Biomechanical and histological comparison of self-drilling and self-tapping orthodontic microimplants in dogs

Yan Chen,a Hong-In Shin,b and Hee-Moon Kyungc
Hohhot, China, and Daegu, Korea

Introduction: The purpose of this study was to compare the influences of different implant modalities on orthodontic microimplants and surrounding tissues biomechanically and histologically. Methods: Fifty-six titanium alloy microimplants placed on the buccal side of the maxillae and the mandibles in 2 dogs were divided into 2 groups of 28; one group of microimplants was self-drilling, and the other was self-tapping. Approximately 200 g of continuous and constant forces were applied immediately between 2 microimplants by stretching closed nickel-titanium coil springs for 9 weeks. Peak insertion torque and removal torque were recorded immediately after the implants were placed and when the dogs were killed, respectively. Undecalcified sections of the microimplants and the surrounding tissues were studied with light microscope and fluorescent microscope. Results: Success rates were higher in the self-drilling group (93%) than in self-tapping group (86%). Higher peak insertion torque and peak removal torque values were seen in the self-drilling group in both the maxilla and the mandible. A tendency to fracture was found in self-drilling group. The percentage of bone-to-implant contact values was greater in the self-drilling group. Conclusions: Self-drilling microimplants can provide better anchorage and can be recommended for use in the maxilla and in thin cortical bone areas of the mandible. (Am J Orthod Dentofacial Orthop 2008;133:44-50)

The self-tapping method of microimplant placement is an excellent approach in orthodontics, although it has some shortcomings.1,2 Compared with the pretapping method, the self-tapping method offers quicker placement, less damage to bone, and a better grip in bone.3 A prerequisite for self-tapping placement is pilot drilling to prepare a hole for the implant.4 Particularly for interradicular microimplants, pilot drilling has potential dangers, such as damage to tooth roots, drill-bit breakage, overdriilling, and thermal necrosis of bone.5,8 Also, the process takes time.

The growing demand for absolutely rigid orthodontic anchorage has led to an expansion of implant technology.5 Recent advances in biomaterials have resulted in a new self-drilling implant system for rigid internal fixation in maxillofacial surgery.8 The self-drilling procedure is simpler and involves less use of instruments.9

Nevertheless, differences in biomechanical characteristics and mechanisms between self-drilling microimplants (SDIs) and self-tapping microimplants (STIs) in terms of how they are anchored to bone have not been clarified. In previous animal10-12 and clinical studies,13-16 osseointegrated dental implants have behaved like ankylosed teeth to provide orthodontic anchorage. In theory, SDIs might cause less damage to bone during placement; therefore, osseointegration might happen earlier and be better than with STIs.17 Because primary stability is thought to be essential in achieving ideal bone-to-implant contact (BIC), clinical studies have shown significantly higher placement torque with SDIs,18 but no histologic data of BIC values have been shown. Based on the limited literature and clinical experiences,8,19 SDIs might have a relatively high anchorage value for the en-masse movement of anterior teeth, molar uprighting, and forward movement. Perhaps the BIC values at the interface can be enhanced with SDIs,17 so that they can be expected to improve the anchorage of implants, especially in areas of low bone density, to increase the success rate.

The objectives of this study were to compare the biomechanical properties of microimplants with different drilling methods by measuring peak insertion torque.
(PIT) and peak removal torque (PRT) in an animal model, and to investigate the influence of self-drilling and self-tapping techniques on BIC values under orthodontic force.

**MATERIALS AND METHODS**

Two adult female mongrel dogs (weight, >13 kg) were housed in the animal laboratory at Kyungpook National University Medical College in Daegu, Korea. All permanent teeth were erupted, and maxillary and mandibular growth was completed. The treatment of the experimental animals was approved by the ethics committee of the Medical College at Kyungpook National University.

Fifty-six threaded microimplants (Absoanchor, Dentos, Daegu, Korea) made of titanium alloy (titanium, aluminum, vanadium) were used for this experiment and divided into 2 groups. The head of the microimplant was hexagonal to enable placement with hand-driver; it had a small hole for threads and ligature wires. SDIs, with a specially designed sharp tip of conical shape with threads, served as the study group, and STIs with an ordinary tip served as the control group (28 for each group). Size 1312-07—tapered with 1.3 mm neck diameter, 1.2 mm diameter near the apex, and threaded intrabone part 7 mm—was chosen for this experiment (Fig 1). The 2 types of microimplants were the same size and shape (except for the tip), had the same placement angle and similar force magnitudes, and were intended for similar bone densities.

