Influence of pre-drilling diameter on the stability of orthodontic anchoring screws in the mid-palatal area

Yasuki Uchida1), Yasuhiro Namura1), Mizuki Inaba1), Ayaka Osada2), Tasku Charleston-Coad2), Yoshiki Nakamura2), and Mitsuru Motoyoshi1)

1) Department of Orthodontics, and Division of Clinical Research, Dental Research Center, Nihon University School of Dentistry, Tokyo, Japan
2) Department of Oral Structural and Functional Biology, Nihon University Graduate School of Dentistry, Tokyo, Japan

Abstract

Purpose: The aim of this study was to investigate the stability of orthodontic anchor screws (OASs) in the mid-palatal area according to pre-drilling diameter.

Methods: The success rate of 161 OASs (83 patients, ø2.0 mm, 6.0 mm in length) placed in a corresponding area to the mesial and distal borders of the first molar (mesial zone and distal zone) was assessed according to placement location and pre-drilling diameter (1.2 and 1.5 mm). Placement torque values from 73 OASs with a pre-drilling diameter of 1.2 mm were compared between success and failure groups.

Results: The success rates of OASs pre-drilled with ø1.2 and 1.5 mm were 94.5% and 83.0%, respectively (P < 0.05); corresponding rates in the mesial zone were 100.0% and 77.3% (P < 0.005), and those in the distal zone were 89.2% and 88.6%, respectively. Placement torques of OASs pre-drilled with ø1.2 mm in the success and failure groups were 25.9 and 19.2 N·cm, respectively (P < 0.05).

Conclusion: A smaller pre-drilling diameter was associated with a higher success rate of OASs in the mid-palatal area, especially in the mesial zone. When pre-drilling diameter of 1.2 mm was used for ø2.0 mm OAS, greater placement torque was indicative of greater OAS stability.

Keywords: mid-palatal area, orthodontic anchor screw, orthodontic mini-implant, pilot hole, pre-drilling diameter, success rate
pre-drilled and the distal OAS was placed in a reference zone to enable distal contact with the maxillary first molars along the mesiodistal axis. The mesial OAS was then inserted 6.0-9.0 mm mesial to the distal OAS (Figs. 1 and 2). The OAS placement was performed by 2 skilled clinicians (Y.U., M.I.) who each had over 10 years of clinical experience.

Orthodontic force of approximately 2.0-4.0 N was measured using the tension gauge and applied horizontally to each OAS via a palatal attachment (Palatal Lever Arm System; Biodent, Tokyo, Japan; Fig. 3). 1.0-2.0 N (approximately 150 g) was loaded horizontally on each hook of the palatal attachment in both sides, and in total 2.0-4.0 N (approximately 300 g) was distributed and applied to two OASs. After OAS placement, each patient was prescribed an antibiotic for 3 days in order to control infection and received instructions on how to maintain hygiene of the OAS; cleaning with the collutorium for initial 2 weeks, and then brushing by minimal force later. OAS placement was considered to be successful when the OAS endured the application of orthodontic force for ≥6 months without loosening or detachment.

OAS stability according to pre-drilling diameter
The placed OASs were divided into two groups according to pre-drilling diameter: φ1.2 mm (73 OASs in 38 patients [16 OASs in 9 male patients and 57 OASs in 29 female patients], average age, 25.2 ± 8.2 (range, 13.3-55.2) years, placed from Oct. 2016 to Jan. 2019) and φ1.5 mm (88 OASs in 45 patients [29 OASs in 15 male patients and 59 OASs in 30 female patients] average age, 27.3 ± 10.7 [range, 15.0-59.5] years, placed from Jul. 2011 to Sep. 2016; Table 1).

Relationships were evaluated among the placement location (mesial and distal), pre-drilling diameter (1.2 and 1.5 mm), and success rate. Sex differences in the success rate according to pre-drilling diameter were also evaluated.

Relationship between OAS stability and placement torque in φ1.2 mm group
Recording of the maximum placement torque values in mid-palatal area was started in order to monitor excessive placement torque extending to fracture of the OASs pre-drilled with φ1.2 mm from Oct. 2016. The relationship between OAS stability and placement torque was examined in 73 OASs (φ1.2 mm group) placed with the maximum torque in the mid-palatal area. One examiner (M.I.) measured placement torque using a digital torque tester (Newton-1; KTC, Kyoto, Japan). The difference in placement torque between the success and failure groups was determined.

