Placement and removal torque values of orthodontic miniscrew implants

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Introduction: The purpose of this study was to analyze the maximum insertion torque (MIT) and maximum removal torque (MRT) values of orthodontic miniscrews. Methods: Two hundred eighty titanium miniscrews were placed in several sites in the maxillae and mandibles of orthodontic patients to provide skeletal anchorage. Two types of miniscrews were used: predrilling, cylindrical miniscrews, and self-drilling, conical miniscrews. A force of 50 g was applied with nickel-titanium coil springs 2 weeks after placement. MIT and MRT values were assessed with a digital torque gauge. Torque values were subjected to the paired t test, Student t test, chi-square test, and 1-way analysis of variance (ANOVA) \( (P < 0.05) \). Results: MIT values were significantly higher for the self-drilling miniscrews (mean, 14.5 Ncm; 95% CI, 13.6-15.3) than for the predrilling miniscrews (mean, 9.2 Ncm; 95% CI, 8.6-9.9) in all implant sites. For both predrilling and self-drilling miniscrews, the highest MIT values were observed at the midpalatal suture site followed by the dentoalveolar bones of the mandible and maxilla, respectively. In contrast, MRT values were significantly higher for the predrilling miniscrews (mean, 22.6 Ncm; 95% CI, 22.0-23.3) than for the self-drilling miniscrews (mean, 17.6 Ncm; 95% CI, 16.8-18.4). Accordingly, the mean torque ratio of predrilling miniscrews was twice that of the self-drilling miniscrews. Conclusions: An inverse relationship between MIT and MRT values was observed. The results suggest that relatively lower MIT values were more favorable to osseointegration than higher values. (Am J Orthod Dentofacial Orthop 2011;139:669-78)

Miniscrew implants have become an accepted and reliable method for providing temporary additional anchorage during orthodontic treatment.\(^1\)\(^2\) Because these miniscrews use the bone as anchorage, they have become broadly accepted as viable alternatives to extraoral devices in patients who either have insufficient dental support suitable for anchorage or are not compliant in wearing extraoral devices.\(^2\)\(^4\)

These miniscrew implants have several advantages—relatively simple implantation and removal procedures, and reduced costs—over the conventional methods of skeletal anchorage.\(^4\)\(^5\) Moreover, their small diameter allows placement into several areas of the maxilla and mandible that were previously unavailable, such as the alveolar bone between the roots of adjacent teeth.\(^5\)\(^7\)

Miniscrew implants are generally made of commercially pure titanium or titanium alloy.\(^8\) However, unlike conventional dental implants, miniscrews are manufactured with an untreated, smooth surface, because they are intended to be removed by the end of their clinical application.\(^4\)\(^5\) Consequently, osseointegration surrounding the miniscrew is not highly desirable, since it would complicate the miniscrew removal by increasing removal torque values.\(^9\)\(^10\)

Moreover, studies have shown that miniscrews do fracture at removal if the removal torque exceeds the limits that the miniscrew can withstand.\(^9\) Removal of the remnant of the miniscrew can be complex and might require additional surgical intervention with a trephine drill; this might lead to substantial bone removal and potential risks to the patient.\(^9\)\(^10\)

Application of immediate loading protocols has been suggested, when sufficient primary stability is achieved, as a practical approach to avoid the risks of osseointegration, since the loading is applied directly on the unhealed wound.\(^11\) However, recent clinical and experimental studies have demonstrated that even immediately loaded implants can become partially osseointegrated with various degrees of bone-to-implant contact.\(^12\)\(^14\)
Removal torque assessment has been suggested as a reliable method of determining the extent of osseointegration for conventional implants. However, only a few studies have been conducted to assess the effect of removal torque of miniscrew implants. Moreover, the findings of these studies are conflicting. Chen et al. assessed the removal torque of miniscrews in several sites in the maxilla and the mandible. They concluded that the miniscrew stabilization to the bone was mainly obtained through mechanical retention rather than osseointegration, since immediate loading was used. In contrast, Favero et al. evaluating the removal torque of miniscrews in patients, concluded that the immediately loaded miniscrews were partially osseointegrated. However, in these studies, placement torque, a valid parameter to assess the primary stability of these miniscrews, was not assessed. The primary stability of miniscrew implants has been frequently associated with increased success rates of miniscrews.

