ABSTRACT

Objectives: To investigate the performance of microimplants incorporating a newly designed asymmetric thread.

Materials and Methods: Three microimplants were compared. The control group comprised microimplants with the original v-shaped thread. The two experimental groups (Taper 1.0 and Taper 1.25) comprised prototype microimplants constructed with the new asymmetric thread; the Taper 1.25 specimens had a 1.25-mm-long and sharper tip, while the Taper 1.0 and control groups had a less sharp 1-mm tip. Two specially designed artificial bone blocks mimicking soft (maxillary) and hard (mandibular) bone were used to evaluate the microimplant insertion characteristics and postinsertion lateral stability. The peak insertion torque, insertion time, Periotest value (PTV), and torsional strength were measured. Then the microimplants were evaluated clinically over a 3-month period.

Results: Significant differences in peak insertion torque, insertion time, and PTV were observed and favored the experimental groups. Although statistically insignificant, the clinical success rate was also higher in the Taper 1.25 experimental group than in the control group (87.2% vs 75.6%).

Conclusions: The better performances of the experimental microimplant, under both laboratory and clinical conditions (although statistically insignificant in the latter), demonstrate the superiority of the new asymmetric thread. (Angle Orthod. 2015;85:585–590.)

KEY WORDS: Orthodontic microimplant; Asymmetric thread; Lab test; Clinical test

INTRODUCTION

The thread is a key part of the orthodontic microimplant.1–3 Microimplants are anchored in bone by mechanical fit (or press-fit), and the fit quality and stability are largely determined by the thread. Important parameters, such as the implant body surface area, cross-sectional area, and volume—factors determining the insertion torque, stability, and stress—are closely related to the thread size and profile.4,5

The thread may be more important in small-diameter microimplants; because small microimplants can lose stability more easily6,7 and are more prone to fracture during insertion or removal, the appropriateness of their design, especially the thread, is likely to be more important than in the case of large ones. Large microimplants, although inherently more stable and stronger, should not be considered a first-line option in the treatment. Given the narrow width of interdental spaces, the most common microimplant placement sites, small ones are beneficial in that they are less invasive and less likely to cause tooth root injury. Therefore, it would be logical to improve the performance of small microimplants by strengthening their advantages and reducing their disadvantages. Improvement or optimization of the thread might be an effective approach.

In this study, in order to investigate the performance of a new asymmetric thread designed for the small-diameter (1.4-mm) microimplant shown in Figure 1, we fabricated prototype experimental microimplants and tested them under laboratory and clinical conditions.
MATERIALS AND METHODS

Three microimplant groups were tested. The control group comprised the original Absoanchor SH1413-07 model (Dentos Inc, Daegu, South Korea). The two experimental groups (Taper 1.0 and Taper 1.25) comprised the experimental microimplants with the new asymmetric thread. The shape and detailed dimensions are shown in Figure 1.

In the Taper 1.0 specimens, only the thread was altered; all other geometric parameters were identical to those of the control microimplant. In addition to the asymmetric thread, the Taper 1.25 specimens had a slightly longer, and as such, sharper, tip than that used in the other two groups (1.25 mm vs 1.0 mm). The Taper 1.25 group was included in this study because of the superior penetration performance of the 1.25-mm tip (combined with the asymmetric thread) in preliminary tests.

Laboratory Test

The (1) insertion torque and insertion time, (2) postinsertion lateral stability, and (3) mechanical strength were measured in all three implant groups.

Insertion Torque and Insertion Time

The microimplants were inserted into two double-layer artificial bone blocks (Sawbones, Pacific Research Laboratories Inc, Vashon, Wash; Table 1), each measuring 180 mm (length) × 130 mm (width) × 40 mm (thickness). The first block mimicked soft bone and had a 1-mm top layer with a 40-pcf density and a 39-mm base layer with a 10-pcf density. The second block mimicked hard bone and had a 3-mm top layer (50 pcf) and a 37-mm base layer (30 pcf).

Each microimplant group comprised 30 specimens; each group was further divided into two subgroups (15 specimens each), which were inserted into the soft bone or the hard bone. Without pre-drilling, one orthodontist inserted all microimplants perpendicularly into the bone blocks at 30 rpm using a surgical engine (Elcomed SA200C, W&H, Burmoos, Austria) capable of measuring torque at 1/8-second intervals and 0.01-Ncm accuracy. The torque data recorded during insertion were used to calculate the peak insertion torque (peak torque) and insertion time.

