original article

Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal

Maha S. Al Amri,[a] Hanadi M. Sabban,[b] Doaa H. Alsaggaf,[a] Fahad F. Alsulaimani,[a] Ghassan A. Al-Turki,[a] Mohammad S. Al-Zahrani,[c] Khalid H. Zawawi[a]

From the [a]Department of Orthodontics, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia; [b]Department of Oral Diagnostic Sciences Faculty of Dentistry King Abdulaziz University; [c]Department of Periodontics, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia

Correspondence: Prof. Khalid H. Zawawi · Department of Orthodontics, Faculty of Dentistry, King Abdulaziz University, PO Box 80209, Jeddah 21589, Saudi Arabia · kzawawi@kau.edu.sa · ORCID: https://orcid.org/0000-0002-4148-8407

Citation: Al Amri MS, Sabban HM, Alsaggaf DH, Alsulaimani FF, Al-Turki GA, Al-Zahrani MS, et al. Anatomical consideration for optimal position of orthodontic miniscrews in the maxilla: a CBCT appraisal. Ann Saudi Med 2020; 40(4): 330-337 DOI: 10.5144/0256-4947.2020.330

Received: April 10, 2020

Accepted: May 22, 2020

Published: August 6, 2020

Funding: None.

BACKGROUND: Orthodontic miniscrews are commonly used as temporary anchorage devices. Bone thickness and bone depth are important factors when placing miniscrews. There are no studies to assess the maxillary bone thickness for optimum miniscrew placement in a Saudi population.

OBJECTIVE: Assess the proximity of the maxillary sinus and nasal cavity in areas where miniscrews are usually inserted using cone beam computed tomography (CBCT).

DESIGN: Retrospective, cross-sectional.

SETTING: Department of maxillofacial radiology in a Saudi dental school.

PATIENTS AND METHODS: Using CBCT images, we measured the distance between the maxillary sinus and nasal cavity to the palatal bone, buccal intra-radicular and infrazygomatic crest areas. Mean values (SD) were compared at various locations, including by gender, and correlation with age was calculated.

MAIN OUTCOME MEASURE: Mean bone thickness at commonly used sites for orthodontic miniscrew placements in the maxilla. Secondary outcome was the insertion angle in the infrazygomatic crest area.

SAMPLE SIZE: CBCT images of 100 patients (50 males and 50 females).

RESULTS: The mean (standard deviation) age for the sample was 25.4 (6.5) years with no significant difference between males and females. In the palate, the distance to the nasal cavity and maxillary sinus was greater anteriorly and decreased significantly posteriorly (P<.001). Buccally, the interdental bone depth was significantly greater between the second premolar and first molar (11.96 mm) compared to between the central and lateral incisors (7.53 mm, P<.001). The mean bone thickness of the infrazygomatic crest area at a 45° insertion angle was 4.94 mm compared to 3.90 at a 70° insertion angle (P<.001). No correlation was found between age and bone thickness.

CONCLUSION: The distance to the nasal cavity and maxillary sinus was greater in the anterior than posterior areas. There is minimal risk of injuring the maxillary sinus or nasal cavity using the buccal approach. Caution is needed when placing miniscrews in the infrazygomatic crest area.

LIMITATIONS: Cross-sectional study from one center; hence, findings cannot be generalized to other populations.

CONFLICT OF INTEREST: None.

Anchorage consideration during orthodontic treatment with fixed appliances, especially in extraction cases, is critical.[1] Anchorage may become challenging due to a reduced number of teeth or periodontal disease; hence, the need for additional extra- or intraoral anchorage is essential.[1-3] During the last two decades, the use of miniscrews as temporary anchorage devices has become common in orthodontic practice due to reduced treatment time, minimal patient compliance, minor surgical procedure and high patient acceptance.[1,2,4-6] These miniscrews can be inserted in many areas of the alveolar bone and can withstand immediate loading, therefore increasing orthodontic anchorage.[3,7,8] The site and position of miniscrews depends on the quality and quantity of bone.[9-11] Common miniscrew insertion sites in the maxilla include the buccal aspect, the palate and the infrazygomatic crest.[1-3,10,12-15] The palate is considered an ideal site for placement of miniscrews because of the quality of cortical bone, availability of keratinized mucosa and low failure rates.[14,16-20] Recently, the infrazygomatic crest, which is a cortical bony ridge that is clinically palpable between the zygomatic and alveolar processes, has been considered an alternative site for miniscrew anchorage.[21,22] The palate and infrazygomatic crest have an advantage over the buccal approach because miniscrews inserted in these locations are far from the roots and will not interfere during tooth movement.[1,20,23]

