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Comparison between the oblique and vertical interradicular placement of the mini-screw in the buccal alveolar bone between the maxillary second premolar and first molar using CAD technology

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Abstract

Introduction: The purpose of the study was to compare the oblique with the vertical buccal interradicular placement of the mini-screw between the maxillary second premolar and first molar in terms of the safety of placement and the potential maximum distalization of the maxillary dentition. **Materials and methods:** Using 22-patient maxillary cone beam computed tomography (CBCT) scans and computer-aided design (CAD) technology, a virtual screw was inserted into the buccal process at the angle of 30 degrees (30^{o} group) or 90 degrees (90^{o} group) to the long axis of the upper second premolar. The space between the

virtual screw and adjacent roots, the length of the virtual screw in the bone and the maximum distalization of the maxillary dentition were measured. **Results:** The means of space were around 1.52 mm in the 30^{o} group and 1.16 mm in the 90^{o}group with significant difference (P< 0.001). The means of the maximum distalization were 2.85 mm in the 30^{o} group and 1.24 mm in the 90^{o} group with significant difference (P< 0.001). The means of the virtual screw length in the bone were 5.60 mm and 5.77mm in 30^{o} and 90^{o} groups respectively without significant difference (P>0.05). **Conclusions:** The oblique (30°) placement of mini-screw was much safer and had more potential for distalization of the maxillary dentition compared with the vertical (90°) placement.

Keywords: comparison, oblique, vertical, buccal interradicular, mini-screw placement, CAD

The utilization of temporary anchorage devices (TAD)like miniplates and mini-screws has been expanding the scope of orthodontic therapy and improving the quality of orthodontic treatment. Unlike miniplates, the mini-screw placement does not require mucus membrane flap and is less invasive. Therefore, more and more practitioners are embracing mini-screws in their practice. Furthermore, the mini-screw can be placed in interradicular bone as skeletal anchorage. One of recommended sites for interradicular placement of mini-screws is between the maxillary second premolar and first molar in the buccal alveolar bone [1,2]. However, the interradicular space between the maxillary second premolar and the first molar is only 2.40 to 3.35 mm [1]. Some researchers choose to place mini-screws into this buccal interradicular bone at an oblique angle of 20 to 40 degrees to the long axis of the proximal tooth to avoid injury to adjacent roots [3,4]. The potential risks of this placement method are soft tissue irritation and slippage of the mini-screw. Other researchers prefer to place mini-screws at an almost vertical angle to the long axis of the proximal tooth [5,6].

Interradicular placement of mini-screws in the maxillary posterior region might cause trauma to the periodontal ligament or the dental root, slippage of mini-screw and perforation of the maxillary sinuses [7]. The overall failure rate of mini-screws is around 13.5% [8,9]. The 12-month survival rates of the mini-screw placed in buccal interradicular area from second premolars to second molars is 75.3% [10]. The proximity of the mini-screw to the root is a major risk factor for the failure of mini-screw anchorage [11]. Therefore, some researchers

use the mini-screws with small diameter of 1.3 mm [11,12]. Due to concerns regarding primary stability, other researchers choose bigger size mini-screws such as 1.5 or 1.6 mm in diameter [5,6]. One study manifests that the mini-screws placed within 1.4 mm of the root have significantly higher failure rates in the buccal posterior interradicular bone of maxilla [12]. On the other hand, one animal experiment shows that resorption can happen on the root surface only when the distance between the implant and the root surface is less than 1 mm [13]. One clinical research demonstrates that the failure rates of mini-implants with and without root contact are 20.7% and 1.7%, respectively, and the average root proximity ranges from 0.6 to 1 mm [14]. Another animal study reveals that the distance between the screw and the root can not be identified as a risk factor for failure as long as no contact is present between the root and the mini-screw [15].

The purpose of our study was to compare the oblique with the vertical buccal interradicular placement of the mini-screw between the maxillary second premolar and the first molar in terms of the safety of placement and the maximum distance of distalization in the maxillary dentition.

Our null hypothesis was that there was no significant difference between the two different mini-screw placement methods.

