Potential of self-drilling orthodontic microimplants under immediate loading

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Introduction: The aim of this study was to investigate clinically and histologically the efficiency of self-drilling microimplants as orthodontic anchorage with immediate, continuous, and constant loadings. Methods: Titanium-alloy microimplants with diameters of 1.2 to 1.3 mm were manually placed into the buccal sides of both jaws, including the interradicular areas, in 3 dogs. Implants were placed without predrilling in thin cortical bone areas; in thick cortical bone areas, a 2-mm deep pilot hole was drilled. Thirty-six microimplants, subjected to approximately 200 g of immediate horizontal loading, served as the study group. The remaining 8 received no loading and were the controls over the 9-week observation period. The distances of reciprocally loaded microimplants and crestal bone pockets were measured at the beginning and end of loading. Serially undecalcified and decalcified sections of the microimplants and surrounding tissues were studied with light and fluorescent microscopes. After 9 weeks of observation, 22 fixtures were easily removed with a screwdriver. Two were broken, and 1 was movable. Results: Histologic analysis showed good osseointegration in all stable samples, and new bone formation and bone apposition to the surface of the threads in loaded and unloaded samples. Histomorphometric evaluation showed high bone-to-implant contact values in the loaded samples, but no significant statistical differences from the unloaded ones. Conclusions: Titanium alloy microimplants with small diameters (1.2-1.3 mm) are strong enough for self-drilling and immediate loading in thin cortical bone areas, but, to reduce the chance of breakage, a drilling of a pilot hole is suggested in thick cortical bone areas. (Am J Orthod Dentofacial Orthop 2010;137:496-502)

It is not an exaggeration to say that temporary skeletal anchorage is a revolutionary orthodontic technique, because anchorage control is a functional concept in clinical treatment. As a successful routine anchorage device, it simplifies orthodontic treatment, eases the patient’s pain after surgery, and is an efficient treatment method. However, when immediate or early loading is needed, its stability is challenged because of conventional placement methods. The stability of self-tapping miniscrew implants has been reported to be clinically acceptable but not absolute before osseointegration is achieved.

One reason for displacement might be early bone resorption after surgical trauma and early loading. Some intermediary procedures have been proposed after implant bed preparation to enhance the progress of bone healing. Not only is nontraumatic surgery essentially considered, but also several conditions should be included, such as changing the drilling method to reduce original bone damage, chemical modification to increase bone modeling and remodeling, and adding implants to decrease micromovement.

With the improvements in biomaterials, various implants have been designed to be smaller and easier to handle, with less use of instruments. A recently developed form of implants, self-drilling microscrew implants (SDIs), which can be placed without predrilling and no incision, have the advantages of predrilled implants without the potential disadvantages of burning tissues. Less bone damage helps to prevent bone necrosis and screw loosening, and also improves the success rate. Saving time is another advantage of drill-free micromicroimplants.

However, because of limited data about SDIs, their clinical characteristics are unclear, and histologic changes, in particular, with immediate loading are unknown. The issues of what SDIs are as acceptable as predrilled fixtures have been raised, since self-drilling was recommended in some studies. It was stressed that SDIs have a stronger resistance to placement than self-tapping microimplants (STIs). It has been reported that greater bone damage occurs during the placement of self-drilling screws compared with STIs.
The purposes of this study were to examine the potential of SDIs under immediate orthodontic loading clinically and to evaluate the possible damage to bone histologically.

**MATERIAL AND METHODS**

The experimental protocol was approved by the Animal Care Committee of the Medical College at Kyungpook National University, Daegu, Korea. The experimental subjects, assessment methods, and criteria were the same as in our previous STI study. Briefly, 3 female mongrel dogs, 1 year old, with similar weights (14 ± 1 kg), were used to minimize the difference of physical bone reaction. All procedures were performed under sterile conditions, and the animals received general anesthesia with intramuscular injections of a ketamine cocktail. Each dog’s mouth was cleaned with 0.2% chlorhexidine gluconate solution fortnightly.