Statistical analysis
Statistical analyses were performed using the SPSS software for Windows (version 23.0; IBM Corp., Armonk, NY, USA). The χ² test or Fisher’s exact test was used to examine differences in success rates according to OAS placement location and pre-drilling diameter. Independent-samples t test was used to examine significant differences in placement torque among the placement location (mesial vs distal). Welch’s t test was also used to investigate significant differences in placement torque between success and failure groups. Shapiro-Wilk test was used to confirm the normality of each group. Differences with P < 0.05 were considered to be significant.

Table 1 Patients of the φ1.2 mm and φ1.5 mm groups

<table>
<thead>
<tr>
<th>Pre-drilling diameter</th>
<th>Sex</th>
<th>n</th>
<th>Age (years)</th>
<th>Age range (years)</th>
<th>No. OASs</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ1.2 mm</td>
<td>Male</td>
<td>9</td>
<td>21.4 ± 1.4</td>
<td>19.2-54.1</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>29</td>
<td>26.0 ± 8.8</td>
<td>13.3-55.2</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>38</td>
<td>25.2 ± 8.2</td>
<td>13.3-55.2</td>
<td>73</td>
</tr>
<tr>
<td>φ1.5 mm</td>
<td>Male</td>
<td>15</td>
<td>26.8 ± 16.1</td>
<td>15.0-59.5</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>30</td>
<td>27.6 ± 6.9</td>
<td>15.3-41.0</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>45</td>
<td>27.3 ± 10.7</td>
<td>15.0-59.5</td>
<td>88</td>
</tr>
</tbody>
</table>
Table 2 Global OAS success rates according to pre-drilling diameter (1.2 vs. 1.5 mm)

<table>
<thead>
<tr>
<th>Pre-drilling Diameter</th>
<th>Sex</th>
<th>n</th>
<th>Success</th>
<th>Failure</th>
<th>Success Rate</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ1.2 mm</td>
<td>Male</td>
<td>16</td>
<td>14</td>
<td>2</td>
<td>87.5%</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>57</td>
<td>55</td>
<td>2</td>
<td>96.5%</td>
<td>0.2069</td>
</tr>
<tr>
<td>φ1.5 mm</td>
<td>Male</td>
<td>29</td>
<td>21</td>
<td>8</td>
<td>72.4%</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>59</td>
<td>52</td>
<td>7</td>
<td>88.1%</td>
<td>0.0775</td>
</tr>
</tbody>
</table>

Note: *P < 0.05; **P < 0.01; NS, not significant

Results

OAS stability according to pre-drilling diameter

The sample power 1-β was calculated from 0.727 to 0.986. Table 2 shows OAS success rates according to pre-drilling diameter. The global success rate was higher in the φ1.2 mm group (94.5%) than in the φ1.5 mm group (83.0%; P < 0.05). Success rates in the mesial and distal zones according to pre-drilling diameter are shown in Table 3. In the mesial zone, the success rate was significantly higher in the φ1.2 mm group (100.0%) than in the φ1.5 mm group (77.3%; P < 0.005). In the distal zone, the success rates in the φ1.2 mm and φ1.5 mm groups were 89.2% and 88.6%, respectively, with no significant difference.

The global success rates in the mesial and distal zones were 87.5% and 88.9%, respectively, with no significant difference (Table 4). Success rates in the φ1.2 mm and φ1.5 mm pre-drilling groups according to placement location are shown in Table 5. In the φ1.2 mm group, the success rate was significantly higher in the mesial zone (100.0%) than in the distal zone (89.2%; P < 0.05). In the φ1.5 mm group, the success rates in the mesial and distal zones were 77.3% and 88.6%, respectively, with no significant difference.

OAS success rates according to sex in each pre-drilling diameter group are shown in Table 6. OAS success rates for male and female patients in the φ1.2 mm group were 87.5% and 96.5%, respectively, with no significant difference. Those for male and female patients in the φ1.5 mm group were 72.4% and 88.1%, respectively, with no significant difference. Thus, no significant sex-related difference was observed.