An important factor when placing miniscrews for orthodontic purposes is bone thickness at the insertion site. Enough bone should be available to insert the miniscrew with the required length to avoid maxillary sinus or nasal cavity perforation. Poggio et al.[24] found that the buccal area between the first molar and the second premolar had the greatest amount of bone while the tuberosity area had the least amount and thickness of bone. Laursen et al[9] studied the miniscrew buccal insertion angle in human cadavers. They concluded that perpendicular insertion at the level of the mid-root was a safe approach but did not rule out the risk of sinus perforation. Studies have found that the anterior part of the palate was safe for miniscrew placement; however, large individual variations do exist, and care should be taken not to perforate the maxillary sinus.[12,14] The Infrazygomatic crest bone thickness was evaluated at different positions and angles. The mean bone thickness ranged between 5.2 mm at 40° insertion angel and 8.8 mm at a 75° insertion angle.[21] Jia et al[25] reported a high incidence of maxillary sinus perforation when using the infrazygomatic crest approach.

Thus far, no studies have been conducted in Saudi Arabia to investigate the maxillary bone thickness. Therefore, the aim of this study was to determine the palatal, buccal and infrazygomatic crest bone thickness and their relationship to the maxillary sinus or nasal cavity in a Saudi sample.

PATIENTS AND METHODS

This retrospective cross-sectional research was approved by the Research Ethics Committee of the Faculty of Dentistry, King Abdulaziz University, Saudi Arabia (No. 34-04-20). Informed consent was obtained from all patients at the time of pre-treatment CBCT scan. Sample size estimation was carried out using G*Power (version 3.1.9.2).[26] The minimal number of subjects required to detect an average effect size of 0.25 between different maxillary bone locations was 92 subjects at a power of $(1-\beta)=.9$ and $\alpha=.05$. The effect size estimation was based on Ryu et al.[27] Therefore, CBCT scans of 100 dental patients (50 males and 50 females) from the Department of Oral and Maxillofacial Radiology were collected. The inclusion criteria were: 1) Saudi patients 18 years or older, 2) full complement of teeth excluding third molars. 3) good quality scans with similar settings, and 4) complete dental and medical history. The exclusion criteria were: 1) syndromic patients or bone disease, 2) history of facial trauma and/or surgery, 4) history of chronic sinusitis or sinus surgery, and 5) history of orthodontic or surgical periodontal treatment. An expert maxillofacial radiologist evaluated the CBCT scans for any undocumented pathologies.

All CBCT images were acquired using i-CAT Next Generation CBCT unit (Imaging Sciences International, Hatfield, PA, USA) with a slice thickness of 0.4 mm. All images were obtained using the same parameters (120 kVp; 5 mA; exposure time, 4s; voxel spacing, 0.4 mm) with two fields of view. The head was oriented so that the occlusal plane was parallel to the floor. [28]

Palatal and buccal measurements were performed using the i-CAT vision software (Imaging Sciences International, Hatfield, PA, USA). Angles and linear measurements for the infrazygomatic crest were performed using the Carestream 3D Imaging software (CS 3D v3.8.7, Carestream Dental, Atlanta, GA, USA) on a 17inch screen with 3840x2160 resolution. The measurements were performed using a 1.2 mm slice thickness and 1 mm interslice distance. All measurements were performed by one calibrated investigator.

Palatal measurements

Measurements of bone thickness and distance to either the maxillary sinus or nasal cavity were performed at 18 locations in the palate with a CBCT occlusal axial view at the level of the cemento-enamel junctions, of either the first and second premolars or the second and first molars.[12] A midsagittal line was drawn connecting the incisive foramen and the posterior nasal spine equally divided the palate (**Figure 1a**). Three regions were formed by drawing parallel lines lateral to this line at 3-mm increments: A) median, B) paramedian, and C) inter-radicular regions. Six sites on each of these three regions were located by intersecting lines passing through contacts points of following teeth: 1) central and lateral incisors, 2) lateral incisor and canine, 3) canine and first premolar, 4) first and second premolars, 5) second premolar and first molar, and 6) first and second molars. These six intersecting lines were drawn using the coronal view (**Figure 1b**). Using the sagittal view, bone height and distance to the maxillary sinus and nasal cavity were measured at 90° postulating a common path of miniscrew insertion.[29,30] (**Figure 1c**).

Buccal measurements

A panoramic view was reconstructed from the CBCT images to measure the buccolingual bone thickness and distance to the sinus and nasal cavity. A point postulating the path of miniscrew insertion at 90° to the cortical plate[29,30] was located between the roots of adjacent teeth and 6 mm from the CEJ was used (**Figure 2a and 2b**).

