

Cone Beam Computed Tomography References for Placement Site and Insertion Angle of a Palatal Orthodontic Miniscrew in the Posterior Maxillary Area

Xinghan LI

Graduate Training Base of Dalian Medical University, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Jiaojiao LIU

Department of Stomatology, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Jialin XU

Department of Stomatology, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Ying YANG

Department of Stomatology, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Jingfu WANG

Department of Stomatology, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Xiaodong ZHANG (✉ zxd99233@163.com)

Department of Stomatology, The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army

Research Article

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Abstract

Background: To strengthen the safety and stability of palatal orthodontic miniscrew, the interradicular width, and the thickness of palatal mucosal and bone should be considered, providing a reference for placement site and insertion angle of palatal orthodontic miniscrew.

Methods: The imaging data of 90 adult patients were selected for this study, and the jaw bone was reconstructed by scanning. On the maxillary palatal aspect, distances of 12, 14, 16 and 18 mm from the palatal apex of the first maxillary molar between the maxillary second premolar and first molar, and between the maxillary first and second molars were selected as measurement points. Linear measurements included the interradicular width of the palatal root between adjacent teeth, as well as the palatal mucosal thickness and bone thickness if the miniscrew was inserted at 30°, 45°, 60° and 90° relative to the long axis of the tooth. Data comparisons were performed via one-way analyses of variance and least significant difference tests.

Results: The greater the insertion angle, the shorter the interradicular width and mucosal thickness, the difference among all these angles was statistically significant ($P < 0.05$)—an angle between 60–90° was safer for insertion. The higher the placement site, the greater the interradicular width and mucosal thickness, the difference among all placement sites was statistically significant ($P < 0.05$); placement sites between 14–16mm had greater interradicular widths.

Conclusions: It is safer to insert a palatal orthodontic miniscrew at a 60–90° angle 14–16 mm away from the palatal apex of the first maxillary molar between the maxillary second premolar and first molar. Further, we found it is safer to insert a palatal orthodontic miniscrew at a 60° angle 14–16 mm away from the palatal apex of the first maxillary molar between the maxillary first and second molars.

Introduction

In recent years, miniscrews have achieved remarkable therapeutic effects and attracted increasing attention from clinicians [1]. Miniscrews have been used to provide stable anchorage by insertion on the palatal aspect of the posterior maxillary region of the dental arch. Palatal miniscrews can accomplish various orthodontic tooth movements, such as depressing elongated maxillary molars and correcting the buccal tilt of maxillary molars (Fig. 1). Moreover, miniscrews have the advantages of size diversity, flexibility of insertion placement, and convenient insertion; therefore, they can be used as conventional orthodontic auxiliary materials [2]. However, the process of insertion may damage the root or the periodontal membrane of the adjacent teeth and penetrate the maxillary sinus, causing peri-implant inflammation, ultimately leading to the miniscrew detachment. The failure rate of miniscrew ranges between 7–40% [3]. Many elements influence its success rate [4]; one determining factor is the placement site [5]. Herein, cone beam computed tomography (CBCT) was used to measure the interradicular width of the palatal root between adjacent teeth in the posterior maxillary area, as well as the mucosal and bone tissue thicknesses of the insertion path after a miniscrew was inserted at different angles on the

palatal aspect. This study aimed to provide data that could serve as a reference for the clinical selection of palatal orthodontic miniscrew placement sites and insertion angles.

Methods

Study design and sample

Ninety adults (43 men, 47 women) who had undergone CBCT scanning were selected from the department of Stomatology of The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army. Inclusion criteria were as follows: (1) age \geq 18 years old; (2) no severe dentition crowding, no retained deciduous teeth or supernumerary teeth; (3) no dentition missing in the posterior area; (4) erect first maxillary molar without excessive buccal tilt or lingual tilt; (5) no periodontal disease or periapical disease in the posterior area, and no apical previous operation; (6) normal root morphology of the posterior area; (7) no systemic bone metabolic diseases; (8) clear CBCT images. Even if a participant had a normal occlusion, if either arch did not meet the inclusion criteria, he or she was excluded. All participants provided informed consent and all procedures were approved by the Ethics Related Committee of The Northern Theater Command General Hospital.

