torque range that bone can withstand. Stability of orthodontic mini-implants is not directly proportional to the insertion torque.[20] It is more closely related to the maximum removal torque, which relies on the degree of osseointegration.[9,21] In this study, maximum removal torque was slightly higher in the 6-week group than in the 1-week group, but no significant difference was found between the 1-week and 6-week groups.

Histomorphometric analysis measured BIC and BV. BIC was divided into cortical BIC and total BIC, including the cancellous bone, with consideration for the characteristics of rabbit tibial bone. Rabbit cancellous bone is very soft and presents no resistance once the cortical bone is perforated during the predrilling. There was no fracture or bicortical penetration of tibia in this study. Cortical BIC was much higher than total BIC in this study, and this means BIC is higher at the cortical bone than in cancellous bone. Initial stability is obtained mainly in the cortical bone.

Cortical BIC, total BIC, and BV of the 1-week group were lower than those of the 6-week group. This is due to the increase of bone-implant contact by bone remodeling and bone maturation during the first 6 weeks.[16–18] Stability of orthodontic mini-implants was evaluated by measuring removal torque[13,22] and histomorphometric analysis was evaluated by measuring BIC.[23,24] Mechanical analysis showed no change in maximum removal torque or total energy with time lapse. In contrast, histomorphometric analysis revealed an increase of BIC and bone area with time lapse. Deguchi et al.[25] stated that low BIC does not necessarily mean poor stability. Mini-implant stability cannot be determined solely by BIC. It is reported that mini-implants with less than 5% of BIC can successfully withstand orthodontic forces.[26] Although mini-implant stability can be assessed by BIC and removal torque, these values were not related each other in this study.

Not all the surface area of a mini-implant is in direct contact with bone. Although severe marginal bone loss or epithelial proliferation was not observed, fibrous connective tissue was present between the mini-implant and bone in some specimens. It is reported that existence of some fibrous tissue facilitates removal of mini-implants and does not affect the stability of mini-implants.[4,27] But severe marginal bone loss or epithelial proliferation can affect the stability of mini-implants. Foreign body response was not found in any of the specimens.

Maximum removal torque and total removal energy were lower than maximum insertion torque and total insertion energy. This means torque resistance of the mini-implant decreased after placement. Even if mini-screws are placed with the highest rotational force and torque, interfacial strain decreases as the screw is in equilibrium because of changes in the surrounding bone when the rotational force is removed.[28] Osseointegration potential using the motor-driven predrilling method was no different than the manual predrilling method using a hand drill. According to this animal study, manual predrilling with a hand drill can replace conventional motor-driven predrilling without negative consequence. However, it should be noted that this method can significantly vary depending on the clinical environment (visibility and bone quality).[29] Hand drilling of the pilot hole is likely to be more easily accepted by clinicians and patients than handpiece drilling. Further study is required considering the differences between results for this animal study and a human clinical application.

CONCLUSION

- After predrilling and mini-implant placement, no difference in osseointegration potential was found between a conventional handpiece-driven predrilling system and a newly developed hand drill.

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