Infrazygomatic crest measurements

Using the coronal view, two reference lines were drawn: a horizontal line that represents the maxillary occlusal plane and a second line tangential to the buccal surface of the mesiobuccal root of the first molar (**Figure 3a and 3b**). The distance between the sinus wall and the lateral surface of the infrazygomatic crest was measured at different angles by lines drawn at 45°, 55°, and 70° from the occlusal plane (**Figure 3c, 3d and 3e**).[21,22]

Statistical analysis

Data analysis was performed using the IBM SPSS version 25 (SPSS; IBM Corporation, Armonk, NY, USA). The data were collected and organized into tables, from which mean and standard deviation values were calculated. Normality was checked using Q-Q plots, which showed that the data were normally distributed. Repeated measures analysis of variance (ANOVA) was used to investigate differences in means of palatal and buccal measurements. Bivariate gender comparisons were performed using the independent sample *t* tests. Pearson correlation coefficients were calculated between age and all measurements. The Bonferroni adjustment method was used. The difference was considered significant if the *P* value was less than .05

RESULTS

The mean (standard deviation) age for the total sample was 25.4 (6.5) years. There was no significant age difference between males and females [25.34 (6.41) years vs 25.4 (6.73) years, *P*=.95].

Intra-examiner reliability

One calibrated investigator performed all measurements. Intra-examiner reliability was assessed by repeating the measurements at two-week intervals on randomly selected CBCT scans of 10 subjects. Intra-examiner reliability was assessed using the intraclass correlation coefficient (ICC). The reliability (ICC) ranged between 0.75 and 0.98, suggesting high reliability.

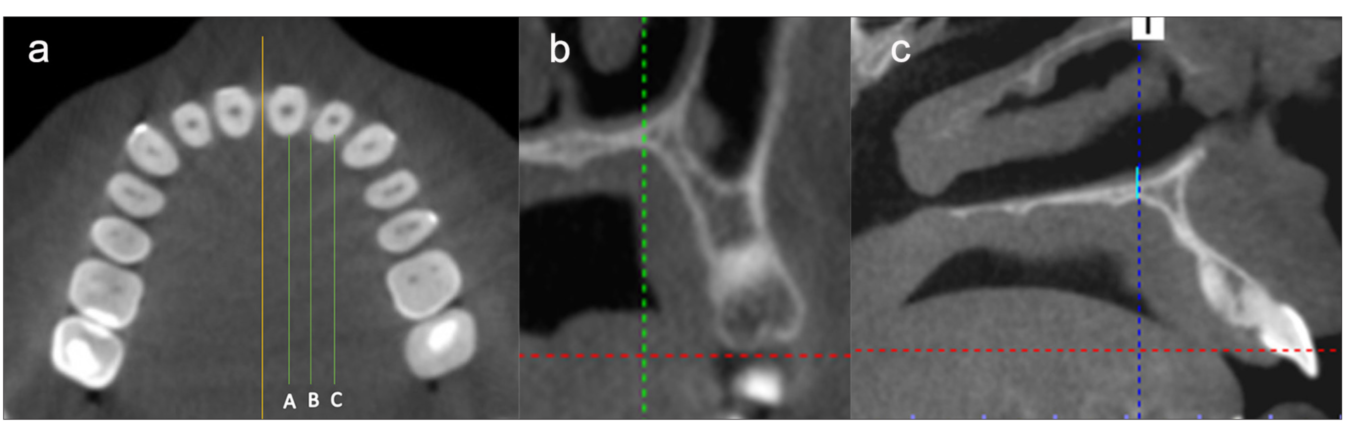

Figure 1. (a) Axial image at the level of the cemento-enamel junction showing a midsagittal line to divide the palate (yellow) and three parallel lines (green) at 3-mm increments: A) median, B) paramedian, and C) inter-radicular. (b) The coronal view with six lines passing through the contacts of each tooth. (c) Sagittal view was used to measure the thickness at the intersection between these three sagittal and six transverse lines.