Postinsertion Lateral Stability

Immediately after insertion, the lateral stability was assessed using the Periotest (Siemens AG, Bensheim, Germany). By tapping the microimplant head and recording the contact time, this device generates Periotest values (PTVs) between -8 and +50; a higher PTV indicates greater mobility or lower stability.9 The hand piece was held perpendicular to the long axis of the microimplant with the tip approximately 2 mm away from the implant head. Three readings were taken for each implant and averaged.

Mechanical Strength

A total of 50 specimens were used to assess the effect of thread profile on the torsional strength of the microimplant body (25 each from the control and Taper 1.0 groups). The Taper 1.25 group was excluded because the threaded bodies of the two experimental groups were nearly identical.

The threaded body was gripped firmly with a three-way chuck, and torque was applied to the microimplant

Table 1. Material Properties of Artificial Bone Materials (Poisson Ratio = 0.3)

<table>
<thead>
<tr>
<th>Density pcf (g/cc)</th>
<th>Compressive</th>
<th>Tensile</th>
<th>Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strength</td>
<td>Modulus</td>
<td>Strength</td>
</tr>
<tr>
<td>10 (0.16)</td>
<td>2.2</td>
<td>58</td>
<td>2.1</td>
</tr>
<tr>
<td>40 (0.64)</td>
<td>31</td>
<td>759</td>
<td>19</td>
</tr>
<tr>
<td>30 (0.38)</td>
<td>18</td>
<td>445</td>
<td>12</td>
</tr>
<tr>
<td>50 (0.80)</td>
<td>48</td>
<td>1148</td>
<td>27</td>
</tr>
</tbody>
</table>

Figure 1. The shape and detailed dimensions of the control group and two experimental group microimplants.
head until fracture using the same engine from the insertion test. The gripping length was carefully controlled to generate the fracture between the topmost and second threads.

**Clinical Test**

The clinical performance was evaluated in the control and Taper 1.25 groups, which performed better overall than the Taper 1.0 group in laboratory tests. A total of 73 patients (mean age: 23.55 years, standard deviation [SD]: 4.26 years) who visited the orthodontic department of MIR Dental Hospital (Daegu, South Korea) participated in this study. After obtaining the ethical committee approval of MIR Dental Hospital, specimens from each group were placed in the right or left jaw between the second premolar and the first molar (in both the maxilla and mandible) using a split-mouth design. Among the participants, 37 received 74 microimplants (37 from each group) in the maxilla; 23 received 46 implants (23 from each group) in the mandible; and 13 received 52 implants (26 from each group) in both jaws. Each microimplant was inserted at an angle of approximately 30° to the long axis of the adjacent teeth, without pre-drilling except in the case of 12 (six control and six experimental ones) in the mandible. Stability was evaluated at 1, 2, 4, 8, and 12 weeks after the surgery. Any degree of loosening was considered failure, as assessed by a single orthodontist.

**Statistical Analysis**

Using the SPSS program (version 21, IBM Corp, Armonk, NY), the peak insertion torque and insertion time (IT) were compared between the three groups using the analysis of variance and Tukey post hoc tests at $P < .05$. Data normality and homogeneity of variance were assessed using the Shapiro-Wilk and Levene tests. The PTV was analyzed with the nonparametric Kruskal-Wallis test, followed by post hoc testing using the Mann-Whitney $U$-test. The independent $t$-test and Chi-square test analyzed the mechanical (torsional) strength and the clinical performance, respectively.

**RESULTS**

The peak torque, insertion time, and PTV in each microimplant group in both soft and hard bone are listed in Tables 2 and 3, respectively. Significant differences

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**Table 2.** Peak Torque (Torque), Insertion Time (Time), and Periotest Value (PTV) Obtained for Three Microimplant Groups in Soft Bone

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control (N = 15)</th>
<th>Taper 1.0 (N = 15)</th>
<th>Taper 1.25 (N = 15)</th>
<th>Significance</th>
<th>Control vs Taper 1.0</th>
<th>Taper 1.0 vs Taper 1.25</th>
<th>Control vs Taper 1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque*, Ncm</td>
<td>Mean 1.91</td>
<td>2.20</td>
<td>2.21</td>
<td>.000*</td>
<td>.001*</td>
<td>.997</td>
<td>.001*</td>
</tr>
<tr>
<td>SD*</td>
<td>0.24</td>
<td>0.21</td>
<td>0.17</td>
<td></td>
<td></td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Time*, s</td>
<td>Mean 16.93</td>
<td>14.24</td>
<td>13.22</td>
<td>.000*</td>
<td>.000*</td>
<td>.000*</td>
<td>.000*</td>
</tr>
<tr>
<td>SD*</td>
<td>0.24</td>
<td>0.24</td>
<td>0.25</td>
<td></td>
<td></td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>PTV*</td>
<td>Mean 8.73</td>
<td>4.20</td>
<td>4.33</td>
<td>.000*</td>
<td>.000*</td>
<td>.679</td>
<td>.000*</td>
</tr>
<tr>
<td>SD*</td>
<td>2.66</td>
<td>0.94</td>
<td>0.62</td>
<td></td>
<td></td>
<td>0.94</td>
<td>0.62</td>
</tr>
</tbody>
</table>

