A comparison of tapered and cylindrical miniscrew stability

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SUMMARY
OBJECTIVES: This study compared the stability of tapered miniscrews with cylindrical miniscrews. MATERIALS/METHODS: One hundred and five tapered and 122 cylindrical self-drilling miniscrews were placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males and 89 females). The insertion torque and removal torque were measured and Periotest values (PTVs) were recorded at implantation. RESULTS: The success rates of the tapered and cylindrical miniscrews examined were similar. In the maxilla, the insertion torque of the tapered miniscrews (8.3 Ncm) was significantly higher than that of the cylindrical miniscrews (6.3 Ncm) (P < 0.05). The PTVs of the tapered miniscrews were statistically significantly lower in the maxilla (P < 0.05). The removal torque values showed no significant difference between the tapered and cylindrical miniscrews in the upper and lower buccal areas (P > 0.05). CONCLUSIONS: Tapered miniscrews had higher initial stability when compared to cylindrical miniscrews, whereas the clinical success rates and removal torques were similar between the two designs. The long-term stability is not directly affected by the miniscrew design.

Introduction
Orthodontic miniscrews have shifted the paradigm of anchorage in orthodontics and tooth movements that were once difficult have become easier with the aid of miniscrews.

Miniscrew failure rates have been reported to be between 10 and 15 per cent (Miyawaki et al., 2003; Motoyoshi et al., 2006; Tseng et al., 2006) and contributing factors associated with success rate include bone quality, patient age, interradicular space, anatomical location, screw diameter and length, screw design, operator skill, among others. In particular, the initial stability of miniscrews is used as a predictor of success (Motoyoshi et al., 2010). Initial stability also allows for new bone formation at the bone–implant interface (Motoyoshi et al., 2006) and is essential in preventing miniscrew mobility within the physiologic limits of bone remodelling because failure can occur if there is mobility during treatment (Ivanoff et al., 1997; Motoyoshi et al., 2010).

The factors impacting initial stability of a miniscrew can be divided into two main areas: the screw and the host, and for the former, diameter and length (Ivanoff et al., 1997) are reported to play an important role. The quantity and quality of the bone where the screw is placed and cortical bone thickness (CBT) can affect the initial stability of a screw (Cha et al., 2010a).

Measuring insertion torque (Motoyoshi et al., 2006) and Periotest values (PTVs) (Cha et al., 2010c) are efficient ways to evaluate the initial stability of different designs of miniscrews. In order to estimate the miniscrew’s stability after insertion, a number of investigators carried out histomorphometric analysis and measured the removal torque.

As reported by Lim et al. (2008a), an increase in screw diameter can effectively increase the initial stability of a miniscrew. However, increasing the screw diameter can bring about limitations in placement due to root proximity. Therefore, various tapered miniscrews have been designed to circumvent this problem. Tapered miniscrews increase primary stability by inducing a controlled compressive force in the cortical layer without increasing root proximity. This design was originally recommended for immediate loading of prosthetic implants because it increased the mechanical contact between the dental implant and surrounding bone (Motoyoshi et al., 2006).

In a previous animal study model, tapered and cylindrical miniscrews were compared to evaluate miniscrew stability (Cha et al., 2010b). There was a significant difference in removal torque values between the two types of miniscrews when they were removed after 3 weeks. However, there was no statistically significant difference between the two groups when the miniscrews were removed after 12 weeks. Meanwhile, Suzuki et al. (2010) reported that the tapered miniscrews, which had a higher insertion torque required less removal torque than the cylindrical miniscrews. These results differed from previous animal studies (Cha et al., 2010b).

The aims of this investigation were to evaluate the clinical efficiency of tapered and cylindrical miniscrews by...
estimating their success rate and long-term stability, while also evaluating the relationship between initial and long-term stability.