The buccal side of the bilateral maxilla and mandible of the dogs was chosen as the recipient site for symmetrically placing 2 groups of microimplants. The left side was for SDIs, and the right side was for STIs in 1 dog (Fig 2). The left maxilla and the right mandible received SDIs, and the right maxilla and the left mandible received STIs in the other dog. All microimplant placement procedures were performed aseptically with a 90° implant placement angle to the long axis of the teeth. Oral hygiene was achieved by rinsing each dog’s mouth biweekly with 0.2% chlorhexidine gluconate solution.

For the placement of the microimplants, the dogs were anesthetized with a cocktail composed of ketamine (Ketara; Yuhan, Seoul, Korea) at a dose of 10 mg per kilogram of body weight, xylazine (Rompun Bayer Korea, Seoul, Korea) at 0.4 mg per kilogram of body weight, and saline solution.

Twenty-eight SDIs were placed with the self-drilling method. They were manually placed through the attached gingiva with a long hand-driver (Dentos, Daegu, Korea) that was especially designed for these microimplants, without pilot drilling and incision. The head of the microimplant remained outside the attached gingiva for connecting the nickel-titanium springs (Fig 2). Twenty-eight STIs were placed with the self-tapping method. A pilot hole was drilled first with a 0.9-mm diameter round bur, as deep as the length of microimplant thread part, with a handpiece at a speed of 500 rpm by drilling intermittently. Saline solution was used to keep the bur and drill cooled and the placement site lubricated. Then the microimplants were manually placed with the same long hand-driver, according to the technique described by Kyung et al.²⁰

Approximately 200 g of continuous and constant horizontal force was immediately applied by stretching nickel-titanium superelastic closed-coil springs (Tomy, Tokyo, Japan) between 2 microimplants for 9 weeks (Fig 2). The springs contacted the microimplants directly. An operator who has placed more than 100 microimplants in patients and for animal experiments placed all the microimplants.

PIT—the force of the maximum clockwise movement that stripped bone from screw insertion until it was perfectly placed—was measured with a precision digital indicator (EMT, E-mobile tech 17000 series; SEEC, Seoul, Korea) drilling after placement for all

---

**Fig 1.** Microimplants and hand-driver used in this study: A, STI with tip; B, SDI with tip; C, microimplant head; D, hand-driver.
microimplants in the 2 groups. After 9 weeks of observation, PRT—the force of the maximum counterclockwise movement to loosen the microimplants—was measured with the same machine for 12 stable microimplants at symmetrical sites in each group.

The stability of the microimplants was measured with dental tweezers; failure was defined if a microimplant could be moved in any direction after the 9-week observation period.

A vital staining procedure was used for the animals. Oxytetracycline (15 mg per kilogram per day) was given intramuscularly for the first 4 days after the microimplants were placed. A subcutaneous injection of 1% calcitein (15 mg per kilogram per day) was given at the fourth week, and 0.16% alizarin red (75 mg per kilogram per day) was injected intramuscularly at the seventh week.

The anesthetized dogs were killed by intracardial perfusion with neutral 10% formaldehyde solution. The maxillary and mandibular bones containing microimplants were dissected. The specimens were fixed in the same solution for more than 24 hours. After being washed with distilled water, each implant area was separated with a saw (D-54518, Proxxon; Woo Sung E & I Co, Ltd, Tokyo, Japan).

Fourteen microimplants with surrounding tissue were selected for histologic evaluation from the 2 groups at symmetrically interradicular areas of the maxillae and the mandibles of the 2 dogs. These specimens were infiltrated with vilanueva bone stain propylene oxide from a starting solution of 70% alcohol and stained. This procedure included 11 steps and lasted more than 3 weeks.

Before being embedded in vilanueva bone stain propylene oxide, the specimens were dehydrated and defatted with graded ethanol. Each embedded implant with bone was sectioned sagittally with a low-speed digital saw (Accutom-50; Stryers, Ballerup, Denmark) into thicknesses of 500 μm. These sections were ground with a grinding machine (Rotopol-35; Stryers) until the implants and the surrounding tissues could be seen clearly. Microscope slides, prepared by mounting

### Table 1. Comparison of peak insertion torque values between groups (in Ncm)

<table>
<thead>
<tr>
<th>Group (n = 14 each group)</th>
<th>STI</th>
<th>SDI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>3.5 ± 2.1</td>
<td>5.6 ± 1.1</td>
<td>.017</td>
</tr>
<tr>
<td>Mandible</td>
<td>7.4 ± 1.1</td>
<td>8.7 ± 2.3</td>
<td>.029</td>
</tr>
</tbody>
</table>

Significance, P < .05.