Materials and methods

This research was approved by the Regional Ethical Review Board. The sample of our research consisted of maxillary CBCT scans of 22 patients (12 men, 10 women; mean age 25.3 years; range 12–46 years) collected from our office CBCT file according to the following exclusion criteria: (1) incomplete eruption, ectopic eruption, and obvious rotation of crowns of the maxillary second premolar and first molar, (2) radiographic sign of worse than mild alveolar bone resorption at the sites of the maxillary second premolar and first molar, (3) crowding or spacing between the maxillary second premolar and first molar.

A craniofacial CBCT (Kodak Dental Imaging Software 3D module v 2.4, protocol 80.25 x 80.25 x 50.55 mm @120.0 KV 8.0 mA 15.0 s for kids or 20.0 s for adults) was scanned at the patient natural head position. The CBCT scans were uploaded on CoDiagnostiX software (Dental Wings GmbH, Germany), a virtual mini-screw (1.5 mm x 8.0 mm) was chosen to place in buccal interradicular bone between the maxillary second premolar and the first molar on both sides. With the vertical placement, the virtual mini-screw was placed 4-6 mm apical

to the alveolar crest and at an angle of 90 degrees to the long axis of the adjacent maxillary second premolar (90° group). With the oblique placement, the virtual mini-screw was placed in the cortical and cancellous bone from around the joint between crest and buccal aspects of alveolar bone at an angle of 30 degrees to the long axis of the adjacent maxillary second premolar (30° group). The average nearest space between the virtual mini-screw and adjacent roots, the length of the virtual mini-screw in the alveolar bone, and the potential maximum distalization of the maxillary dentition were measured by one author on the condition that the virtual mini-screw was placed at least 5.0 mm in the bone but without perforation of the maxillary sinus. Each measurement was performed twice and the average was adopted (Figure 1).