The assessment of both placement and removal torque values should provide important information about the effect of the primary stability on the extent of osseointegration surrounding the immediately loaded miniscrews. Therefore, the purpose of this study was to analyze the placement and removal torque values of orthodontic miniscrew implants in several sites in the maxilla and mandible.

**MATERIAL AND METHODS**

The sample consisted of 280 miniscrew implants that were systematically implanted into the bone of orthodontic patients, rigorously following the protocol of the Miniscrew Implant Group, Department of Orthodontics, Faculty of Dentistry, Chiang Mai University in Thailand, for safe miniscrew implant placement. The sample comprised 120 predrilling, cylindrical type (Sistema Nacional de Implantes, São Paulo, Brazil) and 160 self-drilling conical type (ACR Mini-Implant, BioMaterials Korea, Guro-gu, Seoul, Korea) titanium miniscrew implants (Fig 1, A). All miniscrew implants were 1.5 mm in diameter and 6 or 8 mm in length. Miniscrew implants of 8-mm length were used in the dentoalveolar bone of the maxilla and the mandible, and those of 6-mm length were used in the midpalatal suture area. All miniscrew implants were used for orthodontic anchorage purposes during retraction of anterior teeth in patients who needed premolar extractions; 0.018-in slot preadjusted brackets were used in all patients. The same types of archwires and biomechanics were used for all patients.

Anterior retraction was performed with nickel-titanium closed-coil springs (50 g) attached to the heads of the miniscrew implants. The subjects were 40 males and 55 females with ages ranging from 12.0 to 46.6 years (average age, 25.6 years; SD, 6.7 years). In accordance with the policies of the ethics committee at the Faculty of Dentistry, Chiang Mai University, we informed all patients about the risks and complications involving the use of miniscrew implants. All patients signed the informed consent form.

In this study, the planning and miniscrew placement into the dentoalveolar bone were performed by the same orthodontist (E.Y.S.), aided by a 3-dimensional (3D) surgical guide (Y&T Products, Chiang Mai, Thailand). The 3D surgical guide was used to aid placement into the dentoalveolar bone to safely place the miniscrew implants between the roots of adjacent teeth.

Preoperative bitewing radiographs of the selected implant site were made by using the vertical bitewing technique aided by a film holder (Rinn XCP film holding system, Dentsply International, York, Pa) to ensure the precise mapping of the optimum implant site (Fig 2). Radiographs were made with the 3D surgical guide in position to show the relationship of the guide to surrounding structures and available bone. The 3D surgical guide was positioned as accurately as possible at the preselected miniscrew implant site. A radiograph was made to determine whether the image of the radiopaque tube was in the correct location. If it was not, the device was adjusted, and additional radiographs were made until a definitive implant placement position was determined that would not violate any surrounding structures. The radiographic image of the surgical guide projected onto the recipient bone oriented the ideal miniscrew implant placement position relative to the surrounding structures.

After the optimum implant position had been determined, the patients were instructed to rinse the mouth with chlorhexidine solution for 1 minute for hygiene in the oral cavity and to reduce the risks of infection during the surgical procedures. Infiltrative local anesthetic was used in all subjects. All miniscrews were placed through the attached gingiva. A high-speed diamond bur was used to expose the underlying bone. No flap elevation was performed.

For the predrilling miniscrew implants, a pilot hole was drilled with a 1.1-mm diameter spiral drill by using a manual drill with normal saline-solution irrigation to prevent excessive heat generation and to remove the bone debris from the drilling site. The miniscrew implants were placed into the pilot hole through the surgical guiding tube with a manual screwdriver to reduce the risks of implant deviation during placement and to ensure the precise 3D placement into the preoperatively planned position.
The self-tapping miniscrew implants were placed directly through the gingival tissue into the bone, without creating a pilot hole, by using manual screwdrivers. Maximum insertion torque (MIT) and maximum removal torque (MRT) were assessed with a torque wrench (Imada, Northbrook, Ill) (Fig 1, B). The appropriate screwdriver of the corresponding miniscrew's manufacturer was adapted into the Jacobs chuck of the torque wrench and applied to the miniscrew (Fig 1, C). Placement and removal torque values of all miniscrews were assessed by the same orthodontist (E.Y.S.).

