AJO-DO

Effects of acid etching and calcium chloride immersion on removal torque and bone-cutting ability of orthodontic mini-implants

Tae-Ho Jang,[a] Jae-Hyun Park,[b] Won Moon,[c] Jong-Moon Chae,[d] Na-Young Chang,[d] and Kyung-Hwa Kang[d]
Cheongju, Seoul, and Iksan, Korea, Mesa, Ariz, and Los Angeles, Calif

Introduction: The 2-fold purpose of this study was to evaluate the effects of acid etching and calcium chloride immersion on removal torque and the bone-cutting ability of orthodontic mini-implants (OMIs). **Methods:** For the removal torque part of the study, 3 types of OMIs (titanium alloy) were evaluated in a rabbit model: OMIs with acid surface etching with and without calcium chloride immersion (ECG and EG, respectively) and a control group (CG), in which the OMIs had an untreated, machined surface. We inserted 126 OMIs (42 OMIs per type) into both tibias of 21 male rabbits (5 months of age) with body weights of 3.0 to 3.5 kg. Removal torque was evaluated after 1, 4, and 7 weeks. To determine the OMIs' bone-cutting ability, total insertion time to place an OMI 6 mm into artificial bone was measured (6 OMIs per group). **Results:** Removal torque values for the EG (3.97 ± 0.52 Ncm) and ECG (4.21 ± 0.44 Ncm) were statistically and significantly higher than those of the CG (3.02 ± 0.53 Ncm) 1 week after implantation ($P < 0.05$). The ECG (6.54 ± 0.50, 6.61 ± 0.66 Ncm) showed the highest removal torque value followed by the EG (5.68 ± 0.58, 5.89 ± 0.70 Ncm) and CG (3.43 ± 0.62, 3.38 ± 0.54 Ncm) at 4 and 7 weeks after implantation ($P < 0.05$). Removal torque did not change over time with the CG, but with the ECG and EG, it was significantly higher in weeks 4 and 7 than in week 1 ($P < 0.05$). Total insertion time was significantly greater for the EG than for the ECG and CG ($P < 0.05$). **Conclusions:** Treating OMIs with a calcium chloride solution improved the initial bone reaction by preventing contamination of the implant surface, and increasing the surface roughness of OMIs by acid etching enhanced their stability without decreasing the bone-cutting ability compared with OMIs without surface treatment. (Am J Orthod Dentofacial Orthop 2018;154:108-14)

Anchorage control is an important factor in orthodontic treatment that can often determine whether treatment is successful. Extraoral anchorage provides stability and has traditionally been used to control unwanted movements of teeth.

[a]Private practive, Cheongju, Korea.
[b]Postgraduate Orthodontic Program, Arizona School of Dentistry & Oral Health, A. T. Still University, Mesa, Ariz; Graduate School of Dentistry, Kyung Hee University, Seoul, Korea.
[c]Section of Orthodontics, School of Dentistry, Center for Health Science, University of California, Los Angeles.
[d]Department of Orthodontics, School of Dentistry, University of Wonkwang, Wonkwang Dental Research Institute, Iksan, Korea.
All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest, and none were reported.
Sponsored by Soongsan Fellowship at Wonkwang University in 2015.
Address correspondence to: Kyung-Hwa Kang, Department of Orthodontics, School of Dentistry, Wonkwang University, 460 Iksandae-ro, Iksan-si, 54538, Korea; e-mail, pigtail@wonkwang.ac.kr.
Submitted, November 2016; revised and accepted, October 2017.
0889-5406/$36.00

https://doi.org/10.1016/j.ajodo.2017.10.032

However, the constraints of extraoral anchorage include limitations in the direction and range of applied forces and the fact that the outcome depends on patient compliance. To overcome these challenges, orthodontic mini-implants (OMIs) offer orthodontists intraoral skeletal anchorage.[1-3] These devices are easily inserted and removed, cause minimal discomfort to patients, and eliminate the compliance factor. Moreover, treatment outcomes using OMIs are comparable with or superior to those that use traditional anchorage.[4,5]