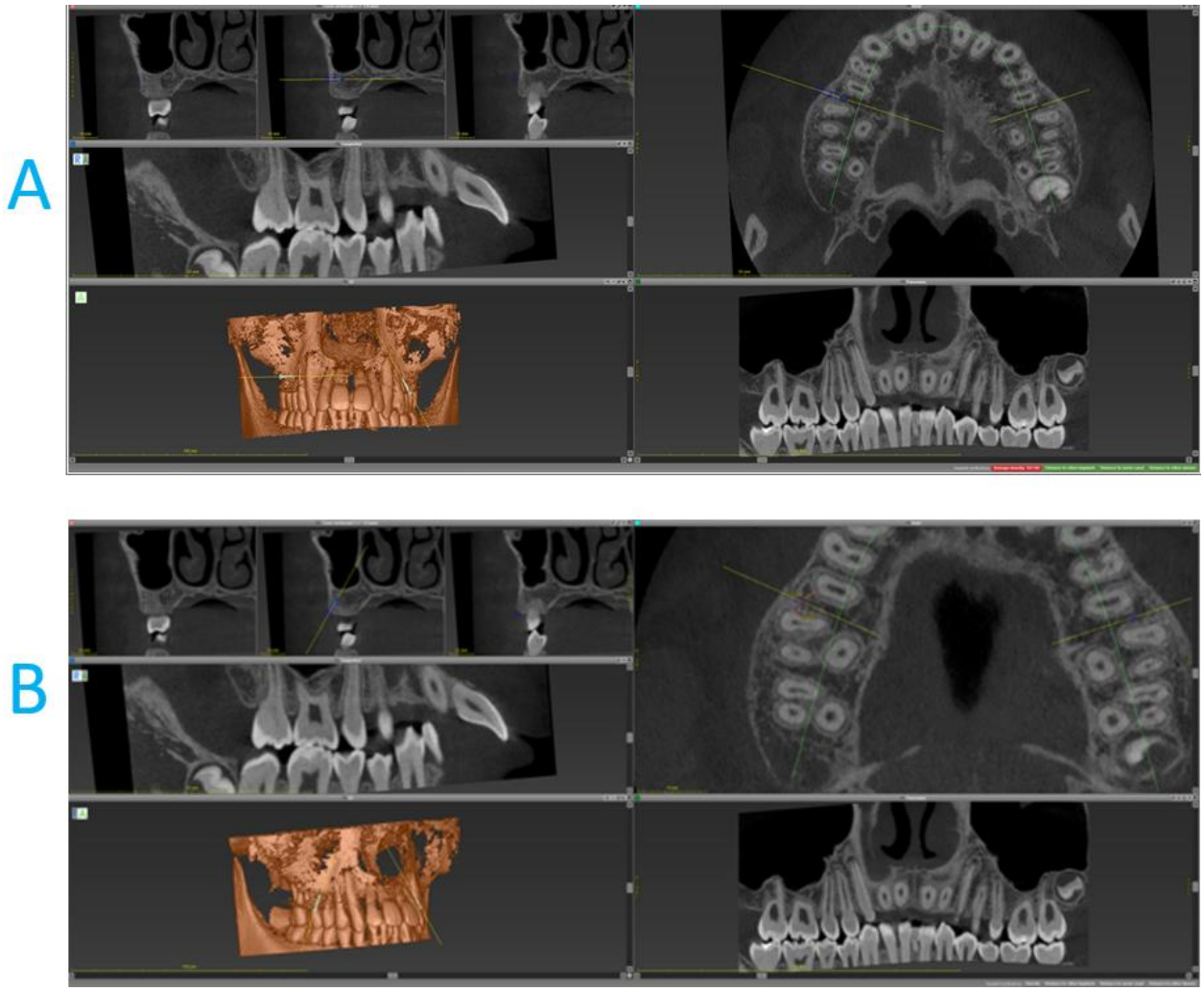

Figure 1. the vertical (90°) placement of the virtual mini-screw (A-right side) and the oblique (30°) placement of the virtual mini-screw (B-right side).

When measuring the potential maximum distalization of the maxillary dentition, the initial position of the virtual mini-screw was positioned at 1.0 mm mesial to the mesiobuccal root of the maxillary first molar. With the help of CoDiagnostic software, a panoramic curve was set as the curvature of the arch form, the distance of the virtual mini-screw movement was set as 0.5 mm increment, the virtual mini-screw was then moved mesially along the panoramic curve. The maximum distalization was defined as the distance from the initial position of the virtual mini-screw to the final point with less than 0.5 mm space before touching the root of the maxillary second premolar (Figures 2 and 3). For safety reasons, 0.5 mm was deducted from the final distalization distance in our results. A paired t test ($t = x_{diff} / (s_{diff}/\sqrt{n})$ was used to compare the means of two groups.

