Original Article

Resistance to Immediate Orthodontic Loading of Surface-Treated Mini-Implants

Sung-Seo Mo[a]; Seong-Hun Kim[b]; Yoon-Ah Kook[c]; Do-Min Jeong[d]; Kyu-Rhim Chung[e]; Gerald Nelson[f]

ABSTRACT

Objective: To test the hypothesis that there is no difference in the stability and resistance to orthodontic forces of immediately loaded sandblasted and acid-etched (SAE) mini-implants and those of machined-surface implants of the same size and shape.

Materials and Methods: Two types of mini-implants were used in the tibiae of 44 rabbits; some had an SAE surface and some had machined surfaces. Orthodontic loading of 150 g was applied immediately after placement. The success rates and maximum removal torque values (RTVs) of 412 mini-implants were recorded and compared immediately after placement, 3 days after placement, and 1, 6, and 10 weeks after placement. The RTV data were analyzed using multiple regression analysis to evaluate differences with respect to surface treatment, loading, and loading periods ($P < .05$). Multiple comparisons using the Scheffé method were performed to evaluate the RTVs for the subsequent loading periods.

Results: Thirteen mini-implants failed during the experimental period. The SAE group had a higher RTV than the machined group, and there was significant difference in RTVs in accordance with loading periods ($P < .001$). However, there was no significant RTV difference between loaded and unloaded mini-implants.

Conclusions: The hypothesis was supported. Both SAE mini-implants and machined mini-implants can be loaded immediately and experience similar success rates. RTVs were higher for the SAE mini-implants than for the machined mini-implants. The latter finding suggests that, for immediate loading, SAE mini-implants may provide more stable retention than machined mini-implants. (*Angle Orthod* 2010;80:123–129.)

KEY WORDS: Partial osseointegration; Mini-implant; Removal torque value; Immediate loading; Surface treatment

INTRODUCTION

Since researchers introduced vitallium screws in dogs and human patients as skeletal anchors,[1–3] orthodontic mini-implants for anchorage are now widely used. Currently, titanium is typically used for orthodontic mini-implants.[4–8] The optimal qualities of the orthodontic mini-implant include a convenient diameter and length that allow placement in the narrow interdental space, resistance to fracture during placement or removal, no tendency to loosen during treatment, and easy removal after treatment. Is osseointegration a benefit as well? To date, most orthodontists have placed temporary machined mini-implants with low osseointegration. One reason for this is to facilitate easy removal.[4–6] Prosthodontists have primarily placed permanent implants that osseointegrate.

This study addresses the following points: Is mechanical retention sufficient for orthodontic anchorage, or do surface treatment and osseointegration help? Is immediate loading preferable, or is it better to

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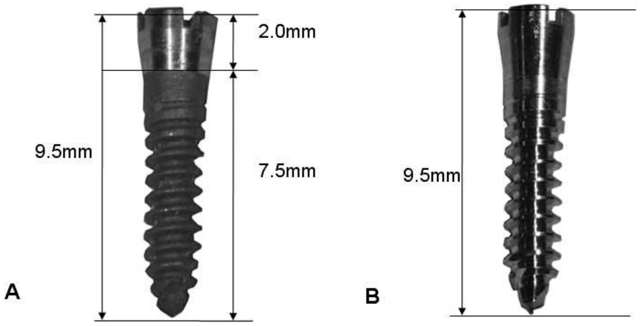

Figure 1. The screw part of mini-implant. (A) SAE mini-implant. (B) Machined-surface mini-implant.

delay loading to allow for healing time after implantation? Recent publications have demonstrated that sandblasted and acid-etched (SAE) mini-implants facilitate resistance to rotational moments and heavy force and also offer long-term stability during orthodontic treatment.[9,10] Removal torque testing is widely used to evaluate the effect of osseointegration potential on the stability of restorative implants.[11–13] However, there is a lack of similar studies of removal torque for orthodontic mini-implants.[14,15] Another issue has been the appropriate timing for the application of orthodontic force. Some clinicians suggest that some healing time is required and recommend delaying force application.[3,8,16] Others, however, state that orthodontic force can be applied immediately after implantation.[17–19] A comparison of immediate loading between SAE mini-implants and untreated mini-implants is lacking. The purpose of this study was to determine the effect of immediate orthodontic loading on the stability and resistance of surface-treated titanium mini-implants in relation to the loading period.