Imaging method

CBCT scanning was performed by experienced radiographers. The scanning parameters were as follows: tube current, 5 mA; thickness is 0.3 mm; scanning range, 23.2 cm \times 17.0 cm; grey scale, 14 bits; tube voltage, 120kV; image was collected through a single rotation of 360°; scan time, 8.9 s; data format, Digital Imaging and Communication in Medicine (DICOM) 3.0. The participant was seated in an upright position with the orbital and auricular plane parallel to the ground, and the head was fixed using a chin strap and headrest. A Kavo 3D CBCT (KavoSybron, USA) was used for each participant with the same settings to scan the jaw from the upper orbital margin to the chin during cusp interlacing.

Measuring points

CBCT scan data were imported into Invivo Dental 5.0 software (Anatomage, USA) in DICOM 3.0 standard file formats. The orbito-ear plane was used as the reference plane to adjust the image in the coronal plane. On the maxillary palatal mucosa, distances of 12, 14, 16 and 18 mm from the palatal apex of the first maxillary molar were selected as reference points (Fig. 2). The interradicular width of the palatal root between adjacent teeth as well as the mucosal and bone tissue thicknesses of the insertion path were measured when the miniscrews were inserted at 30°, 45°, 60° and 90° angles relative to the long axes of the teeth (Fig. 3). All linear measurements were performed by the same researcher. Measurements were separated by one week, and each measurement was repeated three times.

Statistical analysis

The intra-class correlation (ICC) coefficient was used to evaluate the consistency of the three measurements. SPSS 26.0 software was used to conduct one-way analyses of variance and least

significant difference paired comparisons for the mean values obtained via the three measurements. $P < 0.05$ indicated a statistically significant difference.

Results

The ICC value obtained from comparing the measured values of the same measurement item was 0.981–0.996; since the ICC > 0.75 , the three measurements exhibited good consistency.

Comparison of interradicular width at various miniscrew insertion angles and placement sites

The larger the insertion angle, the shorter the interradicular width; the difference among all these angles was statistically significant ($P < 0.05$). The interradicular width was shorter and the probability of contacting the adjacent root was higher when the miniscrew was inserted at an angle of 90° , as shown in Tables 1 and 2. The lower the insertion placement site, the shorter the interradicular width; the difference was statistically significant ($P < 0.05$). Compared with that at 12 mm site, miniscrew was inserted at 14–16 mm sites exhibited larger interradicular widths, as shown in Tables 1 and 2. At this point, the probability of damaging the roots of adjacent teeth can be reduced.

Comparison of mucosal thickness at various miniscrew insertion angles and placement sites

The lower the insertion angle, the greater the mucosal thickness and this difference was statistically significant ($P < 0.001$), as shown in Tables 3 and 4. Compared with that at 30° and 45° , the mucosal thickness was reduced at 60° – 90° , and the length of the miniscrew penetrating the bone tissue was greater. The higher the insertion placement site, the greater the mucosal thickness, significantly decreasing the length of miniscrew penetrating the bone tissue ($P < 0.001$), as shown in Tables 3 and 4. Compared with that at 18 mm site, miniscrews inserted at 14–16 mm sites exhibited shorter mucosal thicknesses, and the length of the miniscrew penetrating the bone tissue was greater.

Comparison of bone tissue thickness at various miniscrew insertion angles and placement sites

When the miniscrew was inserted at 30° , 45° , and 60° , the higher the insertion placement site, the shorter the bone tissue thickness ($P < 0.001$), as shown in Tables 5 and 6. Since the maxillary sinus was avoided when the miniscrew was inserted at a 90° angle, there was no significant difference in the bone tissue thickness at different insertion placement sites ($P > 0.05$), as shown in Tables 5 and 6. Compared with that at 18 mm site, miniscrews inserted at 14–16 mm sites exhibited greater bone thicknesses.