**RESULTS**

Not all the microimplants remained firm enough during the experimental period. In the STI group, the overall success rate was 86%; 4 microimplants loosened and tipped. Two failures occurred in the SDI group; 1 microimplant loosened, and another in the distal region of the mandibular second molar fractured in the fourth week. The success rate was 93%.

Mild inflammation and swelling of the alveolar gingiva were observed on both sides of the maxilla and the mandible. They were more serious on the left side in both dogs.

The comparison of the PIT values taken at the beginning of the experiment showed significant differ-
ences between the 3 groups in the maxilla and the mandible (Table I).

The comparison of mean PRT showed no statistically significant difference between the 2 groups after 9 weeks (Table II).

Histologic assessment showed good histocompatibility, with various bone structures interspersed with fibrous connective tissues around the microimplants in both groups (Fig 3). Better osseous tissue formation around the microimplants and greater original bone were seen in the SDI group than in STI group, as evidenced by calcein and oxytetracycline labeling. Remodeling and apposition were seen more in the SDI group than in STI group (Fig 4).

BIC values are shown in Table III.

DISCUSSION

After the 9-week period, an important finding in this study was the high success rates of the SDI and the STI groups. The results confirmed our original deduction of greater success in the SDI group (93%) than in the STI group (86%). Two microimplants failed in the SDI group; 1 loosened, and the other fractured in the fourth week. In a similar animal experiment, Kim and Chang21 observed a higher success rate in the drill-free group than in the drill group with a 1-week healing period.

The main reason for the failures might have been the poor initial stability caused by early loading and the exposed healing situation. This was confirmed in the pig experiment of Heidemann et al19 with a 100% success rate in the groups of self-drilling screws (SDS) and self-tapping screws (STS), which healed in a closed situation and without force.

Because of early loading in our study, the microimplants stayed in the bone with mechanical interlock without bone and implant osseointegration at the beginning of the experiment. Roberts et al1 demonstrated that immediate loading was deleterious to implant stability in their animal study. However, SDIs have been proven to have greater strength and highly mechanical friction with bone to keep initial stability and to resist micromovement.19 Initial stability was believed to play an important role in the success of our intrradicular microimplants that healed in exposed situations.22

PIT, which exhibited the holding strength to resist loosening and loss of the implants, was measured at the beginning of the experiment for each microimplant in both groups. The mean PIT values of the SDIs in the maxilla and the mandible were 5.6 and 8.7 Ncm, respectively. In the STI group, PIT values were 3.5 Ncm for the maxilla and 7.4 Ncm for the mandible. PIT values were found to be significantly different between the SDI and STI groups, both in the maxilla and the mandible, but lower in the maxilla. Our results were similar to those from the clinical experiment of Schon et al23 for craniomaxillofacial procedures; they found that insertion torque of the SDS was higher compared with that of the STS in humans. Microimplants with high PIT might have closer initial contact with bone and might be good for bone remodeling. From an anchorage perspective, the greater the contact between the surface of the microimplant threads and the cortical bone, the higher the initial grip of microimplants would be.24,25

Fracture is a disadvantage of microimplants even when they are placed without excessive force. The results showed high PIT values for thin-diameter microimplants, and high bone density might be dangerous to SDIs. According to the principle of conservation and transformation of energy, SDIs have higher pressure than STIs, and pretapped implants were placed after the pilot holes were drilled. Even though SDIs have many advantages, if the bone is dense, they should not to be

<table>
<thead>
<tr>
<th>Group (n = 6 each group)</th>
<th>STI</th>
<th>SDI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>−5.7 ± 2.3</td>
<td>−6.5 ± 2.2</td>
<td>NS</td>
</tr>
<tr>
<td>Mandible</td>
<td>−6.1 ± 0.5</td>
<td>−7.1 ± 2.0</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS, P >.05.
chosen. STIs should be considered instead. In the maxilla and areas with thin cortical bone in the mandible, microimplants would penetrate easily. Failure due to stripping of bone was infrequent, so pilot drilling was not necessary.

Heidemann et al. reported the increase of PIT and shearing forces on the screw itself; fracture of the screws was caused in thick cortical bone in their in-vitro test. Ellis and Laskin believed that, if a screw was stressed sufficiently in tension or torsion, it ultimately would be broken. They thought that, if screws were subjected to torsion and flexion stress, they would fail at a lower tensile stress value.

This was validated by an in-vitro trial of screws with diameters of 0.8 to 2.0 mm; the screw diameter was the major predictor for holding and breaking strength. The authors of that study emphasized that the larger the diameter of the screw, the better its holding strength in thick bone.