MATERIALS AND METHODS

The protocol for the animal study and the methods were approved by the committee on Animal Research at Uijongbu St Mary's Hospital, Korea. Forty-four adult white rabbits (each weighing 3.1 to 4.0 kg) were used. Eight mini-implants were placed in the tibiae of each animal (n = 340). Four SAE mini-implants and four machined mini-implants were placed in each tibia. We used two types of mini-implants (Cimplant Co, Seoul, Korea); they were 1.8 mm in diameter and 9.5 mm in overall length and had a separate coronal portion. One group received SAE mini-implants (n = 180; Figure 1A) and the other received machined-surface mini-implants (n = 160; Figure 1B). SAE vs. machined implants position was decided by side and randomized. Both types of implants were placed in each animal (bilaterally).

The animals were anesthetized intramuscularly with a combination of ketamine (Ketara, Yuhan Co, Seoul, Korea; 44 mg/kg of body weight) and xylazine (Rompuns, Bayer Korea, Seoul, Korea; 7 mg/kg of body weight). The tibial metaphysis was exposed by incisions through the skin, fascia, and periosteum. The cortical bone of the preparation sites was penetrated using a 1.5-mm-diameter guide drill (Stryker-Leibinger Co, Freiburg, Germany) under profuse irrigation. After pilot drilling, the mini-implants were placed using a manual driver (Figure 2A,B). All mini-implants were allowed to penetrate the first cortical layer only. When loading, nickel-titanium closed-coil springs (Jinsung Co, Seoul, Korea) were applied to the coronal portion of the mini-implants with 150 g of force (Figure 2C,D). After mini-implant insertion, the mucoperiosteum and muscle were sutured in separate layers using absorbable sutures. The rabbits were sacrificed 3 days, and 1, 6, or 10 weeks after mini-implant placement using an overdose of anesthetics.

Removal Torque Value Measurement

The mini-implant sites were exposed, and any bone and soft tissues that had formed on top of the implants were carefully removed (Figure 3A). The force needed to remove the mini-implant was measured using a digital torque sensor with 0.01-Ncm accuracy (STS-31, Lorenz Messtechnik Germany/Emobile Tech Co, Seoul, Korea) (Figure 3B). The result was recorded by measuring the peak removal torque value (RTV) at which fracture occurred between the mini-implant and neighboring bone. All the mini-implants were either loaded or unloaded in the following sequence: immediately, 3 days, 1 week, 6 weeks, and 10 weeks after placement (Figure 4). The RTVs were recorded at each stage. In the four SAE/Machined mini-implants placed on one side, two mini-implants were loaded and two mini-implants were not loaded. Loading/unloading was done in a randomized fashion. Loading continued until sacrifice of the animals. The concrete information about time and surface type of mini-implants is listed in Table 2. Among these groups, the immediate and 3-day groups used the same subjects because the immediate group was tested without the animals being sacrificed; then the implants were reinserted with the same mini-implants and used as the 3-day group. If one loaded screw failed in the SAE side, then the unloaded screw in the same side was also excluded from the data analysis and considered a failure, and vice versa. Because one rabbit in the machined group expired during the waiting period, 412 mini-implants were available for data analyses in this study.

Statistical Analysis

Statistical analyses were carried out using SAS 9.1 (SAS Institute, Cary, NC). The means and standard