Discussion

Measuring Marks

A previous study [6] used CBCT to measure and analyse the alveolar bone thickness in the buccal, proximal, and distal directions in horizontal sections at 2, 5, 8 and 11 mm at the top of the maxillary alveolar crest. Similarly, the present study also used CBCT to measure the interradicular width of the palatal root in the posterior maxillary area as well as the mucosal and bone tissue thickness along the insertion path. Most studies on the safety of miniscrew insertion used a distance 2–3 mm away from the alveolar crest as the initial measurement point [7], and measured every 2–3 mm. Although this method permits easy determination of the marker points, the conclusions drawn from those studies are difficult to apply in clinical practice. In clinical practice, doctors cannot directly observe the alveolar crest, although palatal apex attrition of the maxillary molars is rare [8]. Therefore, the palatal apex of the first maxillary molar is generally selected as the reference point in clinical practice, and a periodontal probe was used to determine the distance, selecting placement sites on the palatal mucosa. The innovation of the present study was to use the palatal apex of the first maxillary molar as a reference point, allowing the conclusions drawn from this research can be directly applied to clinical practice. Our method has the advantages of high operability and allows the determination of measurement points. On the palatal aspect, we chose 12 mm from the palatal apex of the first maxillary molar as the starting measurement point. Using a 2 mm interval, distances of 12, 14, 16 and 18 mm from the palatal apex of the first maxillary molar were selected as measurement points. Linear measurements were obtained from these sites, including the interradicular width as well as the mucosal and bone tissue thicknesses along the insertion path.

Factors Affecting Insertion

When placing a screw on the maxillary palatal aspect, care should be taken to avoid damaging the adjacent root and penetrating the maxillary sinus. In clinical practice, the placement site of the palatal miniscrew is carefully selected along the extension line of the contact point of the two adjacent teeth. Since the interradicular width as well as the mucosal and bone tissue thicknesses along the insertion path vary with height, the placement site and insertion angle of the miniscrew should be further scrutinized. Previous studies have confirmed the insertion angle of the miniscrew is a key factor affecting insertion stability [9]; an angulated placement is strongly recommended in the maxillary posterior area. Park et.al. [3] reported that when a miniscrew was inserted at an angle between 30–40°, the tip of the miniscrew could be inserted in the apical site, allowing more width to prevent damaging the root. Mai et. al. [10] found that when the miniscrew was inserted at a 70°–80° angle, the thickness of the penetrating cortex increased, which enhanced the stability of the miniscrew.

The present study's findings showed that, as the placement height was increased, the interradicular width also increased. Furthermore, even if the placement site remains the same, different insertion angles will lead to differing interradicular widths when the screw passes through the palatal mucosa and bone plate to reach the palatal root plane. If the miniscrew was inserted at 30°, the position of the miniscrew was higher when approaching the palatal root plane, leading to a greater interradicular width. If inserted at 90°, the miniscrew was lower in the palatal root plane and had a shorter interradicular width between the palatal root of adjacent teeth. For instance, the interradicular widths at the 14 mm and 16 mm sites were only 3.6 mm and 3.8 mm, respectively, if inserted at 90° between the maxillary first and second molars. Previous studies showed that ≥ 1 mm of bone around the miniscrew increases the stability [11]. At this point, the miniscrew diameter should not exceed 1.6 mm. The palatal aspect of the maxillary molars differs from the buccal aspect. The maxillary first and second molars have two buccal roots and one palatal root each. Due to the scattered buccal roots, the interradicular widths are greater palatally than they are buccally, and this difference is even greater between the maxillary second premolar and first molar. Even if inserted at 14 mm and 16 mm sites with an angulation of 90° between the maxillary second premolar and first molar, the interradicular widths were 4.8 mm and 5.2 mm, respectively. The space was even sufficient to accommodate a 2 mm diameter screw. Because of the maxillary palatal miniscrew, most applications are used to depress the maxillary molars and correct the buccal tilt of the molars. Therefore, if the insertion angle is too oblique, such as 30°, a reaction force opposite to the insertion direction will be generated, making the screw susceptible to detachment.