* One-way analysis of variance with Tukey post hoc test.

* SD indicates standard deviation.

* $P < .05$. 

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**Table 3.** Peak Torque (Torque), Insertion Time (Time), and Periotest Value (PTV) Obtained for Three Microimplant Groups Tested in Hard Bone

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control (N = 15)</th>
<th>Taper 1.0 (N = 15)</th>
<th>Taper 1.25 (N = 15)</th>
<th>Significance</th>
<th>Control vs Taper 1.0</th>
<th>Taper 1.0 vs Taper 1.25</th>
<th>Control vs Taper 1.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque*, Ncm</td>
<td>Mean 9.59</td>
<td>9.31</td>
<td>9.29</td>
<td>.001*</td>
<td>.003*</td>
<td>.970</td>
<td>.001*</td>
</tr>
<tr>
<td>SD*</td>
<td>0.26</td>
<td>0.22</td>
<td>0.17</td>
<td></td>
<td></td>
<td>0.22</td>
<td>0.17</td>
</tr>
<tr>
<td>Time*, s</td>
<td>Mean 19.45</td>
<td>17.23</td>
<td>14.94</td>
<td>.000*</td>
<td>.000*</td>
<td>.000*</td>
<td>.000*</td>
</tr>
<tr>
<td>SD*</td>
<td>0.64</td>
<td>0.57</td>
<td>0.67</td>
<td></td>
<td></td>
<td>0.57</td>
<td>0.67</td>
</tr>
<tr>
<td>PTV*</td>
<td>Mean 4.60</td>
<td>4.53</td>
<td>4.40</td>
<td>.592</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>SD*</td>
<td>0.51</td>
<td>0.52</td>
<td>0.74</td>
<td></td>
<td></td>
<td>0.52</td>
<td>0.74</td>
</tr>
</tbody>
</table>

* One-way analysis of variance with Tukey post hoc test.

* Kruskal-Wallis test.

* SD indicates standard deviation.

* $P < .05$. 

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(P < .05) were observed in the peak torque, insertion time, and PTV values in soft bone (Table 2). The mean peak torque of the control group (1.91 Ncm) was lower than that observed in both experimental groups, but the difference between the experimental groups was not statistically significant. The insertion time differed significantly between the three groups, and the Taper 1.25 group had the smallest value. The highest PTV (8.73) was obtained in the control group, indicating that this group was the least stable. The PTV in the two experimental groups, however, showed no significant difference between each other.

There were statistically significant differences in the peak torques obtained in hard bone (Table 3). The control group exhibited the highest value (9.59 Ncm), and the two experimental groups showed no significant difference between each other. As observed in soft bone, the insertion time differed significantly between the three groups—it was smallest in the Taper 1.25 group and largest in the control group. However, there was no significant difference in PTV between the groups.

Table 4 details the mechanical strength test results. The control group had a significantly higher mean strength (18.56 Ncm) than did the Taper 1.0 group (17.38 Ncm).

Clinical results are summarized in Table 5. During the 3-month observation period, the Taper 1.25 had higher success rates in both the maxilla and mandible. Although statistically insignificant, the overall success rate was higher than that observed in the control group (87.2% vs 75.6%).

**DISCUSSION**

The layer thicknesses of the bone blocks were chosen based on previous anatomical studies. Using computed tomography, Ono et al. observed that the average thickness of maxillary cortical bone is approximately 1.2 mm. Kim et al. found similar results in their cadaver study. Others report that the buccal cortical bone in the posterior mandible can be up to 3 mm thick. The bone block densities were carefully selected to allow the soft bone specimen to exhibit slightly softer properties than normal maxillary bone, while the hard bone specimen was slightly harder than the normal mandibular bone. The use of bone blocks mimicking alveolar bone properties in a slightly exaggerated manner can amplify the differences in the insertion performance of the microimplant groups and ease comparison.