The use of reverse torque for measuring the shear force required to rupture the bone-microimplant interface provided important information concerning bone growing into the fixture surface. Our PRT values were 6.5 Ncm in the maxilla and 7.1 Ncm in the mandible in the SDI group, and 5.7 Ncm in the maxilla and 6.1 Ncm in the mandible in the STI group. Removal torque, as a biomechanical method to measure anchorage or endosseous integration in which greater forces are required to remove microimplants, might be associated with increases in the strength of osseous integration.

Compared with STIs, SDIs showed good resistance to shear force with bone growing into the threads of the microimplants. The secondary bone healing response resulted in biomechanical bone interlocking, which developed sufficient interface to resist shear strength and was sufficient to withstand orthodontic loads.

However, there was no statistically significant difference in PRT between the 2 drilling methods. This was supported by the results of Schon et al. in which the PRT value of the SDIs was similar to that of the STIs at the same location: 4 Ncm in the maxilla and 12 Ncm in the mandible. The PRT values in the SDI and STI groups might suggest that certain factors associated with microimplants stimulate in-vivo incorporation of bone. Several previous investigations pointed out that removal torque measurement usually gave concomitant results with histomorphometric evaluation of BIC. As time went on, the PRT values in the SDI and STI groups might be similar, and it was not expected that SDIs would have greater PRT values than STIs. In contrast to previous reports, our lower PRT values might be explained by the small size of the microimplants and the short observation time.

It has been widely accepted that osseointegrated implants can provide absolute anchorage for tooth movement. The BIC value is a parameter for the linear

Table III. Comparison of BIC values between groups

<table>
<thead>
<tr>
<th>Group</th>
<th>SDI</th>
<th>STI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>39.28% (n = 4)</td>
<td>27.96% (n = 4)</td>
</tr>
<tr>
<td>Mandible</td>
<td>47.44% (n = 3)</td>
<td>26.35% (n = 3)</td>
</tr>
</tbody>
</table>

Fig 4. Fluorescent microscope views of middle part of peri-implant bone at first molar area of 1 dog’s mandible: A and B, SDI; C and D, STI (100X original magnification).
surface of microimplants that is directly in contact with bone matrix and is calculated with software and expressed as a percentage of the total microimplant surface. In this study, the mean BIC values in the SDI group were 39.28% in the maxilla and 47.44% in the mandible. In the STI group, the mean BIC values were 27.96% and 26.35% in the maxilla and the mandible, respectively. Because the BIC values were higher in the SDI group than in the STI group, this showed that the drilling method had an effect on bone-to-microimplant contact; this was further confirmed by PRT values and histologic findings of more original and new bone in the SDI group.

BIC values of 93.8% in the SDS group and 81% in the STS group were found after 6 months of observation in pigs. Heidemann et al demonstrated that the BIC values in the SDS group were superior to those in the STS group because of the greater amount of original bone in the threads of the drill-free screws. Similarly, in the study of Kim and Chang, the mean BIC value (43.68%) in the drill-free group was higher than in the drill group (23.41%) in dogs. Obviously, compared with previous studies, our results indicate that using SDIs without chemical and biologic modification caused less damage to bone, and the time of bone modeling and remodeling was reduced because the bone debris was transported and deposited on the bone surface around the implant tip because of the conical shaft.

Compared with the results of Heidemann et al., the BIC values in our study were lower. This difference could be an internal response of bone to the implant time and the healing condition. Melsen and Costa observed BIC values of 10% to 58% after 6 months of forcing without a healing period for miniscrews. They could be an internal response of bone to the implant time and the healing condition. Melsen and Costa observed BIC values of 10% to 58% after 6 months of forcing without a healing period for miniscrews. They found that the BIC ratio increased with implantation time but was independent of the type of bone and the magnitude of force. Our results have elucidated the mechanism behind the behavior of cells on implant surfaces, and we report an increase in BIC contact by using different drilling methods.

Because the numbers of dogs and microimplants were limited, this study might be regarded as a pilot. However, the results were unequivocal because the tested microimplants were placed symmetrically. Further studies with different force magnitudes after a short healing period are required for more discussion and definite results.

CONCLUSIONS

By comparing the biomechanical and histologic properties between SDIs and STIs, without a healing period, we found high success rates in both groups. PIT, PRT, and BIC values were higher in the SDI group than in the STI group.

We recommend using SDIs in the maxilla and the thin cortical bone areas of the mandible because there is less damage and use of instruments. In areas of dense cortical bone, STIs and SDIs with larger diameters can be recommended.

REFERENCES