When considering the stability of palatal orthodontic miniscrew, the mucosal thickness should be considered in addition to the bone thickness [12]. The palatal mucosa is denser and thicker than the buccal mucosa, and its thickness varies with the placement height. Since the main objective of orthodontic miniscrews is to gain maximum retention, they are placed in areas with thinner soft tissue and thick bone tissue. Since the depth of bone penetration needs to be ≥ 5 mm for most screws, an extremely thick mucosa will inevitably reduce the penetration into the bone, affecting the miniscrew's stability [11]. Hendriks et. al. [13] proposed that the maxillary palatal mucosa was very thick, reaching up to 6 mm. The maxillary palatal mucosa differs from the buccal mucosa; the further from the neck to the palatal midline, the thicker the mucosa. The results of this study also demonstrated that the bone tissue thickness decreased gradually from the gingival margin to the palatal dome, while the mucosal thickness gradually increased.

Due to the greater distance from the greater palatine neurovascular bundle [14], the palatal mucosa is dense and thick, and the trauma during insertion is also minimal. Therefore, there is a low risk of clinical injury to the greater palatine neurovascular bundle.

Selection Of Orthodontic Miniscrews

Although parameters such as diameter, length, and shape determine the quantity and quality of osteointegration, it is hard to make a conclusive statement regarding the optimal miniscrew dimensions

under orthodontic loading. Previous studies have proposed that miniscrews can maintain certain stability only when the penetration depth is ≥ 5 mm [15]. Therefore, to guarantee an adequate length of miniscrew penetrates the bone, a minimum length of 10 mm is recommended. The results of this experiment showed that the mucosal thickness was excessive if inserted 18 mm from the palatal apex of the first maxillary molar. At this point, the length of the miniscrew penetrating the palatal bone tissue is less than the recommended value, and even if a miniscrew with a length of 10 mm is used, the probability of detachment is increased.

Miniscrew dimensions are another key parameter affecting the insertion stability. The diameter and length of miniscrews commonly used in clinical practice range between 1.2–2 mm and 6–11 mm, respectively [11]. Previous studies have shown that for a miniscrew length < 8 mm, stability increases with increasing length. However, for lengths > 8 mm, there is no significant relationship between stability and length. At that point, the diameter becomes more significant to miniscrew stability [16].

Limitation and future research direction

The limitation of this experiment is that it did not consider the influence of gender and bone density on the stability of miniscrew insertion, which will be explored in future studies. Currently, the palatal miniscrew is widely used in clinical practice. This study is clinically useful because the conclusions drawn from our research can be directly, conveniently, and safely applied to clinical practice.

Conclusions

Based on the present study's results, we propose a more comprehensive consideration of different miniscrew placement sites and insertion angles. It is safer to insert a palatal orthodontic miniscrew at a 60–90° angle 14–16 mm away from the palatal apex of the first maxillary molar between the maxillary second premolar and first molar; further, we found it is safer to insert a palatal orthodontic miniscrew at a 60° angle 14–16 mm away from the palatal apex of the first maxillary molar between the maxillary first and second molars.

Abbreviations

CBCT, Cone beam computed tomography; DICOM, Digital Imaging and Communication in Medicine; ICC, intra-class correlation.

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethics Related Committee of The General Hospital of the Northern Theater Command of the Chinese People's Liberation Army (2019-58). All methods were carried out in accordance with relevant guidelines and regulations. Informed consent was obtained from the legal guardians of participants involved in the study.

Consent for publication

The authors understand that if the manuscript is accepted, the Editors reserve the right to determine whether it will be published in the print edition or solely in the online edition of the Journal. Articles accepted for publication are subject to editorial revision.

Availability of data and materials

The data analysed in this article will be shared on reasonable request to the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

XL collected, processed and analysed the data and wrote the main manuscript. JL, JX, and YY processed and analysed the data. JW and XZ designed the study and reviewed the manuscript. Both authors read and approved the final manuscript as submitted.

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Not applicable.

Authors' information

Not applicable.