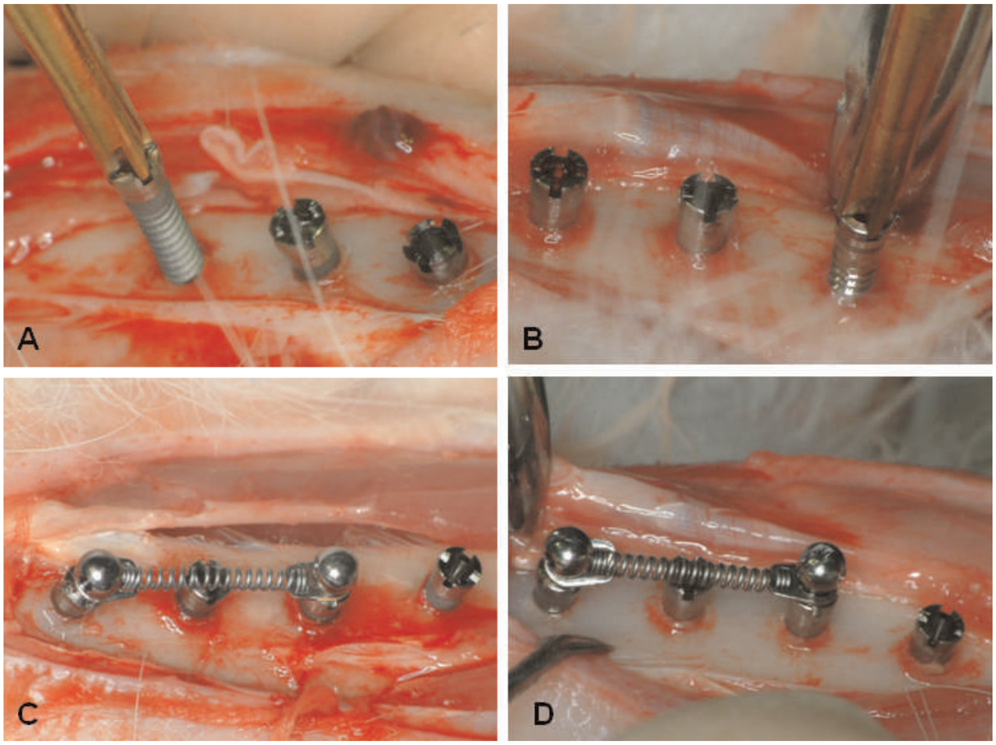

Figure 2. Surgical procedure of mini-implant placement and force application. (A,C) SAE mini-implant. (B,D) Machined mini-implant.

deviations (SD) were calculated for each variable in all groups. The RTV data were analyzed using 3-way factor analysis of variance (ANOVA) to evaluate the differences in relation to surface treatment, loading, and loading periods ($P < .05$). There was no statistically significant interaction between each variable. ANOVA and a multivariable comparison using Scheffé method were used to compare the RTVs for the subsequent loading periods (immediately, 3 days, and 1, 6, and 10 weeks). A *t*-test was performed to evaluate the effects of surface treatment and loading differences.

RESULTS

Thirteen of the 412 total mini-implants failed, which yielded a failure rate of 3.16% (survival rate: 96.8%). There was no difference in survival rates among the experimental groups. The 13 failed screws included the four corresponding loaded mini-implants, which showed good stability (Figure 4).

The SAE group had a higher mean RTV than the machined group (Table 1; $P < .0001$). However, there was no significant difference between the loaded and unloaded groups ($P = .1396$). The RTV results of five