Forty-four self-drilling, machined-threaded titanium alloy (Ti-6Al-4 V) microimplants (Absoanchor, Dentos, Daegu, Korea; SH1312-07, 1.2-mm tip diameter, 1.3-mm neck diameter, 7-mm length) were manually placed with a hand driver made especially for them without incisions. During placement, 3 implants at the inferior and posterior area of the mandible were broken (2 in dog A, 1 in dog C), so, in a thick cortical bone area, an approximately 2-mm deep pilot hole was drilled. Eighteen pairs of implants were unsubmerged in both jaws and immediately loaded with approximately 200 g of continuous and constant force by stretching 8-mm superelastic closed nickel-titanium springs (Tomy, Tokyo, Japan) for 9 weeks; they were the test group. One microimplant at the maxillary left second premolar area of dog A loosened during spring placing. The remaining 8 unloaded fixtures (2 in dog A, 4 in dog B, 2 in dog C) were placed at the buccal sides of both jaws as controls (Fig 1). Another 4 microimplants were replaced in addition to the broken and loosened ones.

Mobility of the microimplants was measured with dental tweezers and recorded on a 3-grade scale in which 0 denoted no mobility and was defined as a success. Grade 1 indicated palpable mobility, and grade 2 meant visible mobility; both were defined as failures. The mobility examinations were performed before and after the observations. Crevicular pocket depth was measured on the mesial and distal aspects of the test and control implants with a custom-made periodontic probe before and after loading. For the assessment of implant dislocation, the distances between the reciprocal loaded pair implants were clinically and directly measured with a sharp-point digital sliding micrometer (Ortho114, Seoul, Korea) in each dog’s mouth before and after loading. Every measurement was made twice, and the mean value was taken. The dislocation was decided by dividing the difference of the 2 readings before and after loading.

Fluorochrome bone labeling was used to assess the rates of bone modeling and remodeling. Each dog was given doses of oxytetracycline (25 mg per kilogram per day of body weight; Kepro Oxytet, Barneveld, the Netherlands) for the first 4 days after the implants were placed. One dose of calcein (25 mg per kilogram per day of body weight; SIGMA, Steinheim, Germany) was subcutaneously administered at the fourth week. A dose of 0.16% alizarin red (75 mg per kilogram per day of body weight; SIGMA) was intramuscularly injected at the seventh week.

All retrieved specimens that would be subject to decalcified and undecalcified evaluation were fixed in

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**Fig 1.** Positions of microscrew implants. The circles denote the tested samples; the asterisks denote the controls.
10% formaldehyde for 48 hours at room temperature and then changed to phosphate-buffered saline solution (pH 7.4). For assessing bone apposition, bone remodeling, and bone osseointegration, 15 specimens were stained with Villanueva solution and embedded in polyester resin after they were dehydrated and defatted in graded ethanol. Longitudinal sections of the bone-implant interface were cut at thicknesses of 500 μm with a low-speed digital saw (Struers Accutom-50, Bellerup, Denmark) and ground to 50 μm until the implants and surrounding tissues could be clearly seen with light and fluorescent microscopes.

Four specimens were stained with hematoxylin and eosin for assessing the orientation of the surrounding bone and root damage.

Histomorphometric analysis was performed on combined images including the entire implant surface. The micrograph was spliced by using MagicScan32 (version 4.6, SPSS Science, Chicago Ill). Each implant consisted of 7 magnification (100 times) objectives (Olympus BX51, Tokyo, Japan) from the Villanueva-stained specimens. The spliced implant images were quantitatively analyzed by using computer-assisted image-analysis software (Image & Microscope Technique, Calif) to calculate the percentage of bone-to-implant contact (BIC) on the mesial and distal aspects of the implants. Two ways were used for expressing the percentages of BIC contact. The first way was used for considering the ratio of the length of the bone contact area to the total length of the implant interface. The second was for calculating the ratio of the length of bone contact area to the length of the implant interface in the cortical bone area.

RESULTS

The dogs remained in good health without obvious weight loss during the experimental period and with no complications in the whole procedure. During placement, 3 implants fractured at the caudal aspect of the head, and 1 loosened during loading. Broken and loose implants were substituted for the supplemented 4 microimplants for the analysis of success rate. Other mini-screw implants of the 2 groups had primary stability, and most remained stable for the 9-week observation period, except for a loose one (in dog A) in grade 2 and 2 broken implants (1 in dog A, 1 in dog C) at the fourth week. The success rate was 91.67% in the loaded group, with no failures in the unloaded group. The distribution of the microimplants is shown in Figure 2.

At the end of the observation period, 18 miniscrew implants in the loaded and 4 unloaded samples were unscrewed with a screwdriver easily, and no breakage occurred, even without soft and hard tissues being abstracted.
No pockets of the peri-implant were seen at the mesial and distal sides of the implants of the 2 groups. The gingiva around the unloaded implants was observed to be clinically healthier than that around the loaded implants.