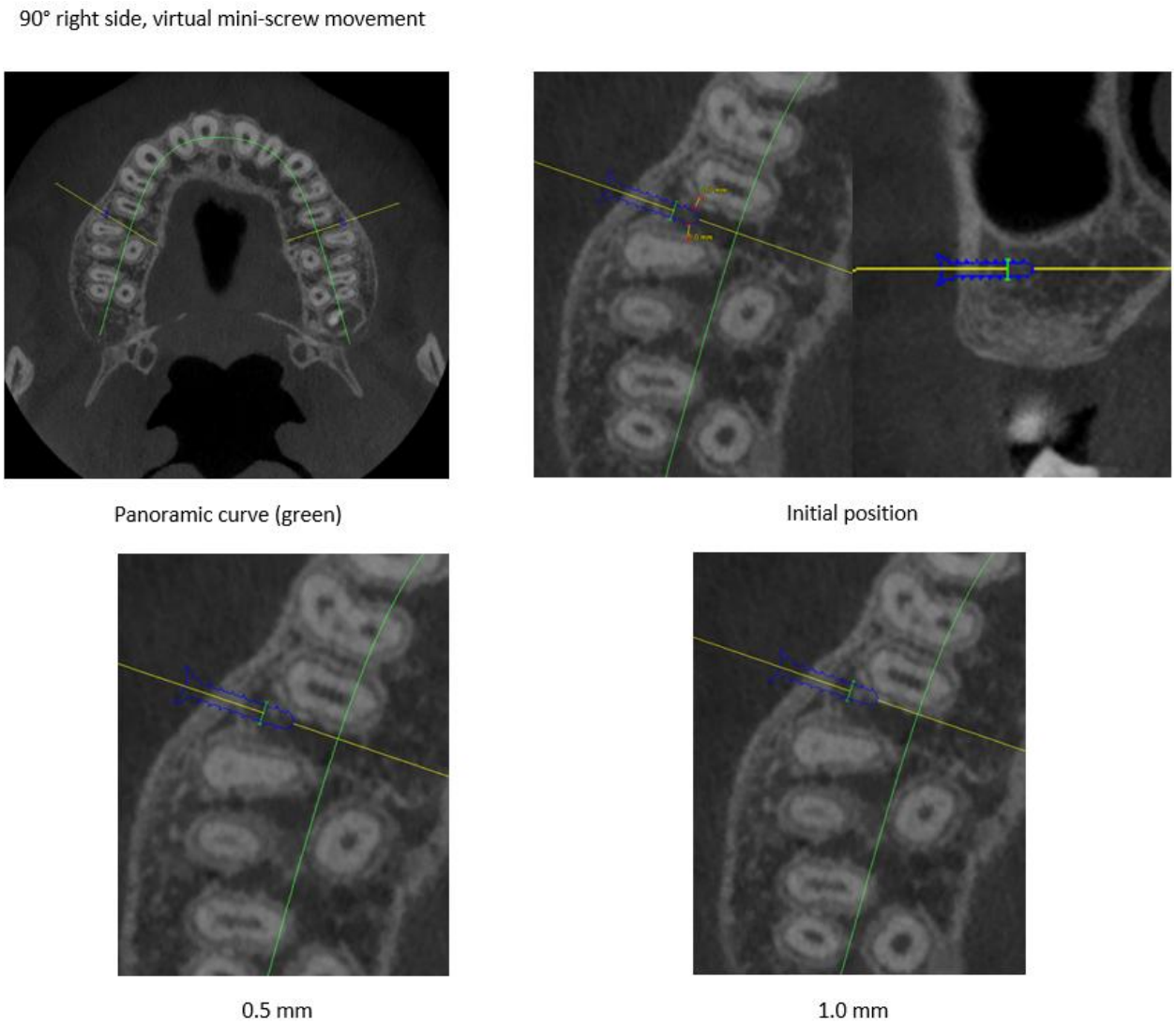

Figure 2. the virtual mini-screw moving mesially along the panoramic curve in increments of 0.5 mm on the right side in 90° placement.