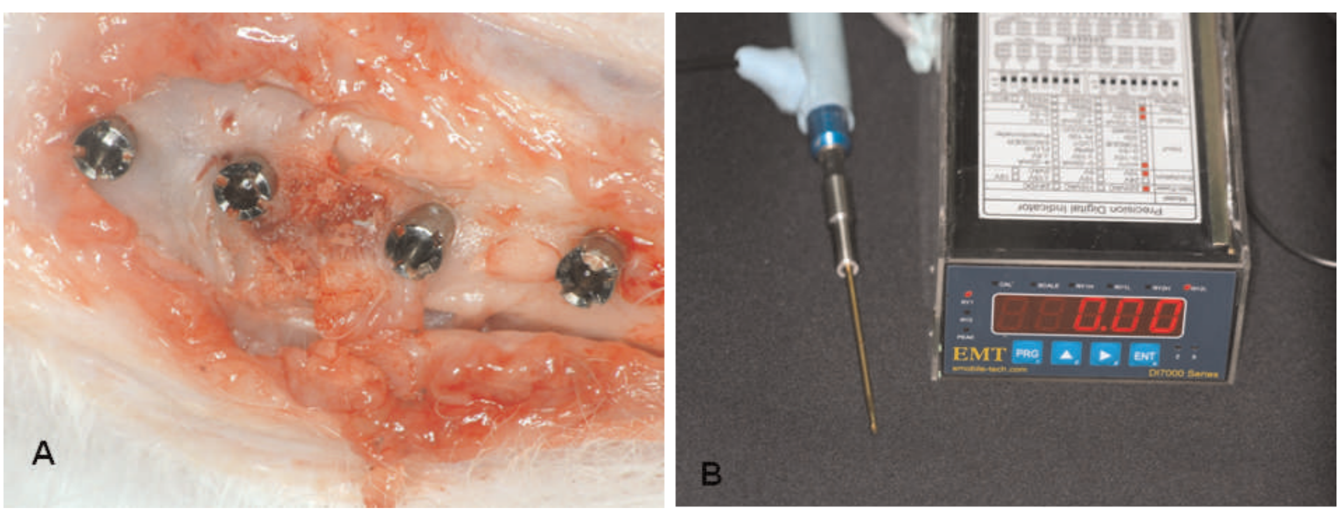

Figure 3. (A) The screw parts placed in the rabbit tibia before removal. (B) Torque driver with digital torque sensor with 0.01-Ncm accuracy.

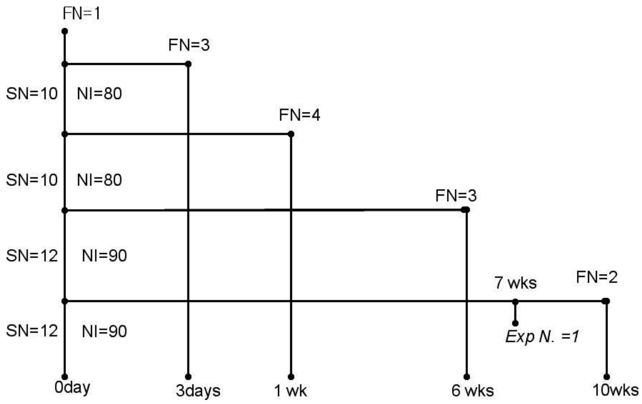

Figure 4. Schematic illustration of experimental design. SN indicates subject number; NI, number of mini-implant, FN, failed number of mini-implants; and Exp N, expired rabbit number.

sequential loading periods showed a statistically significant difference ($P < .0001$). A multiple-variable comparison, using the Scheffé method, was re-performed, and the periods showing statistically significant differences were set aside into groups and classified by characters. In the ANOVA results, all the groups except for the SAE loaded group showed statistically significant differences in RTVs in accordance with the experimental periods (Table 2). Figure 5 showed that the SAE groups had higher RTVs compared to machined groups at 3 days and 6 weeks for both loaded and unloaded mini-implants and 1 week for the unloaded group ($P < .05$). However, there was no difference between the SAE and machined groups at 1 week for the loaded group and 10 weeks for both the loaded and the unloaded groups. The unloaded mini-implants had statistically higher RTVs compared to the loaded ones in the 3-day group for both machined and SAE implants. However, there was no statistically significant difference for implants in the 1-, 6- and 10-week groups.

Table 1. Comparison of Maximum Torque (Means ± SDs, in Ncm) During Removal of Mini-Implants with Respect to Surface Treatment, Loading, and Duration of In Situ Period

Variables	NI[a]	RTV[a]	Significance[b]
Surface treatment			
SAE[a]	208	8.23 ± 4.31	***
Machined	191	5.80 ± 3.37	
Loading			
Loaded	168	6.24 ± 3.35	NS[b]
Unloaded	231	7.67 ± 4.43	
Time			
Immediate	79	9.57 ± 5.42ABCDE	***
3 d	77	6.70 ± 3.71AB	
1 wk	76	6.49 ± 3.09AC	
6 wk	87	5.75 ± 3.22AD	
10 wk	80	6.92 ± 3.49AE	

[a] SAE indicates sandblasted acid-etched mini-implants; NI, number of mini-implants removed; and SD, standard deviation.

[b] Statistically significant difference between designated groups after multiple regression analysis; ** $P < .01$; *** $P < .001$; NS indicates no significance.