MIT was assessed simultaneously with the miniscrew placement procedures into the bone. The miniscrew implants were either placed into the prepared pilot hole (predrilling) or screwed directly into the bone (self-drilling).

The MIT was recorded at the terminal turning applied to tighten the miniscrew into the bone. The terminal turning was determined clinically, when the platform of the miniscrew gently touched the surface of the attached gingiva without provoking ischemia of the surrounding tissues.

Miniscrew implants were removed from each patient after the completion of their clinical application by using the torque device. The timing of removal was dictated by the orthodontic treatment plan. Miniscrew implants were able to function as skeletal anchorage against an orthodontic load for an average period of 44 ± 11 weeks with a minimal healing period of 2 weeks. MRT was assessed during the miniscrew removal procedures. The MRT value was considered the peak torque value necessary to unscrew the miniscrew. In general, the MRT value was the torque necessary to loosen the miniscrew at the initial turn.

The torque ratio (TR) of MRT to MIT was calculated. The TR of miniscrew implants is an important clinical criterion to determine the changes at the bone-miniscrew interface throughout orthodontic loading.
Statistical analysis

The statistical analyses were performed using the SPSS software program (version 17.0, SPSS, Chicago, Ill) on a personal computer. A paired \( t \) test statistical analysis was used to compare the MIT and the MRT of the predrilling and self-drilling miniscrew implants. The Student \( t \) test was used to compare the MIT and the MRT between the predrilling and self-drilling miniscrew implants and to determine any difference in the MIT values of the failed and successful miniscrews. Descriptive statistics and multiple comparisons between groups were performed with 1-way analysis of variance (ANOVA) and the post-hoc Tukey test to detect any differences between the locations of the miniscrews. The chi-square test was used to estimate differences in the success rates according to miniscrew type and placement site. The significance level was established at 0.5%.

RESULTS

Failure of miniscrew implants was observed in 7 predrilling miniscrews and 12 self-drilling miniscrews. The failure rates of both groups were similar. The failures occurred 2 to 6 weeks after their placement. The most common site of failure was the dentoalveolar bone of the maxilla, followed by the mandible. No failure was observed in the miniscrews placed in the midpalatal suture (Table I). No statistically significant difference between the MIT values of successful and failed miniscrew implants was observed (Table II). Fractures during removal occurred in 4 predrilling miniscrews. One self-drilling miniscrew was fractured during placement in the midpalatal suture.

A statistically significant difference was observed between the MIT and the MRT values of the successful predrilling and self-drilling miniscrew implants placed in the dentoalveolar bone sites of the maxilla and the mandible, and the midpalatal suture. For both predrilling and self-drilling miniscrews, the MRT values were significantly higher than the MIT values \((P < 0.01)\). The TR of predrilling miniscrews (2.5) was twice that of the self-drilling miniscrews (1.2) (Table III).

MIT values were significantly higher for the self-drilling miniscrews (14.5 Ncm; 95% CI, 13.6-15.3) than for the predrilling miniscrews (9.2 Ncm; 95% CI, 8.6-9.9) in all implant sites. For both predrilling and self-drilling miniscrews, the highest MIT values were observed at the midpalatal suture followed by the dentoalveolar bone of the mandible and the maxilla, respectively. In contrast, the MRT values were significantly
higher for the predrilling miniscrews (22.6 Ncm; 95% CI, 22.0-23.3) than for the self-drilling miniscrews (17.6 Ncm; 95% CI, 16.8-18.4) (Table IV).