The mean displacements of the loaded implants were 0.36 mm in the maxilla and 0.18 mm in the mandible, ranging from –0.03 to 0.58 mm. For the unloaded samples, only 4 implants at the posterior buccal side of dog B were measured, and a –0.13-mm displacement was found.

After the soft tissues were removed, 3 to 5 threads of the microimplants at the anterior buccal sides of both jaws were found out of the bones. The findings from the light microscope for the slides stained with hematoxylin and eosin showed a little irregular bone direction at the interface of surrounding bone, but no root damage was visible.

Through a general light microscope for the Villanueva-stained specimens, most of them were monocortical. On average, 5.5 threads of the microimplant were in cortical bone, ranging from 2 to 8 threads, because of the extrusion and the bone marrow cavity.

Osseointegration between implants and surrounding bone was seen in all stable samples. Apposition was slightly more in the loaded samples. Proliferation was seen at the neck and the marrow side in the unloaded samples, which were composed of thin, compact bone and had a highly porous, spongy inner structure (Fig 3).

Under the high magnification of a general light microscope, the findings from the longitudinal sections of the Villanueva-stained specimens showed less complete osseointegration in the unloaded specimens (Fig 4). The microimplants were primarily osseointegrated with cortical alveolar bone, and no fibrous tissue intervention was observed in the 2 groups. More mature trabecular bone and new bone interspersed with less bone resorption were generally observed at the bottom of the threads in the loaded specimens.

Specimens stained with Villanueva solution were evaluated with a fluorescent microscope. The longitudinal sections of microfluorescence resembled the findings in Figure 4. New compact bone tissue was seen growing into the threads of the microimplants along endosteal surfaces where there was no bone in the first week after surgery, as shown by the lack of oxytetracycline labeling. A slightly wider nonoxytetracycline area was seen in the unloaded samples, suggesting less resorption in the loaded samples. At the cortical bone area, internal remodeling with cutting-filling cones in mature secondary osteins was observed with no clearly different calcein lines in the loaded and unloaded specimens (Fig 5).

Histomorphometric evaluation of the longitudinal sections was performed on 15 specimens. Slightly higher BIC values were found for loaded than for unloaded specimens, but there was no statistically significant difference. The BIC values were not associated with the thicknesses of cortical bone. The average BIC value of the stable microimplants was 24.94% (n = 15), ranging from 15.63% to 44.23%. The BIC values
of the first and second sections are shown in Table I. The BIC values of microimplants in the cortical bone areas are shown in Table II.

DISCUSSION

This study was undertaken to assess the potential of the self-drilling microimplant system as orthodontic anchorage. The implants were placed without predrilling, but 3 fractured during placement at the inferior and posterior areas of the mandible, so a 2-mm deep pilot hole was drilled. The placement of SDIs without pilot drilling is made possible by changing the tip of the implant. By using such techniques, placement of SDIs is easy in the maxilla. In agreement with Heidemann et al.,\textsuperscript{11} it is easy to penetrate thin cortical bone, whereas
screw failure from stripping of bone threads is infrequent, so predrilling is unnecessary. If strong resistance is noticed during screw placement, it should be interrupted, and a pilot hole should be drilled in case of breakage.

Clinical results clearly demonstrate that SDIs are effective orthodontic anchorage devices to sustain immediate 200-g loading for 9 weeks. One loose and 2 broken implants were found in the test group at the fourth week. Because gingiva on the buccal side in dogs is limited, most implants must be placed into movable mucosa areas. After the mucosa was removed, 3 to 5 threads of the stable microimplants were found out of the bone in the anterior buccal sides of both jaws. This was attributed to incomplete placement because of the thickness of the mucosa and extrusion by loading. So it seems that the submerged part of microimplants should be longer than 5 mm, and the amount of surrounding bone should be sufficient for enough rigidity to support immediate orthodontic loading.

Before and after loading, no peri-implant pockets were observed in the compression and tension sides of loaded and unloaded fixtures. These results show that SDIs have good bone-to-implant mechanical integration compared with dental implants, so they might have little chance for bacterial plaque. Aldikacti et al. reported, after 52 weeks of force application, greatly increased pocket depths. Akin-Nergiz et al. noted significant increases in pocket depths around unloaded implants.