Table 2. Comparison of Removal Torque Values (RTVs) Between SAE Mini-implants and Machined Mini-implants with Respect to Time

Surface Treatment	Loading	Periods	NI[a]	RTV (Ncm)	SD	P[b]
SAE[a]	Loaded	Immediate	39/40	10.72	6.29	NS
		3 d	18/20	7.32	4.10	
		1 wk	18/20	6.96	3.50	
		6 wk	30/30	7.69	3.37	
		10 wk	28/28	7.23	3.18	
	Unloaded	Immediate	39/40	10.72	6.29	**
		3 d	19/20	10.25	3.43	
		1 wk	20/20	8.43	3.24	
		6 wk	20/20	6.30	3.25	
		10 wk	16/18	7.17	3.16	
Machined	Loaded	Immediate	40/40	8.46	4.22	**
		3 d	20/20	4.06	1.64	
		1 wk	18/20	5.12	2.39	
		6 wk	18/20	3.46	1.30	
		10 wk	18/18	6.87	3.59	
	Unloaded	Immediate	40/40	8.46	4.22	***
		3 d	20/20	5.44	2.11	
		1 wk	20/20	5.40	1.98	
		6 wk	19/20	4.31	2.16	
		10 wk	18/18	6.27	4.26	

[a] SAE indicates sandblasted acid-etched mini-implants; NI, number of mini-implants removed; and SD, standard deviation.

[b] Statistically significant difference between designated groups after multiple regression analysis; ** $P < .01$; *** $P < .001$; NS indicates no significance.

DISCUSSION

The focus of this study was to discover differences in the resistance to removal between surface-treated and smooth-surfaced mini-implants and to evaluate the stability of implants with these different surfaces. Osseointegration may improve stability when forces other than the typical lateral static force are applied, eg, maxillomandibular elastics or other heavy or dynamic forces.[9,20,21] Resistance to rotational moments provided by osseointegration permits other force systems, such as torque and intrusion of anterior teeth, and dynamic forces.[21,22]

The animal study of Kim et al[10] showed that higher total energy was required to remove SAE mini-implants compared to machined-surface mini-implants, indicating higher osseointegration shortly after insertion. Also, SAE implants showed resistance to counterclockwise rotational forces, a quality that suggests valuable biomechanical possibilities in orthodontics. However, the authors measured RTV only after a healing period and did not assess RTV immediately after placement or shortly after placement.[10] With a sufficient healing period, partial