For the predrilling miniscrew implants, statistically significant differences in the MIT values between the maxilla and the midpalatal suture and the maxilla and mandible were observed (Table III). No significant difference in the MIT values between the mandible and the midpalatal suture was observed. Statistically significant differences in the MRT values between the dentoalveolar bone of the maxilla and the midpalatal suture and the dentoalveolar bone of the maxilla and the mandible were also observed. No significant difference between the MRT values of the mandible and the midpalatal suture was observed. Miniscrew implants placed in the midpalatal suture had the highest MIT (14.5 Ncm; 95% CI, 13.9-15.0 Ncm) and MRT (26.9 Ncm; 95% CI, 26.1-27.7 Ncm) values (Table IV).

For the self-drilling miniscrew implants, a statistically significant difference in the MIT values between all locations was observed. Similarly, a statistically significant difference in the MRT values between all locations was observed. Miniscrew implants in the midpalatal suture had the highest MIT (21.1 Ncm; 95% CI, 20.3-21.9 Ncm) and MRT (23.2 Ncm; 95% CI, 22.4-23.9 Ncm) values. In contrast, miniscrew implants in the dentoalveolar bone of the maxilla had the lowest MIT (12.1 Ncm; 95% CI, 11.5-12.7 Ncm) and MRT (15.8 Ncm; 95% CI, 15.1-16.5 Ncm) values (Table IV).

**DISCUSSION**

Both placement and removal torque values were assessed to evaluate the biomechanical properties of miniscrew implants. Placement torque has been shown to be a valid parameter to assess the quality of the recipient bone, and measuring the removal torque has been used to assess the extent of osseointegration. Therefore, the assessment of both placement and removal torque values provides important information about the effect of the primary stability on the osseointegration of immediately loaded miniscrew implants.

In this study, relatively high success rates were observed with both predrilling (94.2%) and self-drilling (92.5%) miniscrew implants. These results are slightly higher than those of previous studies that investigated the stability of miniscrew implants. Miyawaki et al investigated the success rates of several types of miniscrew implants and observed success rates of 83.9% (1.5-mm diameter) and 85% (2.3-mm diameter). Moon et al observed an overall success rate of 83.8% for miniscrew
implants placed in the maxillary and mandibular posterior buccal regions. The improved success rates in our study might be explained by the use of a strict protocol for safe and accurate miniscrew implant placement into the dentoalveolar bone with the 3D surgical guide, thus avoiding contact with the roots of adjacent teeth.\textsuperscript{20,21}

Significant differences in the overall success rates among the locations (maxilla, mandible, midpalatal suture) of the miniscrew placement were observed. The midpalatal suture site exhibited higher success rates than the other areas, perhaps because this site is composed of dense cortical bone.\textsuperscript{22} These results agree with those of Lim et al,\textsuperscript{23} who evaluated the factors associated with initial stability of miniscrew implants.

However, significant differences in the success rates among the locations for miniscrew placement were observed only with the predrilling miniscrews. The results suggest that the placement procedure might play an important role in the success rate of miniscrew implants. The nonsignificant differences in the success rates among the locations of the self-drilling miniscrews suggest that these miniscrews induce tighter bone tissue contact; therefore, they might provide improved primary stability.\textsuperscript{24}

Differences in the overall dimensions of the devices used in this study, particularly of the neck of the miniscrew, could be related to different levels of peri-implant tissue inflammation after placement; this is also an important factor in the stability of this kind of implant. According to Miyawaki et al,\textsuperscript{18} miniscrews with diameters of 1.0 mm or less, inflammation of the peri-implant tissue, and a high mandibular plane angle were associated with the failure of miniscrews placed in the buccal alveolar bone.

In this study, fracture of 1 self-drilling miniscrew implant occurred during placement in the midpalatal suture, and 4 predrilling miniscrew implants fractured during removal in the dentoalveolar bone of the maxilla, thus indicating that the applied torque exceeded the limits that the miniscrew implants could withstand.\textsuperscript{9}

Fracture of the self-drilling miniscrew implant during placement could be avoided by either monitoring the MIT values to prevent excessive torque or preparing a pilot hole beforehand in proportion to the bone stiffness and the cortical bone thickness.\textsuperscript{16} On the other hand, fracture at removal of the predrilling miniscrews, caused by the strength of the osseointegration surrounding the miniscrew implant, could not be avoided (Fig 3).