By measuring the distance between 2 reciprocally forced microimplants, the mean implant displacements were 0.36 mm in the maxilla and 0.18 mm in the mandible. The displacement was smaller than our previous STI study in both the maxilla and the mandible, with the same immediate loading. The difference can be deduced by the technique of self-drilling, which causes little original bone damage by placement and secondary bone resorption by burning because placement might generate less heat. This surgical protocol is less invasive and offers promising alternatives for orthodontic anchorage. From the anatomic and physiologic viewpoints, microimplants should have sufficient surrounding bone to guarantee their initial stability, to prevent damage to adjacent anatomic structures, and also to provide enough bone for modeling and remodeling. Immediate loading for orthodontic SDIs is clinically acceptable, because their displacement will not cause anchorage tooth movement at the direction of loading. This result is also different from osseointegrated implants that produced a smaller displacement after 22 weeks of loading. Because the sizes of the implants, the placement sites, and the loading times were different from previous studies, it is necessary to understand the histologic responses of the surrounding bone for full evaluation of the SDIs.

Direct contact of bone and microimplant with no intervening soft tissue, especially in the cortical bone area, was seen in loaded and unloaded histologic samples. This agrees with the findings of STIs and dental implants.

New bone formation in trabecular bone and more lamellar bone around the loaded and unloaded microimplants were observed, and slightly more bone apposition in the surface of surrounding bone was seen in the loaded samples. Consistent with our previous study, immediate loading does not prevent new bone formation for SDIs but activates physiologic bone adaptation and stimulates the remodeling of the original surrounding bone.

In this study, histomorphometric analyses are made of 15 samples. BIC values, as the osseointegration index, were evaluated in 2 ways. The average BIC value, expressed for considering the ratio of the length of bone contact area to the total length of the implant interface, was 24.94% (range, 15.63%-44.23%). This result is similar to our previous STI study, even though the collagen infection and resorption were less in most of these samples. This indicates that, if the total BIC value is larger than 15%, the microimplant will be stable enough to sustain 200 g of orthodontic loading, and when the BIC value is lower than 44%, a microimplant with a diameter of 1.2 mm will not break during removal.

BIC values, calculated by using the ratio of the length of bone contact area to the total length of the implant interface in cortical bone, had means for the test implants in the maxilla and the mandible of 51.18%
and 40.63%, respectively. In the unloaded implants, the BIC values were 28.42% for the maxilla and 27.89% for the mandible. The BIC values were obviously higher in the loaded specimens than in the unloaded ones, and also higher in the maxilla than in the mandible. BIC values of 37.51% in the maxilla and 38.56% in the mandible were found for STIs with immediate loading in our previous study.\textsuperscript{14} The high BIC values further confirm that self-drilling produces only a little damage to the surrounding bone. This was also supported by the study of Kim et al.\textsuperscript{17} After a 1-week healing period, their BIC values of 36.2% in the maxilla and 62.8% in the mandible for a mini-implant with a 1.6-mm diameter in the self-drilling group were higher than those in the self-tapping group. Roberts et al\textsuperscript{18} believed that there was no significant difference in the percentage of bone interface associated with a supplemental load. Even though no study has investigated the effect of healing times on the BIC values of SDIs, it might not be the main factor that increases BIC value.

Although in an in-vitro test by Sowden and Schmitz\textsuperscript{13} self-drilling screws consistently had large voids surrounding the implant surface and the endosteal surface, good bone structure in thin cortical bone areas was seen in our study. Especially different from previous STI studies, higher BIC values were found in the loaded maxillary implants. This might be attributed to less bone damage in the maxilla during placement and early healing because of less burning caused by drilling.

The second histologic difference from our previous study was that no root damage was caused by microimplants because no motor drills were used over the cortical bone, and the self-drilling method allows the operator to feel when tooth roots are hit. SDIs have all of the advantages of previous predrilled implant systems without the potential disadvantages of damaging tooth roots, burning tissues, and breaking drills. The roots are safely avoided by using monocortical 5 or 7 mm long SDIs and a 30° placement angle.\textsuperscript{6}

CONCLUSIONS

Our findings suggest that titanium alloy microimplants with small diameters (1.2-1.3 mm) can be placed with self-drilling in thin cortical bone areas and be stable enough for immediate loading.

Compared with unloaded ones, loaded SDIs show more favorable patterns of bone osseointegration and bone apposition, suggesting that self-drilling might cause less damage to the surrounding bone, and immediate loading might lead to early bone healing.

When immediate or early loading is needed, the clinical stability of SDIs is better than that of STIs, but they do not remain absolutely stable like endosseous implants. The small diameter of SDIs appears suitable for orthodontic anchorage and might be a preferred design. But for reducing the chance of breakage, a 2-mm pilot drill is suggested in thick cortical bone areas.

REFERENCES