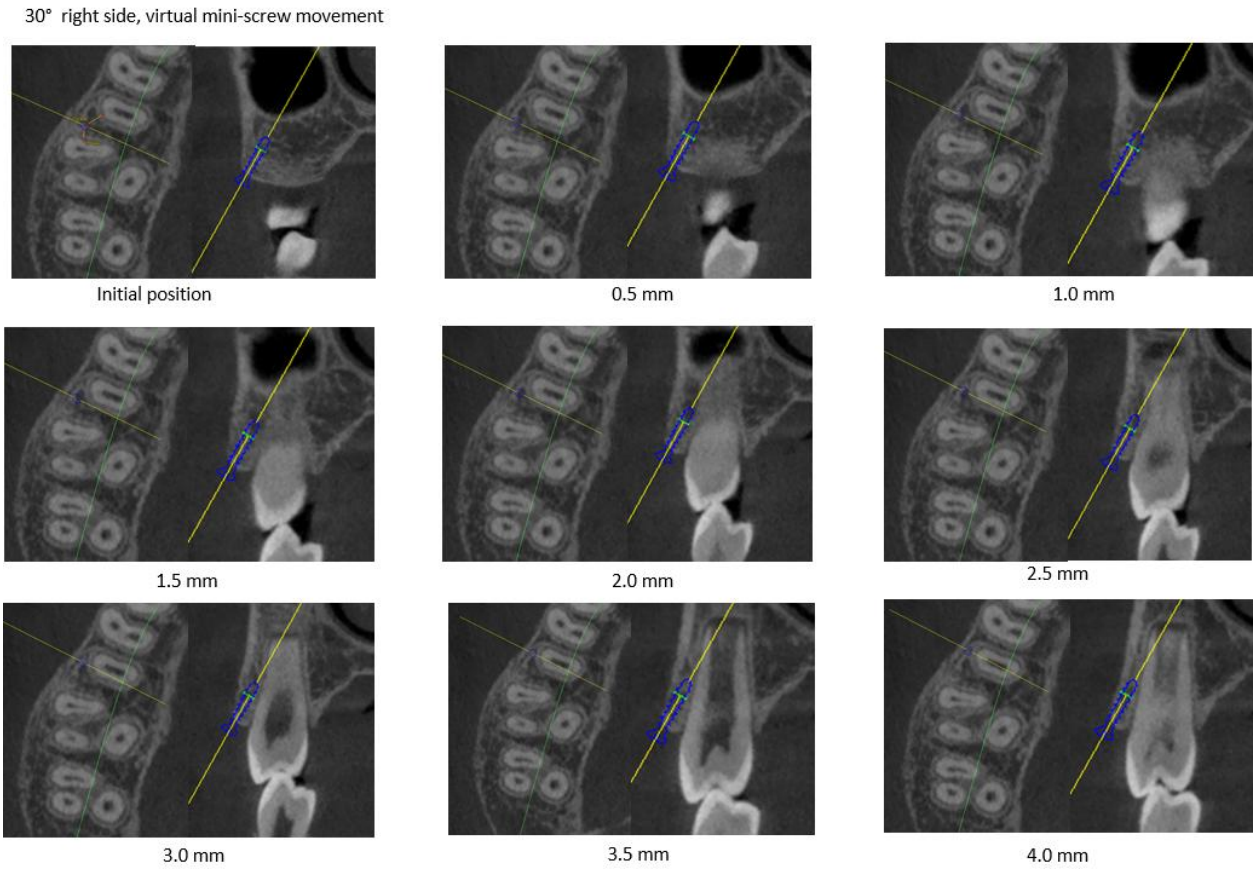

Figure 3. the virtual mini-screw moving mesially along the panoramic curve in increments of 0.5 mm on the right side in 30° placement.

Results

The average nearest space

The means of average nearest spaces between the virtual mini-screw and adjacent roots were 1.51 mm (SD = 0.41) on the left side and 1.53 mm (SD =0.37) on the right side in the 30° group and 1.11 mm (SD =0.44) on the left side and 1.21 mm (SD =0.35) on the right side in the 90°group (Tables 1 and 2). The differences of two groups on both sides were extremely statistically significant with the P value < 0.001.

Table 1. Space between screw and root and length of screw in the bone on the maxillary left side

Patients	30° angulation		90° angulation	
NO	space(mm)	length(mm)	space(mm)	length(mm)
1	2.0	4.0 *	1.0	5.0
2	1.5	5.4	1.2	6.0

3	2.1	5.2	1.5	6.0
4	1.1	5.2	0.25	4.0 *
5	2.25	5.8	1.85	5.4
6	1.25	5.0	0.9	5.8
7	1.15	5.3	1.0	6.0
8	1.95	5.3	1.35	6.0
9	1.7	5.6	1.25	6.0
10	2.35	6.0	2.25	6.0
11	1.5	5.3	0.8	5.1
12	1.4	6.0	0.75	5.5
13	1.3	5.0	0.7	6.0
14	1.3	5.4	1.45	6.0
15	1.55	5.8	1.15	5.1
16	1.45	6.0	1.5	6.0
17	1.2	5.7	0.9	6.0
18	1.7	6.0	1.25	6.0
19	1.25	5.4	1.1	5.5
20	1.4	6.0	0.75	6.0
21	1.1	6.0	0.9	6.0
22	0.7	5.7	0.65	6.0
Mean ± SD	1.51 ± 0.41	5.51 ± 0.48	1.11 ± 0.44	5.7 ± 0.51

* The length of virtual mini-screw in the bone was limited due to the maxillary sinus