Relationship between OAS stability and placement torque in the φ1.2 mm group

The sample power 1-β on placement torque was 0.865. Shapiro-Wilk test indicated the normality (P > 0.05) in both success group (P = 0.378) and failure group (P = 0.992). Table 7 shows the OAS placement torques and success rates in the φ1.2 mm group according to placement location. For mesial OASs, the success rate was 100.0% and the mean placement torque indicated the normality (P > 0.05) in both success group (P = 0.378) and failure group (P = 0.992).

Stable power analysis on the success rate and the placement torque to calculate sample power at 0.30 and 0.80, respectively.

University of Düsseldorf, Düsseldorf, Germany) was used to perform the post-hoc power analysis on the success rate and the placement torque to calculate sample power at 0.30 and 0.80, respectively.
Thus, for the mid-palatal area, application of the 62.5% is presumably similar to the thick cortical bone in the mid-palatal area. Furthermore, the high-density synthetic bone used in their study strength and excessive placement torque) corresponds to 62.5% of the OAS provided greater OAS stability.

To increase the primary stability, the OAS placement with pilot holes of 1.5 mm for φ2.0 mm OAS was within this range (69.0-77.0% [20]). The diameter of the pilot hole made before OAS placement was focused on and examined as one of the factors for failure. In the present study, the φ2.0 mm OAS that is one of the screw sizes for placing in the palatal area frequently [18,19] was investigated.

The diameter of the pilot hole is presumed to affect the stability of self-tapping OASs [13,20], but no report has indicated a suitable pre-drilling diameter or placement torque for OAS placement in mid-palatal area. Hung et al. [20] investigated the maximum placement torque and pullout strength of φ1.6 mm OASs with 6.0 mm length in synthetic bone. They demonstrated that self-drilling OASs exhibited excessive placement torque; the use of self-tapping OASs with pilot holes of φ1.0 mm decreased placement torque by 32.0% and pullout strength by only 6.5% in high-density bone. The use of OASs with pilot holes of φ1.4 mm decreased placement torque by 55.0%, whereas pullout strength was decreased by 35.0% [20]. Thus, smaller pilot hole size of OAS was reported to contribute toward the resistance to detachment.

In orthodontic department affiliated with the present study, twist drills of φ1.5 mm have been used for the preparation of pilot holes for tapered OASs of φ2.0 mm and 6.0 mm length based on a previous report by Uemura et al. [21]. They investigated the stability of tapered OASs of φ1.3 mm and 4.0 mm length in male Wistar rats, and reported that the hole diameter should be 69.0-77.0% of the OAS diameter to achieve stability. However, success rate of the OASs pre-drilled with 1.5 mm (placed from Jul. to Sep. 2016) remained lower at 83.0% (Table 2), although the predrilling diameter of 1.5 mm for φ2.0 mm OAS was within this range (69.0-77.0%). To increase the primary stability, the OAS placement with pilot holes of φ1.2 mm and the recording insertion torques to monitor the maximum placement torques were started from Oct. 2016. In the present study, OAS success rates in the mid-palatal area differed significantly between two pre-drilling diameters (Tables 2, 3), indicating that the smaller pilot hole provided greater OAS stability.

Considering the results reported by Hung et al. [20], a φ1.0 mm pilot hole for φ1.6 mm OAS (suitable for controlling the reduction of pullout strength and excessive placement torque) corresponds to 62.5% of the OAS diameter. Furthermore, the high-density synthetic bone used in their study is presumably similar to the thick cortical bone in the mid-palatal area. Thus, for the mid-palatal area, application of the 62.5% ratio to the φ2.0 mm OAS used in the present study yields an optimal pre-drilling diameter of approximately 1.25 mm. Therefore, the results in this study were considered to be consistent with the findings of Hung et al. [20].