Because miniscrew implants can achieve partial osseointegration after placement, fracture can occur during their removal if the removal torque exceeds the limits that the miniscrew can withstand.\textsuperscript{13,14} Moreover, the reduced miniscrew diameters combined with the ductile characteristics of the titanium alloy used to manufacture the miniscrew implants also collaborate the increases in the potential risks of miniscrew fracture during removal.\textsuperscript{10}

To retrieve the portions of the partially osseointegrated miniscrew that remain deep in the dentoalveolar bone can be complex and might require additional surgical intervention with a trephine drill; this can lead to substantial bone removal and potential risks to the patient.\textsuperscript{10} Therefore, questions remain about the strength of the osseointegration and whether miniscrew implants can be removed easily and safely from a patient’s mouth.

In this study, the MIT values of the predrilling miniscrew implants were significantly lower (20\%-40\%) than those of the self-drilling miniscrew implants at all implant sites. The difference in MIT can be explained by both the use of a predrilling pilot hole prepared beforehand to aid in the placement of predrilling miniscrew implants and the improved primary stability provided

Table III. MIT and MRT (Ncm) of predrilling (n = 113) and self-drilling (n = 148) miniscrew implants in several sites of the maxilla and the mandible

<table>
<thead>
<tr>
<th>Placement site</th>
<th>n</th>
<th>MIT</th>
<th>MRT</th>
<th>Difference</th>
<th>P</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-drilling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td>113</td>
<td>9.2</td>
<td>3.4</td>
<td>22.6</td>
<td>13.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Dentoalveolar</td>
<td>74</td>
<td>7.2</td>
<td>1.4</td>
<td>21.1</td>
<td>2.5</td>
<td>13.9</td>
</tr>
<tr>
<td>Mandible</td>
<td>27</td>
<td>14.5</td>
<td>1.6</td>
<td>26.9</td>
<td>2.0</td>
<td>12.4</td>
</tr>
<tr>
<td>Midpalatal</td>
<td>12</td>
<td>12.4</td>
<td>1.2</td>
<td>24.5</td>
<td>2.0</td>
<td>12.1</td>
</tr>
<tr>
<td>Dentoalveolar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-drilling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td>148</td>
<td>14.5</td>
<td>4.5</td>
<td>17.6</td>
<td>3.1</td>
<td>4.0</td>
</tr>
<tr>
<td>Dentoalveolar</td>
<td>90</td>
<td>12.1</td>
<td>3.1</td>
<td>15.8</td>
<td>3.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Mandible</td>
<td>30</td>
<td>21.1</td>
<td>2.2</td>
<td>23.2</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>Midpalatal</td>
<td>28</td>
<td>15.7</td>
<td>2.3</td>
<td>17.9</td>
<td>2.3</td>
<td>2.2</td>
</tr>
</tbody>
</table>

\( P \) indicates significance by the paired \( t \) test.
by self-drilling miniscrew implants.\textsuperscript{16,17} Moreover, the self-drilling miniscrew implants used in this study had a conical thread profile that provides increased primary stability, since they produce a tighter contact between the miniscrew and the surrounding bone compared with the predrilling (cylindrical) ones. However, because the success rates of predrilling and self-drilling miniscrews were similar, it might be assumed that large MIT values were not directly related to the failure rates of miniscrew implants. These results agree with those of previous studies that compared the stability of cylindrical and conical miniscrew implants.\textsuperscript{24,25,26} It has been demonstrated by direct measurements that the tapered profile of the conical screws leads to an increase in placement torque.\textsuperscript{25} Kim et al\textsuperscript{24} investigated the mechanical and histologic properties of conical compared with cylindrical miniscrew implants. They observed that conical miniscrews produced significantly higher MIT and MRT values than did cylindrical miniscrew implants.