Table 2. Space between screw and root and length of screw in the bone on the maxillary right side

patients	30° angulation		90° angulation	
NO	space(mm)	length(mm)	space(mm)	length(mm)
1	1.5	6.4	1.25	5.2
2	1.75	5.8	1.6	6.0
3	1.85	5.3	1.5	5.6
4	2.0	5.5	1.6	5.7
5	2.25	5.1	2.0	6.0
6	1.4	5.6	0.9	5.8
7	1.8	6.0	1.6	6.0
8	1.4	5.8	1.3	6.0
9	1.55	5.6	1.4	6.0
10	1.95	5.9	1.7	6.0
11	2.0	5.9	1.25	5.8
12	1.1	6.0	0.65	5.6
13	1.8	5.7	1.15	5.3
14	1.0	5.4	0.8	6.0
15	1.15	5.6	0.85	5.7
16	1.25	5.5	1.25	6.0
17	1.6	5.0	0.9	6.0
18	1.2	6.0	0.9	6.0

19	1.4	5.7	1.0	5.8
20	1.6	5.4	1.0	6.0
21	1.2	6.0	1.1	6.0
22	0.9	5.5	1.0	6.0
Mean ± SD	1.53 ± 0.37	5.67 ± 0.33	1.21 ± 0.35	5.84 ± 0.24

The length

The means of the length of the virtual screw in the bone were 5.51 mm (SD =0.48) on the left side and 5.67 mm (SD =0.33) on the right side in the 30^{o}group, and 5.70 mm (SD = 0.51) on the left side and 5.84 mm (SD = 0.24) on the right side in the 90^{o}group (Tables 1 and 2). The differences of two groups were not statistically significant with the P value =0.124 on the left side and P value =0.098 on the right side. The virtual mini-screw could not be placed into the bone by 5.0 mm in two sites due to the maxillary sinus.

The maximum distalization distance

The means of the potential maximum distance of distalization in the maxillary dentition were 2.86 mm (SD =1.16) on the left side and 2.84 mm (SD =0.92) on the right side in the 30^{o} group and 1.20 mm (SD =0.93) on the left side and 1.28 mm (SD =0.61) on the right side in the 90^{o} group (Table 3). The differences of two groups on both sides were extremely statistically significant with the P value < 0.001.

Table 3. The maximum distance of distalization in the maxillary dentition

Patients	left 30° (mm)	left 90° (mm)	right30° (mm)	right 90° (mm)
1	4.0	1.0	2.0	1.0
2	1.5	1.0	2.0	1.5
3	3.5	3.0	3.0	2.5
4	1.0	0	2.5	2.0
5	4.0	2.5	4.0	2.0
6	2.5	0	2.0	0
7	1.0	0.5	2.5	1.5
8	3.0	1.5	2.0	1.5
9	4.0	1.5	2.5	1.5
10	4.0	3.5	3.5	2.5
11	4.0	0.5	4.0	1.5
12	3.0	0.5	4.0	0.5
13	4.0	0.5	4.0	1.3
14	2.0	1.9	1.5	0.6
15	3.0	1.3	4.0	1.0

16	3.0	2.0	2.5	1.5
17	4.0	0.8	4.0	0.8
18	3.0	1.5	2.0	0.8
19	1.5	1.2	2.5	1.0
20	4.0	0.5	4.0	1.0
21	2.5	0.8	2.5	1.2
22	0.5	0.3	1.5	1.0
Mean ± SD	2.86±1.16	1.20±0.93	2.84±0.92	1.28±0.61

Discussion

Osseointegration is the direct structural and functional connection between living bone and the surface of a load-bearing artificial implant and is also a time-dependent healing process ranging 12 to 16 weeks [16]. Most orthodontic mini-screws are made of pure titanium or titanium alloy (Ti–6Al–4V) which has proven properties of biocompatibility [17], so mini-screws have the potential to naturally form osseointegration with surrounding bone. This has been confirmed by researchers even though it is partial osseointegration [18,19,20]. It is logical to believe that some amount of bone around the mini-screw is necessary not only for early-stage mechanical retention (primary stability) but also for osseointegration.