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Tables

Table 1: Interradicular widths between the palatal roots of the maxillary second premolar and first molar (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	5.49±0.53	6.14±0.32	6.69±0.42	7.61±0.34	53.467	<0.001***
45°	4.96±0.24	5.59±0.21	6.23±0.46	6.76±0.18	50.864	<0.001***
60°	4.72±0.19	5.32±0.32	5.81±0.53	6.54±0.17	62.485	<0.001***
90°	4.48±0.35	4.83±0.43	5.15±0.41	5.68±0.64	46.845	<0.001***
<i>F</i>	37.628	49.862	60.392	42.672		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001***		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 2: Interradicular widths between the palatal roots of the maxillary first and second molars (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	4.41±0.23	5.15±0.32	5.54±0.42	5.71±0.34	24.823	<0.001***
45°	4.13±0.21	4.61±0.18	5.13±0.26	5.21±0.18	33.276	<0.001***
60°	4.01±0.19	4.25±0.23	4.75±0.23	4.98±0.17	22.961	<0.001***
90°	3.51±0.35	3.55±0.43	3.79±0.41	4.63±0.62	28.764	<0.001***
<i>F</i>	32.984	43.785	52.981	44.482		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001***		

p* < 0.05; *p* < 0.01; ****p* < 0.001

Table 3: Mucosal thickness of palatal miniscrew path between the maxillary second premolar and first molar (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	4.77±0.23	5.11±0.32	5.71±0.42	6.01±0.34	27.823	<0.001***
45°	3.72±0.22	4.36±0.27	4.88±0.26	5.63±0.18	33.262	<0.001***
60°	3.23±0.19	3.94±0.23	4.44±0.23	5.33±0.17	32.941	<0.001***
90°	3.19±0.35	3.72±0.44	4.21±0.41	5.01±0.61	22.764	<0.001***
<i>F</i>	26.628	18.927	27.957	34.937		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001***		

p* < 0.05; *p* < 0.01; ****p* < 0.001

Table 4: Mucosal thickness of palatal miniscrew path between the maxillary first and second molars (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	4.24±0.21	5.15±0.22	6.05±0.19	6.13±0.29	30.445	<0.001***
45°	3.38±0.16	4.02±0.14	4.72±0.15	5.69±0.30	27.436	<0.001***
60°	3.01±0.13	3.55±0.13	4.13±0.10	5.14±0.25	21.639	<0.001***
90°	2.72±0.44	3.21±0.39	3.71±0.24	4.26±0.37	36.097	<0.001***
<i>F</i>	28.853	34.728	38.969	41.269		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001***		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5: Bone thickness of palatal miniscrew insertion path between the maxillary second premolar and first molar (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	6.87±0.44	5.94±0.45	5.64±0.43	4.91±0.72	20.721	<0.001***
45°	8.83±0.49	6.99±0.46	6.91±0.43	5.83±0.18	23.318	<0.001***
60°	13.16±0.39	10.61±0.63	8.03±0.57	6.63±0.17	42.011	<0.001***
90°	13.92±0.35	15.39±0.42	15.97±0.52	15.41±0.29	1.573	0.241
<i>F</i>	45.962	49.869	49.896	52.657		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001***		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 6: Bone thickness of palatal miniscrew insertion path between maxillary first and second molars (mm, $\bar{x}\pm s$)

Group	12 mm	14 mm	16 mm	18 mm	<i>F</i>	<i>P</i>
30°	8.34±0.44	6.70±0.45	5.28±0.40	4.04±0.72	20.721	<0.001***
45°	9.45±0.49	7.73±0.46	6.07±0.43	4.27±0.18	23.318	<0.001***
60°	16.06±0.39	10.01±0.63	7.71±0.57	4.93±0.17	42.011	<0.001***
90°	13.99±0.35	15.34±0.42	15.18±0.52	13.51±0.29	1.556	0.240
<i>F</i>	47.793	48.379	51.273	45.729		
<i>P</i>	<0.001***	<0.001***	<0.001***	<0.001		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Figures



Figure 1

A miniscrew inserted in the maxillary palatal aspect to depress the elongated maxillary molar.