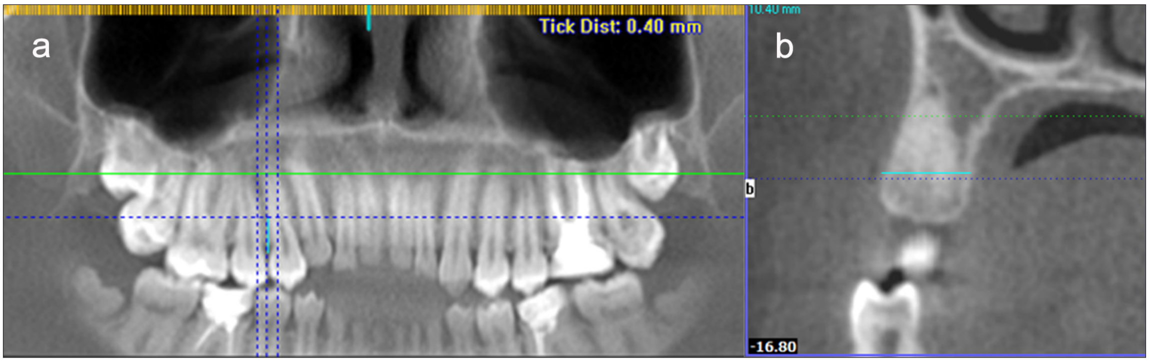

Figure 2. (a) Panoramic view reconstructed from the CBCT images. (b) Using the coronal view, the bucco-palatal width measurements were taken at a point located between the roots of adjacent teeth and 6 mm from the CEJ.

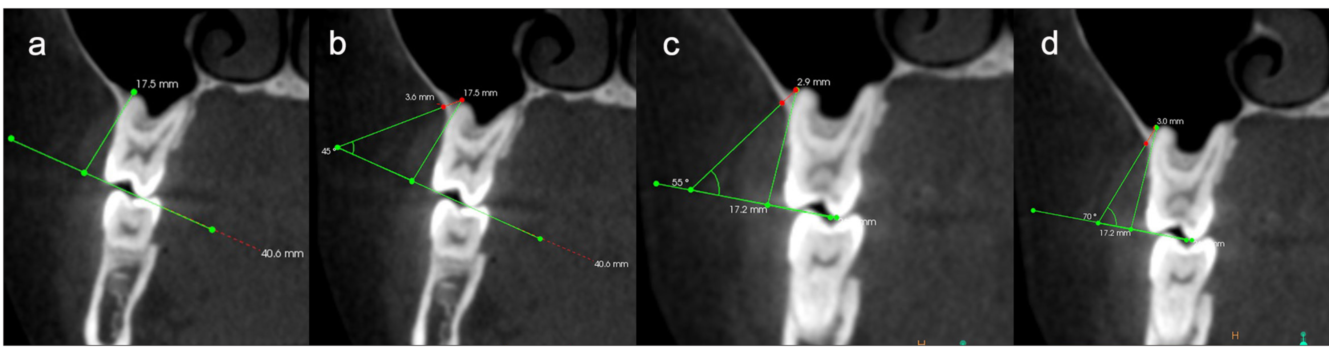

Figure 3. (a) Using the coronal view, two reference lines were drawn: a horizontal line that represents the maxillary occlusal plane and a second line tangential to the buccal surface of the mesiobuccal root of the first molar. The distance between the sinus wall and the lateral surface of the infrazygomatic crest was measured at different angles by lines drawn at 45°, 55°, and 70° from the occlusal plane (b, c and d).

Palatal bone thickness

ANOVA results are shown in **Table 1**. In the median region, the distance to the nasal cavity and maxillary sinus was greater anteriorly (mesial to the first premolar) and significantly decreased in the posterior region (P<.001). The findings were similar in the paramedian and inter-radicular regions (P<.001). In the posterior palate, the median region has significantly greater bone height (mean=4.65 mm) compared to the inter-radicular region (mean=2.95 mm, P<.001).

Comparisons of palatal bone thickness between males and females are shown in **Table 2**. There were statistical differences in 3 out of the 18 measured sites. Males had statistically significant differences in bone thickness in the median region between the lateral incisor and canine (mean difference=0.29 mm, P=.022) and in the inter-radicular region between the second premolar and first molar (mean differences = 0.09 mm, P=.014). Females had statistically significant differences in bone thickness in the paramedian region between the first and second molars (mean difference=0.21 mm, P=.006).

Buccal bone thickness

As shown in **Table 3**, three were statistically significant differences among the 6 locations by ANOVA (P<.001). There were no differences between locations 1 and 2, 3 and 4 and 5 and 6. Significantly more bone thickness was found between the maxillary second premolar and the first molar area (mean=11.96 mm) and between the first and second molars area (mean = 11.69 mm) when compared to other locations (P<.001).

When comparing the buccal bone thickness between males and females, there were statistically significant differences in 2 out of 6 measured sites (**Table 4**). Males had statistically significant bone thickness between the central and lateral incisor (mean difference=0.24 mm, P=.021) and between the first and second premolars (mean difference=0.28 mm, P=.011).