In general, miniscrew implants (predrilling and self-drilling) placed in the midpalatal suture site produced the highest MIT values, followed by the mandibular and maxillary alveolar sites, respectively. The differences in MIT values can be explained by the difference in bone densities in the several sites in the maxilla and the mandible.\textsuperscript{10} These results are in accordance with those of previous studies that investigated the stability of miniscrew implants in different sites in the maxilla and the mandible. According to Kim et al,\textsuperscript{22} the midpalatal suture site is composed of dense cortical bone and, therefore, is recommended as the best anchorage site in the maxilla. Huja et al\textsuperscript{27} examined the pullout strength of screws in the maxilla and the mandible. They concluded that miniscrews in the mandible produced higher placement torque values than did those in maxillary sites. Friberg et al\textsuperscript{28} determined that the cutting torque in the mandible was statistically greater than that in the maxilla, similar to the results of our study. They also found a correlation between implant placement resistance and bone density values and concluded that the stability of miniscrew implants is affected by diameter and bone stiffness.

In our study, however, no significant difference between the MIT values of the failed and successful miniscrew implants was observed. Moreover, the average MIT value varied considerably, depending on the technique used (predrilling or self-drilling) and the site of placement. Therefore, it was not possible to determine an adequate miniscrew implant placement torque value.

Adequate MIT values enhance the primary stability of miniscrew implants, thus avoiding the risks of micromotion and negative tissue responses, such as the formation of fibrous scar tissue at the bone-screw interface during the healing and loading periods.\textsuperscript{27,28} Okazaki et al\textsuperscript{13} suggested that an adequate implant placement torque value in the range of 5 to 10 Ncm for predrilling miniscrew implants placed in the posterior alveolar bone of the maxilla to increase their success rate, similar to our results. In this study, the average MIT values of miniscrew implants placed in the maxillary dentoalveolar bone were 7.2 ± 1.4 and 12.1 ± 3.1 Ncm for the predrilling and self-drilling miniscrew implants, respectively.

### Table IV. Comparison between MIT and MRT values of predrilling (n = 113) and self-drilling (n = 148) miniscrew implants placed in the midpalatal suture, and the dentoalveolar bone of the maxilla and the mandible

<table>
<thead>
<tr>
<th>Placement site</th>
<th>Torque (Ncm)</th>
<th>Predrilling</th>
<th>Self-drilling</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>MIT All sites</td>
<td>113</td>
<td>9.2</td>
<td>3.4</td>
<td>148</td>
</tr>
<tr>
<td>Maxilla</td>
<td>74</td>
<td>7.2</td>
<td>1.4</td>
<td>90</td>
</tr>
<tr>
<td>Midpalatal</td>
<td>27</td>
<td>14.5</td>
<td>1.6</td>
<td>30</td>
</tr>
<tr>
<td>Mandible</td>
<td>12</td>
<td>12.4</td>
<td>1.2</td>
<td>28</td>
</tr>
</tbody>
</table>

Comparisons between locations were made with ANOVA. Significance by the Student t test: * P < 0.05; ** P < 0.01; *** P < 0.001.
confirmed the importance of primary stability of mini-
screw implants for early use in orthodontics. They con-
cluded that a miniscrew implant without primary
stability should be replaced or isolated until it develops
adequate stability supported by osseointegration.

In general, the MRT values of the successful mini-
screw implants (pредrilling or self-drilling) were signi-
ficantly greater than their respective MIT values at all
implant sites. This result indicates that a significant
amount of osseointegration between the miniscrew
and the surrounding bone had occurred. Although it
was not possible to determine the amount of bone-
miniscrew contact, or whether partial or total osseoi-
tegration had occurred, it was possible to assess the
strength of the osseointegration. Moreover, it was pos-
able to confirm that the stability of these miniscrew
implants was related to the initial stability immediately
after placement and to the subsequent stability sup-
ported by osseointegration. These results agree with
those of previous studies. 12,14,29,30 Favero et al, 12 eval-
uating the removal torque of miniscrew implants in
patients, concluded that immediately loaded miniscrews
were partially osseointegrated. Vande Vannet et al 14
reported the histomorphometric findings of the os-
seointegration of bracket screw bone anchors placed
in the alveolar process of the mandibles of beagle
dogs. They concluded that the screws partially osseoin-
tegrated to the bone. Kim et al 29 demonstrated that
bone remodeling and osseointegration occur around
orthodontic miniscrew implants under early orthodontic
forces.