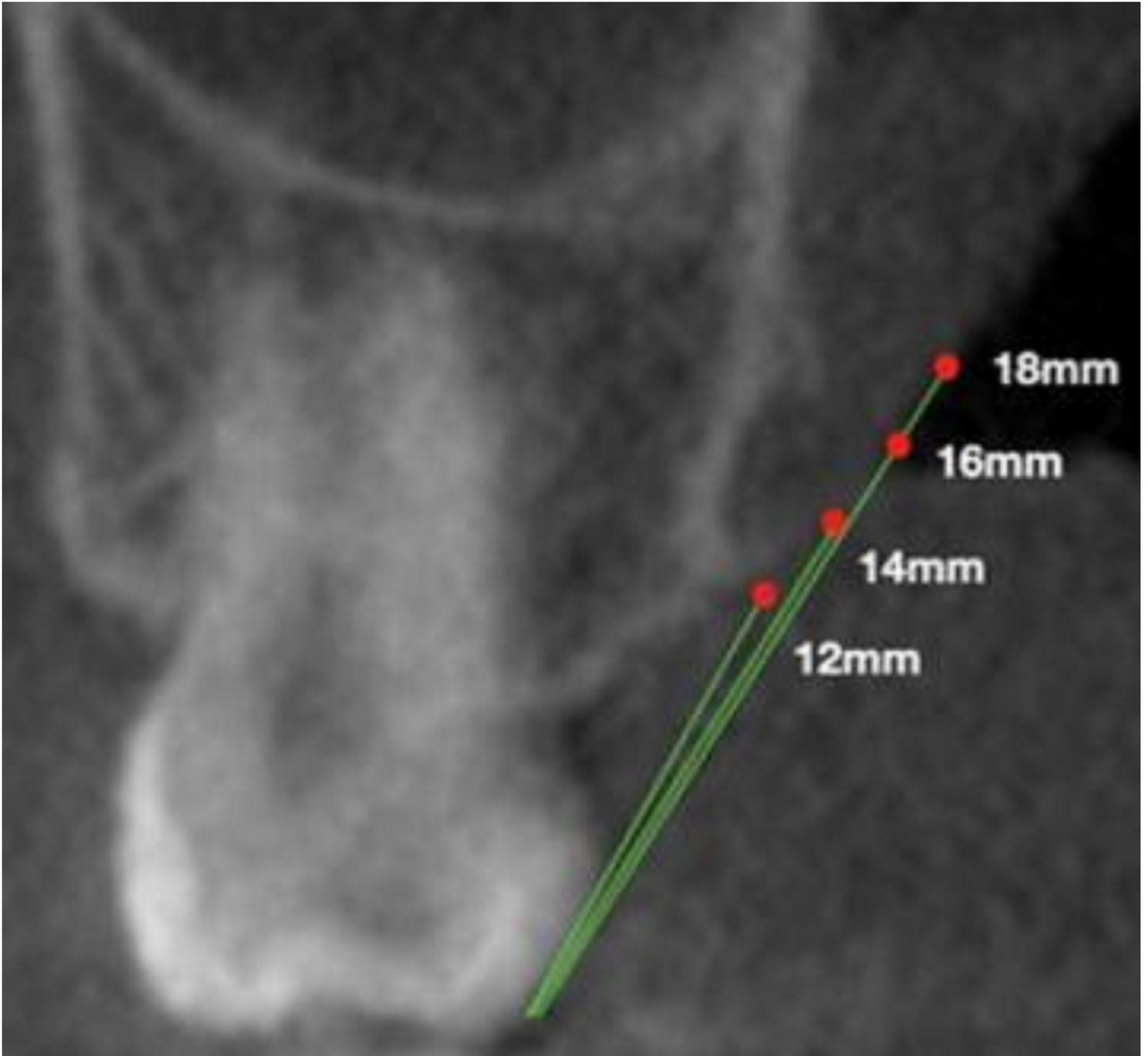


Figure 2

Distances marked along the maxillary palatal aspect.

Distances were marked 12, 14, 16, and 18 mm from the palatal apex of the first maxillary molar in the posterior maxillary region of the dental arch.