**Materials and methods**

*Methods*

Two hundred and twenty-seven self-drilling miniscrews (105 tapered and 122 cylindrical; Biomaterials Korea, Seoul, Korea) were placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males and 89 females; Figure 1). The mean age of the patients was 25.3 ± 8.0 years. The inclusion criteria included patients 1. with no relevant medical history, 2. who were over 16 years old, and 3. who needed miniscrews for orthodontic treatment. The miniscrews (machined surface and self-drilling) were placed between 2008 and 2011 in the Orthodontic Clinic of OO University Dental Hospital in OO. The patients were informed of the advantages and disadvantages of this method for improving anchorage. After collecting informed consent from the patients, the miniscrews were placed. This study was approved by the ethics committee of OO University School of Dentistry with all patients consenting to participate in this study.

Two types of miniscrews of various diameters and lengths were used for orthodontic anchorage: 1. a drill-free and cylindrical type (Biomaterials Korea) with a diameter of 1.5 mm and length of 7 mm and 2. a drill-free and tapered type (Biomaterials Korea) with a diameter of 1.5 mm and length of 7 mm (Figure 1). The miniscrews were placed in the following areas: maxillary buccal and mandibular buccal alveolar areas.

All screws were placed after administering a quarter ample Lidocaine HCL-Epinephrine (Huons, Koren) by local infiltration anaesthesia on the buccal, apical area in which each miniscrew was to be placed. Both types of screws were placed with an angulation of 30–40 degrees to the occlusal plane, using a manual hand driver directly without predrilling. Miniscrews were implanted 3 mm from the cementoenamel junction (CEJ) of the teeth and an effort was made to place the miniscrews in an interradicular space. All screws were placed with normal saline solution irrigation. Each screw was inserted by one of three orthodontic specialists. Though 140 patients initially participated in this study, 8 patients were excluded because of incomplete data and transfer away from the investigation.

Miniscrews were placed in a symmetrical position within an arch and different types of screws were placed on the left and right sides in the respective arch. The locations for

![Figure 1](https://academic.oup.com/ejo/article-abstract/36/5/557/405479)
the different types of screw were decided randomly. The insertion torque and removal torque were measured using a torque sensor (Mark-10, MGT50, California, USA) during implantation and removal of the miniscrews and Periotest® (Siemens, Bensheim, Germany) values were recorded as mobility values at implantation. Post-operative periapical radiographs were taken for all cases.

Almost all of the screws were loaded with 200–250 g and the average placement period of the miniscrews was 15.3 months (cylindrical: 15.2 months/tapered: 15.4 months). The miniscrews were checked after implantation to determine whether they were a success or failure. Success of miniscrews was defined as inserted miniscrews that were maintained for over 6 months. Failed miniscrews included screws that either loosened, so no traction could be applied, or dislodged from the alveolar bone. The patient’s age, gender, working dates, miniscrew design, and insertion sites were recorded.

**Statistical analysis**

All measurements were statistically evaluated using an independent two-sample t-test to determine any difference in the initial and removal torques, PTV and success rates between the cylindrical and tapered miniscrews. A chi-square analysis was used to analyze the relationship between the success rate and miniscrew design, categories of insertion torques and PTV, and the success rates between operators. Logistic regression analyses were employed to test the association between success rate and initial torque, mobility, jaw of placement, age, gender, side of placement, design, and site of placement. Pearson correlation analysis was used to detect any correlations between insertion and removal torques and PTVs. A P < 0.05 was considered statistically significant. All statistical analyses were performed using SPSS (version 18.0, SPSS, Chicago, Illinois).

**Results**

There was no significant difference in success rates among the three operators (P = 0.538). Overall success rates were 82.9 and 80.3 per cent for the tapered and cylindrical miniscrews, respectively. There was no significant difference in the success rates between the cylindrical and tapered miniscrews (Table 1).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Success rate (%)</th>
<th>Success/total miniscrews (N)</th>
<th>P (chi-square or Fisher exact)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>77</td>
<td>57/74</td>
<td>0.228</td>
</tr>
<tr>
<td>Female</td>
<td>83.7</td>
<td>128/153</td>
<td></td>
</tr>
<tr>
<td>Site of placement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxilla</td>
<td>79.1</td>
<td>87/110</td>
<td>0.365</td>
</tr>
<tr>
<td>Mandible</td>
<td>83.8</td>
<td>98/117</td>
<td></td>
</tr>
<tr>
<td>Jaw of placement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>78.5</td>
<td>84/107</td>
<td>0.273</td>
</tr>
<tr>
<td>Left</td>
<td>84.2</td>
<td>101/120</td>
<td></td>
</tr>
<tr>
<td>Site of placement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incisor to PM1</td>
<td>81.8</td>
<td>18/22</td>
<td>0.011*</td>
</tr>
<tr>
<td>PM1 to M1</td>
<td>85</td>
<td>147/173</td>
<td></td>
</tr>
<tr>
<td>M1 to M2</td>
<td>62.5</td>
<td>20/32</td>
<td></td>
</tr>
</tbody>
</table>

PM1, first premolar; M1, first molar; M2, second molar. *Significance at the 0.05 level.