An interesting finding of this study was that the
MRT values of the predrilling miniscrews were signi-
ficantly higher than those of the self-drilling miniscrews,
although the MIT values of the predrilling miniscrews
were significantly lower than the self-drilling minis-
crews in all implant sites. As a consequence, the TR
values of the predrilling miniscrews were twice as great
as those of the self-drilling miniscrew implants. These
results suggest that the relatively lower MIT values
were more favorable to osseointegration than were
higher values. Conversely, it might be assumed that
large MIT values generated high stress levels that pro-
voked local ischemia and necrosis of the bone at the
implant-bone interface, thus leading to deficient
osseointegration. 16,17 The effect of the initial torque on
the strength of osseointegration can be exemplified by
the fact that no self-drilling miniscrew implant fractured
during the removal procedures, but 4 predrilling mini-
screw implants fractured during removal.

These results agree with the findings of Yano et al, 25
who investigated the initial stability of tapered ortho-
dontic miniscrews after placement in the tibia of rats.
They observed a significant difference in the bone-
screw contact ratio between the immediate loading and
healing groups of straight (cylindrical) miniscrews,
whereas no significant difference in the bone-screw con-
tact ratio between the immediate loading and healing
groups of tapered miniscrews was observed. Those
authors further concluded that tapered miniscrews can
be used as orthodontic anchorage immediately after their
placement.

Miniscrew implants are designed to be immediately
loaded, thus providing treatment efficiency without
compromising the treatment duration, and to be easily
removed by the end of their clinical application in ortho-
dontics. Therefore, questions remain as to the strength
of the osseointegration and whether miniscrew implants
can be removed easily and safely from a patient’s
mouth.

In this study, direct analysis was performed of MIT
and MRT values of predrilling and self-drilling miniscrew
implants that were used as skeletal anchorage in ortho-
dontic patients. It has been shown that self-drilling
miniscrew implants have several mechanical advantages
over predrilling miniscrew implants.

Compared with predrilling miniscrews, self-drilling
miniscrew implants require less operating time, since

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**Fig 3.** Partially osseointegrated miniscrew. A piece of
bone is osseointegrated to the miniscrew. High removal
torque is necessary to remove the miniscrew.
they allow simple surgical procedures for placement without the need of a predrilling pilot hole before miniscrew placement. They also provide significantly superior primary stability compared with predrilling miniscrews, therefore allowing the immediate application of loading forces. Although our results showed that osseointegration had occurred on both predrilling and self-drilling miniscrew implants, the strength of the osseointegration was significantly lower for the self-drilling miniscrews. This is of clinical importance, since miniscrew implants are not designed to remain in the bone and, therefore, should be easily removed from the patient’s mouth without risks of fracture.

Analysis of these data indicated that both predrilling and self-drilling miniscrew implants were able to function as rigid skeletal anchorage against an orthodontic load for an average period of 44 weeks with a minimal healing period. A significant amount of osseointegration occurred surrounding both predrilling and self-drilling miniscrew implants. The surgical technique at placement, the design of the miniscrew, the status of the host site, and the MIT values were favorable for bone development around the miniscrew implant.

A limitation of this study was related to the assessment method applied. Although the torque values could be easily assessed clinically during both placement and removal procedures, it was not possible to quantify the amount of bone-screw contact, and therefore it was not possible to define whether partial or total osseointegration had occurred surrounding these miniscrew implants. Moreover, the torque assessment method does not allow monitoring the stability of miniscrew implant throughout the application of orthodontic loading. Therefore, further studies with noninvasive methods, such as resonance frequency analysis, are currently being conducted in our university to assess the stability of miniscrew implants during orthodontic loading.

CONCLUSIONS

Self-drilling miniscrew implants have been shown to have several advantages over predrilling miniscrew implants. They allow simple surgical procedures for placement without the need of a predrilled pilot hole; although they provide significantly superior primary stability compared with predrilling miniscrews, the strength of the osseointegration is significantly lower. This is of clinical importance, since miniscrew implants are not designed to remain in the bone and should be easily removed from the patient’s mouth without risks of fracture.

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