Although OMIs have relatively high success rates, they are lower than those of traditional prosthetic implants[6,7] because of various factors such as early loosening, fractures in the devices, damage to roots, and the potential for infection.[8] Unlike traditional prosthetic implants, forces are applied to OMIs right after insertion; thus, it is important to prevent early loosening by inserting the OMI away from the radicular region and into attached gingiva where there is quality osseous tissue.[9] Knowing this, it is still sometimes necessary to perform insertions in nonideal sites. Therefore, several methods have been developed and studied to reduce OMI failure.[10-15] Early OMI failure can be prevented by maximizing the difference between core and thread diameters of the OMIs. Although increasing the contacting surface area consequently increases retention, reducing the inner core diameter increases the risk of fractures.[10] A novel method known as self-drilling was developed to ensure primary stability between OMIs and bone.[11] Some investigators have attempted to reduce the gap between the OMI and the bone by using conical miniscrews,[12] and to induce osseointegration between the bone and the OMI to achieve early-stage stability.[13-16]

Osseointegration of prosthetic implants is influenced by surface roughness and hydrophilicity, which affect the degree of contact with blood and tissues.[17-19] The speed and extent of osteogenesis were found to increase as functions of implant surface hydrophilicity,[18] which was also positively correlated with increased biologic activity near the implant surface.[19] Based on these findings, many surface treatments such as grit blasting, acid etching, anodization, and calcium phosphate coating have been considered to enhance hydrophilicity and to increase the roughness of the surface. Surface-treated prosthetic implants have been shown to exhibit greater osseointegration than those with untreated, machined surfaces.[20] OMIs have been similarly treated to increase osseointegration.[21,22]

Surface energy levels and contamination affect hydrophilicity even among surfaces with similar amounts of roughening.[23] A comparison of the hydrophilicity of acid-etched and grit-blasted implant surfaces immediately and 4 weeks after production showed that surface hydrophilicity decreased by 10 fold after 4 weeks.[23] Att et al[24] noted that solutions containing Calcium ions have been shown to prevent contamination of hydrophilic surfaces; this enhances biologic activity at the implant site and increases osseointegration.

Another important consideration when treating the surfaces of OMIs is the potential effect of the treatment on the OMI's bone-cutting ability. One study suggested that an excessive insertion force was required when the cutting surface of an OMI was roughened, but OMIs were readily inserted via a self-drilling method with less force when surface treatment was done on all but the cutting surfaces.[25]

Therefore, the aim of this study was to investigate the clinical effectiveness of acid etching and calcium chloride immersion on the removal torque and bone-cutting abilities of OMIs.

Table I. Properties of artificial bone block (polyurethane foam)

Density	Compressive		Tensile		Shear	
	Strength	*Modulus*	*Strength*	*Modulus*	*Strength*	*Modulus*
g/cc	*MPa*	*MPa*	*MPa*	*MPa*	*MPa*	*MPa*
Cortical bone part (1.5 mm)						
0.64	31	759	19	1000	11	130
Cancellous bone part (30 mm)						
0.32	8.4	210	5.6	284	4.3	49

MATERIAL AND METHODS

Conical, self-drilling OMIs made of a titanium alloy (Ti_6Al_4V) with a 1.4-mm diameter and a 6-mm thread length (Osstem Implant, Seoul, Korea) were used. Rabbits (n = 21; 5 months old; weight, 3-3.5 kg; male; New Zealand white) were allowed to acclimate to the laboratory environment for 1 week and had free access to standard feed. Our protocols followed standard guidelines for animal experiments and were approved by the animal research ethics board of Wonkwang University (number WKU15-98).

Bone-cutting capacity was analyzed using polyurethane bone (solid rigid polyurethane foam; Sawbones, Vashon, Wash). Cortical and cancellous bone parts were 1.5 and 30 mm thick, joined by cyanoacrylate, respectively (Table I). Properties of the material followed the specifications of the American Society for Testing and Materials (F-1839).

The experimental groups included OMIs with hydrochloric and nitric acid surface etching with and without immediate storage in calcium chloride solution in sealed vessels (ECG and EG, respectively) (Osstem Implant, Seoul, Korea). OMIs with untreated machined surfaces served as the control group (CG) (Fig 1). To evaluate the influence of the OMI's surface contamination, OMIs were sterilized (gamma sterilization) and separately stored for 3 weeks before insertion. Unlike the CG and EG containers that were exposed to air because of incomplete sealing as per the manufacturing process, the ECGs were stored in a container with calcium chloride solution after sterilization and were vacuum sealed with no exposure to air.

The rabbits were anesthetized by intramuscular injection of tiletamine zolazepam (0.2 ml/kg Zoletil 50; Virbac, Carros, France). The tibias of both legs were shaved and sterilized with povidone-iodine solution 10 minutes after injection. Local anesthesia administered around the tibia was induced by articaine hydrochloride with epinephrine (1:100,000 Septanest; Septodont, Saint-Maur-des-Fossés, France). A 4- to 5-cm incision