Our results indicate that the success rate can be affected by the site of insertion. For instance, the distal area of the first molar had a significantly lower success rate than other sites of insertion (P < 0.05; Table 2). Gender, side of insertion, and jaw had no statistically significant differences in success rate.

On the buccal side of the maxilla, the insertion torque of the tapered miniscrews (8.3 Ncm) was significantly higher than that of the cylindrical miniscrews (6.3 Ncm) (P < 0.05), and the PTV of the tapered miniscrews (−1.9) was statistically significantly lower than that of the cylindrical miniscrews (−0.6) (P < 0.05; Table 3).

On the buccal side of the mandible, the insertion torque of the tapered miniscrews (9.2 Ncm) was higher than the cylindrical miniscrews (7.8 Ncm), but this finding was not statistically significant (P > 0.05). Furthermore, the PTVs of the tapered (−0.6) and cylindrical miniscrews (1.7) were not significantly different (P > 0.05; Table 3).

The removal torque values (cylindrical screws on maxilla: 3.9 Ncm, tapered screws on maxilla: 3.9 Ncm, cylindrical screws on mandible: 3.9 Ncm, tapered screws on mandible: 4.1 Ncm) and PTV values (cylindrical screws on maxilla: 3.8, tapered screws on maxilla: 3.8, cylindrical screws on mandible: 7.8, tapered screws on mandible: 5.2) showed no significant differences between the tapered and cylindrical miniscrews in the upper and lower buccal areas (Table 3).

Furthermore, on the buccal side of the maxilla, the insertion torque values of the success group (7.4 Ncm) were similar to that of the failure group (7.1 Ncm) (Supplementary Table 1, available online). There was no significant difference in insertion torque values between the success group (8.3 Ncm) and failure group (9.2 Ncm) on the buccal side of the mandible. The PTVs showed no significant difference between the success and failure groups in the upper and lower buccal areas as well (Supplementary Table 1, available online).

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Table 1  Success rates of two different miniscrew designs for the maxilla and mandible.

<table>
<thead>
<tr>
<th></th>
<th>Cylindrical</th>
<th>Tapered</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxilla</td>
<td>78.2% (43/55)</td>
<td>80.0% (44/55)</td>
<td>0.815</td>
</tr>
<tr>
<td>Mandible</td>
<td>82.1% (55/67)</td>
<td>86.0% (43/50)</td>
<td>0.570</td>
</tr>
<tr>
<td>Total</td>
<td>80.3% (98/122)</td>
<td>82.9% (87/105)</td>
<td>0.625</td>
</tr>
</tbody>
</table>
Table 3  Peak insertion and removal torque values (in Ncm) and Periotest values.

<table>
<thead>
<tr>
<th></th>
<th>Insertion</th>
<th></th>
<th>Removal</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Torque value</td>
<td>Periotest value</td>
<td>Torque value</td>
<td>Periotest value</td>
</tr>
<tr>
<td></td>
<td>Cylindrical</td>
<td>Tapered</td>
<td>P</td>
<td>Cylindrical</td>
</tr>
<tr>
<td>Maxilla</td>
<td>6.3 ± 2.8</td>
<td>8.3 ± 3.7</td>
<td>0.010*</td>
<td>-0.6 ± 5.0</td>
</tr>
<tr>
<td>Mandible</td>
<td>7.8 ± 3.5</td>
<td>9.2 ± 4.0</td>
<td>0.560</td>
<td>1.7 ± 4.6</td>
</tr>
</tbody>
</table>

*Significance at the 0.05 level.