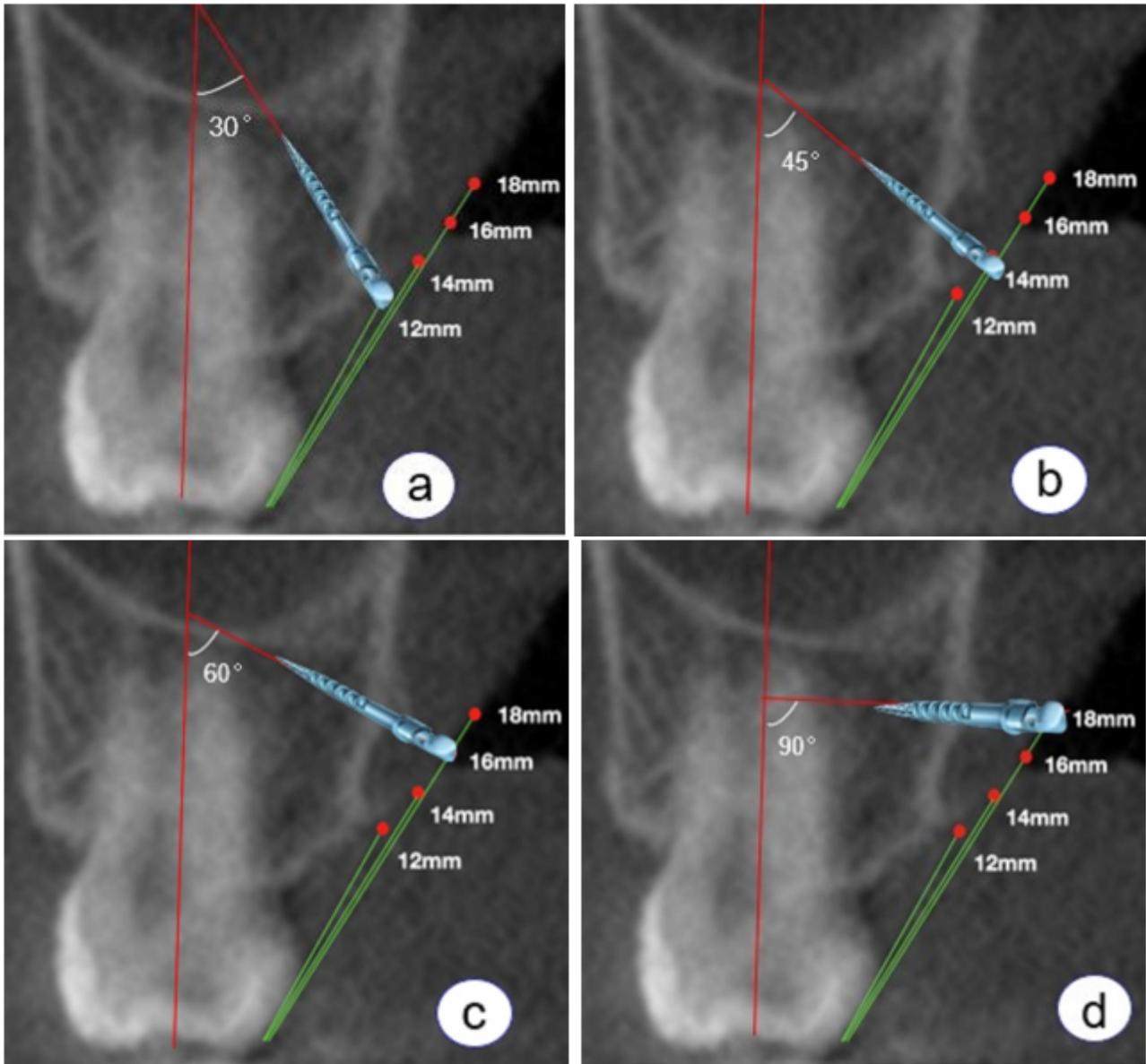


Figure 3

The miniscrews inserted along the long axis of the tooth.

The miniscrews were inserted at different insertion angles relative to the long axis of the tooth on the palatal aspect: a: 30°, b: 45°, c: 60°, d: 90°.