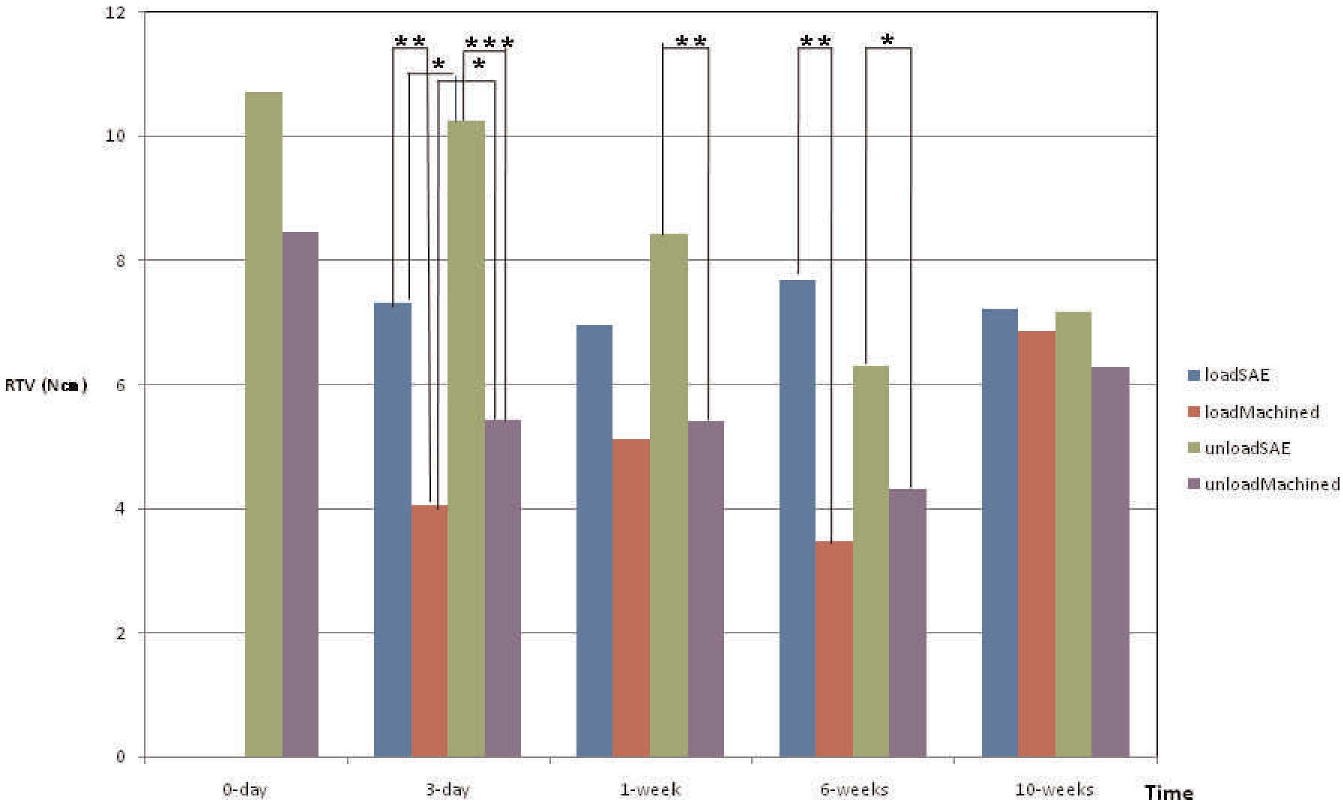

Figure 5. Removal torque value measurements after different loading periods between SAE and machined mini-implants. Statistical analyses are shown on the graphs. *$P < .05$; **$P < .01$; ***$P < .001$.

osseointegration appears to be extensive enough to resist applied biomechanical forces without regard to surface treatment, jaw location, or rotational direction.

SAE treatment is the universal method used to increase the implant surface area available for osseointegration.[23,24] SAE prosthodontic implants experience osseointegration between surrounding bone and the implant shortly after insertion.[24] The present study was designed to assess the RTV of the mini-implants (and thus their osseointegration potential) upon immediate orthodontic loading and with the passage of time.

We measured the differences between surface treatment methods with static lateral force application, which is the most common stability test. Johansson and Albrektsson[11] reported that, with this method, bone-to-implant contact was strongly correlated with RTV. Although all titanium mini-implants experience some osseointegration, machined mini-implants have weak resistance to heavy and dynamic moments. Therefore, our RTV study measured the effects of surface treatment on resistance to moments. We also sought to determine whether osseointegration hampers easy removal. Roberts et al[25] reported that 6 weeks was an adequate healing period after implantation for bone remodeling in rabbits. Hollinger et al[26] showed that osseointegration in rabbits was three times faster than in humans. We measured the RTVs in rabbits after immediately after implantation and at 3 days, 1 week, 6 weeks, and 10 weeks after implantation. The immediate, 3-day, and 1-week groups were considered to be in an early stage of healing. The 6-week and 10-week groups, in which osseointegration had progressed, were also analyzed for stability.

Both SAE and machined-surface implants showed a high success rate of 96.8%. Wu et al[16] recommended more than 4 weeks of healing before loading a mini-implant. Lee et al[19] showed that 250 to 300 g of immediate loading could be applied without any significant increase in the release or mobility of the mini-implant. With a survival rate of about 97% for both surface- treated and untreated mini-implants, some clinicians would recommend the use of untreated mini-implants. However, this study aimed to evaluate not only the differences in survival rates but also the differences in rotational resistance between the surface treatment methods. While a previous hypothesis about stability was confirmed, the hypothesis that there is no significant correlation between surface treatment and RTV was rejected.

Tables 1 and 2 report the change in RTV with the passage of time. The immediate group showed the highest value; this decreased in the 3-day postinsertion group and gradually decreased or recovered as time passed. It is supposed that these results reflect the temporary inflammation reaction caused by insertion trauma and the gradual recovery by bone remodeling afterward. No significant differences in RTV between SAE and machined implants were found in the immediate group.