Discussion

In this study, the tapered miniscrews had higher average insertion torque values (Mx. tapered: 8.3 Ncm, cylindrical: 6.3 Ncm, Mn. tapered: 9.7 Ncm, cylindrical: 7.8 Ncm) than the cylindrical miniscrews in the maxilla. These results are in accordance with those of in vitro studies using synthetic bone (Lim et al., 2008b; Python et al., 2011). However, the measured torque values differed from existing studies possibly because of differences in bone quality and characteristics (Cha et al., 2010a).

Cortical bone in the mandibular buccal area is thicker than in the maxillary buccal area (Hu et al., 2009; Farnsworth et al., 2011) and insertion torque values were expected to be higher in the mandible (Homolka et al., 2002; Cha et al., 2010a). In this study, miniscrews placed in the mandible had higher insertion torque values than in the maxilla, but the difference was not significant. Furthermore, in the mandible, insertion torque values for the two designs differed less when compared to the maxilla. It is possible that our study may have been affected by the difference in placement depths of the miniscrews or physiological limits that were perceived as torque limits during implantation. Placement depth of a miniscrew can be affected by the surrounding soft tissues (Meredith, 1998). Hu et al. (2009) reported the attached gingiva in the maxillary premolar and molar areas to be 2.4 and 3.5 mm, respectively. The width of the attached gingiva in the mandibular premolar area was 1.4 mm, while in the mandibular molar area, the width was 2.3 mm. The zone of attached gingiva in the mandibular premolar area was narrow, making it difficult to ensure placement within the zone, and therefore preventing complete implantation of the miniscrews in the mandible. In particular, due to the increasing diameter of tapered miniscrews towards the head, insertion torque can be lower if the threads are not completely buried.

Suzuki and Suzuki (2011) clinically evaluated the design and stability of miniscrews and reported that tapered miniscrews had higher insertion torque values than cylindrical miniscrews. While this report corresponds to the results of our study, the measured values of insertion torque values (Mx. self-drilling tapered: 12.1 Ncm, predrilling cylindrical: 7.2 Ncm; Mn. self-drilling tapered: 15.7 Ncm, predrilling cylindrical: 12.1 Ncm) were different from values measured in our study. However, objective comparison between the two studies is difficult because different insertion techniques were used for each screw type.

Existing studies regarding insertion torque report that stability is low when insertion torque values are too low or too high. Motoyoshi et al. (2006) reported that miniscrews with insertion torque values in the range of 5–10 Ncm had greater stability for a variety of reasons. Firstly, greater insertion torque of a miniscrew can generate excessive stress surrounding the dental implant threads. If this stress reaches a high level, necrosis and local ischaemia of the bone at the implant–tissue interface can result. Secondly, very high insertion torque can also generate high levels of stress, resulting in degeneration of the bone at the implant–tissue interface, and as a result, bone regeneration surrounding the implant thread may be aggravated (Meredith, 1998). In our investigation, the mid range torque values (insertion torque: 3–11 Ncm) demonstrated a higher success rate than higher or lower values in the maxilla, but this was not significant (Supplementary Table 1, available online). We concluded 1.5 mm diameter miniscrews do not result in excessive insertion torque, which can lead to high levels of stress in the buccal alveolar area. Furthermore, the success
rate in this study affected lower insertion torque more than higher insertion torque.

The removal torque values in the maxilla were 3.9 Ncm for both the cylindrical and tapered miniscrews. In the mandible, these values were measured at 3.9 Ncm for cylindrical miniscrews and 4.1 Ncm for tapered miniscrews. The respective types of miniscrews exhibited similar removal torque values, while the maxilla and mandible also demonstrated similar average values for removal torque. This suggests that the removal torque has no correlation with insertion torque.

Pithon et al. (2011) used mini-pigs in their study and reported that the tapered miniscrews had greater removal torque than cylindrical miniscrews. However, the study differs from ours because the screws were placed in the ribs of the mini-pigs and this does not completely reproduce the conditions of the clinical situation.