Adequate insertion torque is considered an indicator of microimplant stability. Ideally, the insertion torque should be large enough to ensure sufficient primary stability, yet low enough to avoid overcompression of the bone, which can trigger abnormal bone remodeling. Motoyoshi et al. asserted that the peak torque should be 5–10 Ncm for long-term stability of a 1.6-mm-wide and 8-mm-long microimplant. When adjusted for the smaller implants tested in this study (1.4-mm diameter and 7-mm length), this range decreases to 3.3–6.7 Ncm (the torque is proportional to the length and the square of the implant diameter).

Assuming that this adjusted range is ideal, the torque data measured in the three groups were analyzed. The peak torque of the experimental groups in soft bone was significantly higher and closer to the above-mentioned ideal range (3.3–6.7 Ncm) than was observed in the control group (Table 2) and was therefore considered superior. Given the correlation between peak torque and primary stability, this result suggests that the asymmetric thread may enhance the primary stability and implant survival in poor-quality bone.

In contrast, the peak torque values obtained from hard bone were significantly lower in the experimental groups (Table 3), which can be attributed to their sharper asymmetric threads. With the peak torques closer to the ideal range, the experimental groups demonstrated their superiority in dense mandibular bone.
bone as well. Notably, many studies\textsuperscript{19,20} report a lower success rate for microimplants inserted in the mandible. There is no universal consensus on the underlying mechanism, but it has been suggested that excessive insertion torque and the resulting overcompression of the bone may be involved.\textsuperscript{2,21,22}

Large differences were observed in insertion time in both soft and hard bone tests. The Taper 1.25 group had the smallest value, followed by the Taper 1.0 and control groups (Tables 2 and 3). Again, this may be explained by the improved penetration capability of the asymmetric threads with their wider pitch and sharp profile, as well as the longer 1.25-mm tip (Figure 1). A decreased insertion time is advantageous not only for clinicians but also for patients because it decreases intraoperative psychological stress. One risk of the long sharp tip is potential tip fracture during penetration into dense cortical bone. Although not shown presently, the microimplants were examined after the experimental tests using a stereoscopic microscope, and no evidence of damage was observed in any specimen.

The lateral stability test complements the insertion test results and allows evaluation of the reliability of the insertion torque data. For example, a high PTV (high mobility) combined with a high insertion torque indicates that the interfacial bone was substantially damaged during microimplant insertion. High torque in this case does not indicate a high level of primary stability. The peak torque data alone are insufficient to assess primary stability.

The PTV measured between +4 and +9, which revealed that all of the microimplants were sufficiently stable after insertion and that the insertions did not cause excessive damage to the interfacial bone. However, the significantly higher PTV in the soft bone of the control group indicates relatively severe bone damage during insertion. Furthermore, based on the lower PTV and significantly lower peak torque in the experimental groups in hard bone, it can be inferred that these microimplants better preserve the interfacial bone structural integrity during insertion. Collectively, the insertion and lateral stability test results show that the experimental microimplants can enhance primary stability in soft bone, while lowering the risk of bone overcompression in hard bone.

The experimental microimplants had slightly lower torsional strength (Table 4), but this difference was not substantial, and there was a sufficient safety margin. The 17.38-Ncm torsional strength is almost twice the peak torque observed in the hard bone test. Given their ability to reduce the peak torque (Table 3), the true failure risk of the experimental microimplants should be comparable to the risk of the control implants.

The clinical success rate of microimplants reportedly ranges from 57% to 95.3%, with most failures occurring in the first 3 months,\textsuperscript{21,23–26} which was observed in the present 3-month clinical results (Table 5). The higher maxillary success rate than obtained in the mandible is also consistent with previous results.\textsuperscript{19,20} However, unlike the noticeable differences revealed in the laboratory tests, the clinical success rate, although higher in the Taper 1.25 group, was not statistically significant. This may be due to the fact that the normal jaw bones of the patients were less sensitive or more tolerant to the thread differences than the artificial bone blocks with exaggerated properties. Other surgical or host factors may have masked the effect of the implant. Yet the relatively higher clinical success rates obtained with the experimental microimplants in both the maxilla and mandible were in line with the laboratory test results.

**CONCLUSION**

- Within the limitations of the current study, the experimental microimplants incorporating the new asymmetric thread performed better in both laboratory and clinical tests (although the results were statistically insignificant in the latter) and thereby demonstrated the superiority of the new asymmetric thread.

**REFERENCES**