The OAS success rate in the φ1.2 mm group tended to be higher in the mesial zone than in the distal zone (Table 5 and 7). CBCT evaluation has shown that mid-palatal bone thickness tends to decrease from anterior to posterior [22,23]. Bone density has been reported to affect OAS primary stability [24], and Moon et al. [25] reported that bone mineral density tended to decrease from anterior to posterior and from medial to lateral. Bourassa et al. [24] investigated OAS stability in the mid-palatal area using human cadaveric palatal bone, and found the greatest primary stability anterior to the second premolars. The difference in the OAS success rate between mesial and distal zones in the φ1.2 mm group in this study is consistent with these findings from previous studies [22-25]. However, there was no significant difference in the φ1.5 mm group according to placement location (Table 5). It was considered that the use of predrilling diameter of 1.5 mm for φ2.0 mm OAS in mid-palatal area could not provide adequate primary stability even in the mesial zone having favorable conditions.

OAS success rates differed significantly between the φ1.2 mm and φ1.5 mm groups in the mesial zone (P < 0.005), but not in the distal zone (Table 3). Thus, although the smaller pre-drilling diameter yielded a higher OAS success rate in the mesial zone, other factors (e.g. thinner palatal bone, lower bone mineral density, thick soft tissue [22-24] or the transverse palatine suture) might affect OAS stability more strongly in the distal zone. To improve the OAS success rate in the distal zone, placement in thicker soft tissue and immature sutures should be avoided; potential placement zones with adequate bone thickness should be determined using CBCT imaging [24]. Concerning the sex difference in the φ1.5 mm group, previous studies revealed no significant sex-related difference in the OAS success rate in the mid-palatal area [5,15,17], findings from the present study were similar (Table 6).

As OAS placement using a pre-drilling diameter of 1.2 mm entails a risk of cortical bone or OAS fracture due to excessive placement torque, placement torque was monitored routinely for all OASs placed in φ1.2 mm pre-drilled holes in this study. Additionally, clinicians should confirm the bone condition before placement by diagnostic imaging (e.g. CBCT) and should coordinate the pre-drilling diameter in accordance with the bone condition, in case of excessive cortical bone thickness or insufficient bone thickness. The monitoring of placement torque of this study revealed that the mean value in φ1.2 mm group did not differ significantly between the mesial and distal zones (Table 7). Concerning the relationship between the placement torque value and the success rate of tapered OAS, Suzuki et al. [8] investigated the insertion torque using the OASs of 1.2 mm diameter in the buccal interproximal areas, and stated that OASs placed with insertion torque greater than 10 N cm had a tendency for a lower success rate. However, they also concluded that the ideal torque might differ according to the type of OASs. Regarding the OAS in diameter of 2.0 mm, in this study, mean placement torque differed significantly between the success (25.9 ± 5.4 N cm) and failure groups (19.2 ± 3.1 N cm, P < 0.05, Fig. 4), with greater torque indicative of greater stability of OASs placed in the mid-palatal area. According to an in vitro study by Wilmes et al. [26], regarding OASs of φ2.0 mm, the maximum torque at the time of OAS fracture was indicated as 49.2 ± 7.5 N cm (Min: 34.4 N cm, Max: 64.1 N cm). This torque value that caused the OAS fracture should be considered during insertion and the placement torque should be kept away from this range. Therefore, desirable placement torque was likely to be within the range from 20.0 to 30.0 N cm for OASs of φ2.0 mm in the mid-palatal area.

In this study, the stability of OASs in the mid-palatal area according to pre-drilling diameter, and the relationship between the success rate and placement torque were investigated, on the hypothesis that smaller pre-drilling diameter and greater placement torque are associated with a higher stability of OASs in the mid-palatal area. Ultimately, the results in this study were concordant with that hypothesis.

In conclusion, the success rate of OASs pre-drilled with φ1.2 mm was higher than that of OASs pre-drilled with φ1.5 mm group (P < 0.05). This tendency was observed especially in the reference zone to mesial contact of the maxillary first molars (P < 0.005). The ratio (pilot hole/OAS diameter) of approximately 60.0%, that was equivalent to the pilot hole of φ1.2 mm for tapered OASs of φ2.0 mm, was likely to be suitable for OAS placement in mid-palatal area. Concerning the OASs pre-drilled with φ1.2 mm, the
mean placement torque was significantly greater in the success group (25.9 N·cm) than in the failure group (19.2 N·cm; \( P < 0.05 \)).

Acknowledgments

The authors would like to thank “Textcheck Inc.” for language support.

Conflict of interest

The authors declare that they have no conflicts of interest.

References