In the 3-day group, the RTV of SAE implants was significantly higher than that of the machined-surface implants when loaded (7.32 Ncm vs 4.06 Ncm) and was also almost twice that of the unloaded machined implants (10.25 Ncm vs 5.44 Ncm). Consequently, surface-treated implants may have greater stability and better support for force application during this early healing phase. In the 1-week group, the RTV of SAE implants was still significantly higher than that of unloaded machined implants (8.48 Ncm vs 5.40 Ncm). However, as mentioned, after 1 week the resistance was lower than at 3 days. In the loaded group, the mean RTV of SAE implants was higher but not significantly (6.96 Ncm vs 5.12 Ncm for machined implants). In the 6-week loaded group, the mean RTV for SAE implants was more than double that of machined implants (7.69 Ncm vs 3.46 Ncm). Unloaded SAE implants also showed a higher RTV than unloaded machined implants (6.3 Ncm vs 4.31 Ncm). In other words, the surface-treated mini-implant showed sufficient resistance and osseointegration to apply various orthodontic loads immediately and during the early healing phase after insertion. On the other hand, in the 10-week group, the SAE implants showed a higher—but not significantly so—mean RTV than both loaded and unloaded machined implants.

Some authors advise a healing period prior to application of orthodontic forces.[3,8,16] However, our results imply that it is possible to apply a range of force levels and vectors immediately after implantation of the mini-implant. In fact, we observed the highest RTVs immediately after placement. This result may differ according to the quality of bone in the site of implant placement.

Because the rough-surfaced implant showed twice the RTV of the smooth surface implant during the early periods, it should allow more variety of force application both immediately after placement and during the healing period. A 1-week healing period in rabbits is equivalent to a 3-week period in humans. Because until 6 weeks, both the loaded (7.69 Ncm vs 3.46 Ncm) and unloaded (6.3 Ncm vs. 4.31 Ncm) groups measured a mean RTV in SAE implants that was twice that seen in the machined implants, we suggest that this is evidence of earlier osseointegration. A longer healing period (eg, 10 weeks) rendered the RTV differences insignificant. What about removal? Because in all groups the RTV stabilized to similar values, the torque required was the same for both implant types after the 10-week period; thus the surface treatment did not aggravate removal. A human study[9] using the same type of SAE mini-implant showed that all SAE mini-implants remained stable, supported force application, and were removed without mishap even after 6 months in situ without loading.

This current study has some limitations. We placed 9.5-mm-long mini-implants (7.5 mm penetration) into the tibiae of rabbits weighing 3.1 to 4.0 kg. The depth of the tibiae ranged from 8 to 11 mm. Furthermore, the cross-sectional shape of the tibia is triangular. Some mini-implants may have had bicortical contact, even though efforts were made to prevent bicortical contact. With bicortical contact, the mini-implants would show much higher RTV than with monocortical contact. Also, the RTV may vary relative to the quality of bone in the site of implantation. Mini-implants placed closer to the head of the tibia may have shown lower RTV because of lower bone density. Accordingly, we tried to minimize errors relating to placement sites. Further studies will increase understanding of intrabony resistance and osseointegration in relation to implant design, length, and surface treatment method.

Immediately loaded SAE mini-implants may provide more stable retention than immediately loaded machined mini-implants and allow more variety of force and vector application. Since the study subjects were rabbits, recommended time intervals and bone quality will differ in humans. Further study of the relationship between insertion and removal torque values in relation to the stability of mini-implants is advocated.

CONCLUSIONS

- The hypothesis was supported. SAE mini-implants and machined mini-implants can both be loaded at the tested intervals (from immediately after placement to 10 weeks after placement) and show similar survival rates.
- Mean RTVs were higher for the SAE mini-implants than for the machined mini-implants during the early healing period of 6 weeks (the equivalent of 18 weeks for humans).

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REFERENCES

1. Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities in basal bone. *Am J Orthod*. 1945;31:406–417.

2. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. *J Clin Orthod*. 1983;17:266–269.
3. Kanomi R. Mini-implant for orthodontic anchorage. *J Clin Orthod*. 1997;31:763–767.
4. Kyung SH, Lim JK, Park YC. The use of miniscrew as an anchorage for the orthodontic tooth movement. *Korean J Orthod*. 2001;31:415–425.
5. Mah J, Bergstrand F. Temporary anchorage devices: a status report. *J Clin Orthod*. 2005;39:131–136.
6. Costa A, Raffaini M, Melsen B. Miniscrew as orthodontic anchorage: a preliminary report. *Int J Adult Orthod Orthognathic Surg*. 1998;13:201–209.
7. Park SH, Kim SH, Ryu JH, Kang YG, Chung KR, Kook YA. Bone-implant contact and mobility of surface-treated orthodontic micro-implants in dogs. *Korean J Orthod*. 2008;38:304–314.
8. Chung KR, Kim SH, Kook YA. The C-orthodontic micro-implant. *J Clin Orthod*. 2004;38:478–486.
9. Kim SH, Cho JH, Chung KR, Kook YA, Nelson G. Evaluation of the removal torque values of surface-treated mini-implants after loading. *Am J Orthod Dentofacial Orthop*. 2008;134:36–43.
10. Kim SH, Lee SJ, Cho IS, Kim SK, Kim TW. Experimental evaluation of surface-treated mini-implant after rotation force. *Angle Orthod*. 2009;79:899–907.
11. Johansson CB, Albrektsson T. Integration of screw implants in the rabbit: a 1-year follow-up of removal torque test. *Int J Oral Maxillofac Implants*. 1987;2:69–75.
12. Sullivan DY, Sherwood RL, Collins TA, Krogh PH. The reverse-torque test: a clinical report. *Int J Oral Maxillofac Impl*. 1996;11:179–185.
13. Carlsson L, Rostlund T, Albrektsson B, Albrektsson T. Removal torques for polished and rough titanium implants. *Int J Oral Maxillofac Implants*. 1988;3:21–24.
14. Oh NH, Kim SH, Kook YA, Mo SS. Study on removal torque of SLA (sandblasted, large grit and acid etched) treated microimplant. *Korean J Orthod*. 2006;36:324–330.
15. Jeon MS, Kang YG, Mo SS, Lee KH, Kook YA. Effects of surface treatment on the osseointegration potential of orthodontic mini-implant. *Korean J Orthod*. 2008;38:328–336.
16. Wu J, Bai YX, Wang BK. Biomechanical and histomorphometric characterizations of osseointegration during mini-screw healing in rabbit tibiae. *Angle Orthod*. 2009;79:558–563.
17. Melsen B, Costa A. Immediate loading of implants used for orthodontic anchorage. *Clin Orthod Res*. 2003:23–28.
18. Huja SS, Litsky AS, Beck FM, Johnson KA, Larsen PE. Pull-out strength of monocortical screws placed in the maxillae and mandibles of dogs. *Am J Orthod Dentofacial Orthop*. 2005;127:307–313.
19. Lee SY, Cha JY, Yoon TM, Park YC. The effect of loading time on the stability of mini-implant. *Korean J Orthod*. 2008;38:149–158.
20. Chung KR, Nelson G, Kim SH, Kook YA. Severe bidentoalveolar protrusion treated with orthodontic microimplant-dependent en masse retraction. *Am J Orthod Dentofacial Orthop*. 2007;132:105–115.
21. Kim SH, Kook YA, Lee W, Kim IS, Chung KR. Two-component mini-implant as an efficient tool for orthognathic patients. *Am J Orthod Dentofacial Orthop*. 2009;135:110–117.
22. Chung KR, Kim SH, Kook YA, Sohn JH. Anterior torque control using partial osseointegration-based mini-implants: biocreative therapy type I technique. *World J Orthod*. 2008;9:95–104.
23. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *J Biomed Mater Res*. 1991;25:889–902.
24. Roccuzzo M, Bunino M, Prioglio F, Bianchi SD. Early loading of sandblasted and acid-etched (SLA) implants: a prospective split-mouth comparative study. One-year results. *Clin Oral Implants Res*. 2001;12:572–578.
25. Roberts WE, Smith RK, Zilberman Y, Mozsary PG, Smith RS. Osseous adaptation to continuous loading of rigid endosseous implants. *Am J Orthod*. 1984;86:95–111.
26. Hollinger JO, Buck DC, Bruder SP. Biology of bone healing: its impact on clinical therapy. In: Lynch SE, Genco RJ, Marx RE, eds. *Tissue Engineering: Applications in Maxillofacial Surgery and Periodontics*. Chicago, IL: Quintessence; 1999:17–54.