Suzuki and Suzuki (2011) reported that the removal torque values were greater than the insertion torque values for tapered and cylindrical miniscrews. These results are contrary to the findings of this study. Generally, stress resulting from bone decompaction generated during insertion decreases as time passes. Removal torque continues to decrease until complete osseointegration occurs. Motoyoshi et al. (2010) found that removal torque was lower in comparison to insertion torque. In an animal experiment using beagle dogs, tapered and cylindrical miniscrews were removed after 3 and 12 weeks (Cha et al., 2010b). The removal torque of the tapered miniscrew was significantly higher than that of the cylindrical miniscrew in the 3 week group, while removal torque for both types had similar values in the 12 week group (4.2 and 3 Ncm for the tapered and cylindrical miniscrews, respectively). Considering the average placement period of 15.3 months in this study, it was noted that removal torque values became similar between the two types when miniscrews placed in the mouth were maintained over a long period of time. However, an increase in removal torque because of potential osseointegration (Suzuki and Suzuki, 2011) could not be confirmed.

In this study, PTVs of the tapered miniscrews (upper, −1.9; lower, −0.6) were lower than those of the cylindrical miniscrews (upper, −0.6; lower, 1.7), with a significant difference in the maxilla (P < 0.05). The PTVs have been used to evaluate mini-implant stability, and PTVs at insertion have been reported to be significantly correlated with insertion torque, especially in the mandible (Cha et al., 2010c). A previous animal study reported that PTVs were significantly different between tapered and cylindrical miniscrews (Cha et al., 2010a). Pearson correlation suggests that PTVs measured at insertion and removal were correlated in the maxilla (Supplementary Table 4, available online).

The success rate of 81.5 per cent reported here is relatively low when compared to previous investigations. For instance, success rates of 83.9 per cent (1.5 mm diameter) and 85 per cent (2.3 mm diameter) were reported by Miyawaki et al. (2003). Meanwhile, Meredith (1998) reported a miniscrew success rate of 83.8 per cent and Suzuki and Suzuki (2011) reported a success rate over 90 per cent. Our study may have produced a success rate that differs from other reports for a number of reasons. Firstly, some studies incorporated the use of a miniscrew guide during implantation, which can affect the success rate. However, it is not easy to use a miniscrew guide on all patients in a clinical environment. Secondly, operator proficiency in miniscrew placement can influence success rates.

The failure group did not show a significant difference in insertion torque values in the mandible and it is likely that the proximity of the implant to the root of the adjacent teeth may have lead to failure (Asscherickx et al., 2008; Chen et al., 2008). After miniscrew placement, post-operative periapical radiographs were taken for all cases and most of the failed screws were very close to roots radiographically.

Every effort was made to ensure objectivity in this prospective clinical trial. Different types of screws were placed on the left and right sides in the arch randomly, since we considered that the quality of alveolar bone and the thickness of cortical bone differ for each patient, position of the screw, and gender. Future studies further examining miniscrews and the relationship between insertion torque and mobility will help to give us a better understanding of how to maximize and maintain initial stability.

Conclusion

To evaluate the clinical efficiency of tapered and cylindrical miniscrews, 105 tapered and 122 cylindrical self-drilling miniscrews were placed into the maxillary and mandibular buccal alveolar areas of 132 patients (43 males and 89 females) who were over 16 years old.

1. The insertion torque of tapered miniscrews was significantly higher than that of cylindrical miniscrews in the maxilla, while the insertion PTV of the tapered miniscrews was statistically lower than that of cylindrical miniscrews in the maxilla.
2. The removal torque and PTVs of the two types of miniscrews were similar in the maxilla and mandible.
3. Although the tapered design of miniscrews affected the initial stability, the long-term stability and success rates (Table 1) of tapered and cylindrical miniscrews were similar and there was no significant difference in success rates according to gender, jaw, and side of insertion.
4. However, the distal area of the first molar had significantly lower success rates than other sites of insertion (P < 0.01).
5. Stability and success rate of miniscrews can be affected by various factors such as insertion torque, individual anatomical variation, and insertion site.

Supplementary material

Supplementary material is available at European Journal of Orthodontics online.
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Institute of Craniofacial Deformity, 2011.

**References**


Lim S A, Cha J Y, Hwang C J 2008b Insertion torque of orthodontic miniscrews according to changes in shape, diameter and length. The Angle Orthodontist 78: 234–240