It seems reasonable to use small diameter and short mini-screws in the buccal interradicular bone in the maxilla in order to preserve the quantity bone around the mini-screw and reduce the chance of damaging adjacent roots and maxillary sinus. However, small-diameter and short screws obtain less primary stability and might not be strong enough to withstand orthodontic force. In our study, we chose a 1.5 mm x 8.0 mm virtual mini-screw. The means of average nearest spaces were about 1.52 mm in the 30^{o} group and 1.16 mm in the 90^{o}group with statistically significant differences (P value < 0.001). The means of the length of the virtual screw in the bone were about 5.60 mm in the 30^{o}group, and around 5.77 mm in the 90^{o}group without significant difference (P value >0.05). It's obvious that the oblique placement of mini-screw is safer than the vertical placement.

One study reports that the mini-screws placed in less than 4.0 mm of bone and within 1.4 mm of the root have significantly higher failure rates in the buccal posterior interradicular bone of maxilla [12]. Another animal experiment demonstrates that root resorption almost occurred within 0.6 mm from the mini-implant [21]. We think that 1.0 mm space between the mini-screw and adjacent roots and 5.0 mm length of mini-screw in the bone are the safe boundary

when the mini-screw is placed in maxillary posterior buccal interradicular bone without perforation of the maxillary sinus.

The means of the maximum distalization in the maxillary dentition were around 2.85 mm in the 30^{o} group and 1.24 mm in the 90^{o} group after 0.5 mm deduction for safety with statistically significant difference (P value < 0.001). Our result in the 30^{o} group was similar with the previous research report of 2.8 mm distalization [4], but bigger than 1.4 to 2.0mm posterior teeth distalization in another research [22]. Around 1.24 mm maximum distalization in the 90° group in our study was smaller compared with the 2.0 mm of distalization in one study [5]. The difference may come from the 0.5 mm deduction for safety in our study.

Most studies find success rates of the mini-screw greater than 80% [8,9,23,24]. The proximity of the mini-screw to the root is a major risk factor for the failure of mini-screw [11,12]. Referring to a previous study report [25], using CAD and computer-aided manufacturing (CAM) technology, we could 3D print surgical guides for pre-drilling to guide the placement of the mini-screw in practice in order to reduce possible risks and predict the amount of distalization of the maxillary dentition before placement of the mini-screw.

Dealing with a failed mini-screw is challenging. A mobile mini-screw should be replaced with a bigger one as soon as possible. A mobile implant is a failure even if it appears to be surrounded by adequate bone, because mobility reflects a fibrous rather than a bony interface [26]. The delay of replacing mobile mini-screw will reduce the chance of success for the subsequent bigger mini-screw because more fibrous tissue will grow in leading to more surrounding bone loss. If the bigger one fails too, maybe a new same size mini-screw can be placed after placing some allograft particles in the surgical site. We have tried this method in one case, unfortunately we were unsuccessful. Changing the angulation of the mini-screw placement is usually risky. Changing mini-screw placement sites like from buccal to paramedian palatal bone, is an option. In some situation, giving up using the mini-screw is unavoidable.

Conclusion

Using 22-patient CBCT scans and CAD technology, our study displayed that oblique placement of mini-screw was much safer and had more potential for distalization than the vertical placement with statistically significant differences (P value < 0.001). More

importantly, this method allows us to notice the feasible risks and predict the maximum distance of distalization of maxillary dentition before placement of the mini-screw.

Authors

Wenyong Liang received his DMD (Doctor of Medicine in Dentistry) in 1988 and MDS (Master of Dental Science in Orthodontics) in 1993 from West China College of Stomatology, Sichuan University, China. He studied at University of Washington, USA as a visiting scholar from 1999 – 2000. Dr. Liang received his DDS in 2005 from Western University, Schulich School of Medicine and Dentistry, Canada. He is in private practice in Toronto and is a member of Ontario Dental Association, Canada. ORCID ID: 0000-0002-2217-8104. Publications: (1) "Application of surgical guide for pre-drilling for the successful placement of orthodontic mini-screws using CAD/CAM technology in two cases" in Journal of Orthodontics, 2023; 50(2): 243-251. (2) "Treatment of Severe Crowding and Unilateral Scissors Bite with Leong Premolars: A Case Report" in Oral Health, Canada; 09/08/2023. (3) "Bilateral Scissors Bite Correction with Removable Appliances in an Adolescent" in Ontario Dentist, Canada; March 2022.

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