Infrazygomatic crest area

Table 5 shows comparisons of infrazygomatic crest bone thickness between males and females at different insertion angles. No significant differences were found in bone thickness by gender at all insertion angles.

Table 1. Comparisons of palatal bone thickness between the selected regions and locations (n=100).

Anteroposterior Location	Regions (A) Median	(B) Paramedian	(C) Inter-radicular	*P* value[a]
Central and lateral incisors	7.52 (0.97)	7.49 (0.65)	8.66 (0.82)	< .001
Lateral incisor and canine	8.07 (0.64)	7.89 (0.72)	8.76 (0.98)	< .001
Canine and first premolar	4.93 (0.47)	3.82 (0.36)	7.15 (0.37)	< .001
First and second premolars	4.51 (0.38)	3.65 (0.37)	4.48 (0.38)	< .001
Second premolar and first molar	4.52 (0.40)	2.94 (0.15)	2.99 (0.17)	< .001
First and second molars	4.65 (0.39)	2.88 (0.11)	2.95 (0.15)	< .001
P value[b]	< .001	< .001	< .001	

Data are presented as mean (standard deviation) in millimeters. [a]ANOVA results between regions, [b]ANOVA results between locations

Table 2. Comparisons of palatal bone thickness between males and females.

Anteroposterior Location	Region	Males (n=50)	Females (n=50)	Diff.	*P* value
Central / Lateral Incisors	Median	7.51 (0.94)	7.53 (1.01)	0.02	.927
	Para-Median	7.42 (0.67)	7.58 (0.64)	0.16	.237
	Inter-Radicular	8.74 (0.75)	8.59 (0.90)	0.15	.372
Lateral Incisor / Canine	Median	7.92 (0.42)	8.22 (0.79)	0.29	.022
	Para-Median	7.89 (0.74)	7.89 (0.71)	0.00	.999
	Inter-Radicular	8.73 (0.92)	8.80 (1.05)	0.07	.723
Canine / 1st Premolar	Median	5.00 (0.47)	4.86 (0.48)	0.13	.160
	Para-Median	3.76 (0.39)	3.88 (0.35)	0.12	.117
	Inter-Radicular	7.17 (0.38)	7.14 (0.36)	0.02	.748
1st Premolar / 2nd Premolar	Median	4.49 (0.35)	4.53 (0.42)	0.04	.646
	Para-Median	3.67 (0.39)	3.64 (0.38)	0.02	.755
	Inter-Radicular	4.49 (0.41)	4.47 (0,36)	0.02	.796
2nd Premolar / 1st Molar	Median	4.53 (0.41)	4.52 (0.41)	0.01	.884
	Para-Median	2.95 (0.16)	2.93 (0.16)	0.01	.707
	Inter-Radicular	3.03 (0.21)	2.95 (0.11)	0.09	.014
1st Molar / 2nd Molar	Median	4.55 (0.36)	4.76 (0.40)	0.21	.006
	Para-Median	2.88 (0.12)	2.89 (0.12)	0.01	.800
	Inter-Radicular	2.98 (0.15)	2.93 (0.15)	0.05	.105

Data are presented as mean (standard deviation) in millimeters.

However, the infrazygomatic crest bone was significantly thicker in both males and females at an insertion angle of 45° (mean=4.94 mm) than at 55° (mean=3.73 mm) and 70° (mean=3.90 mm) (*P*<.001).

Correlation between age and bone thickness

Pearson correlational analysis showed that there were no significant correlations between the age and palatal, buccal or infrazygomatic crest bone measurements.

DISCUSSION

An important factor to consider when planning orthodontic miniscrew placement is safety by avoiding injury to adjacent anatomical structures such as roots, blood vessels, nerve fibers, nasal cavity and the maxillary sinus.[31-36] There are studies that have evaluated bone thickness, bone volume and height in the maxilla, but no consensus has been reached on the proximity of the maxillary sinus and nasal cavity to areas where miniscrews are frequently inserted.[12,13,21,22,37-40] Furthermore, a large number of studies have been performed on either dry skulls or cadavers.[9,10,12,37,3]8 In our study, CBCT images of 100 Saudi patients with an equal sex distribution and similar age were used to assess the anatomical variation of the palatal, buccal cortical and infrazygomatic crest bones thicknesses and their relationship to the maxillary sinus and nasal cavity.

The results of the current study showed that the palatal bone thickness decreased from the anterior to the posterior region and from medial to lateral, respectively. These results are consistent with the findings of Kang et al[19] who found that the palatal bone thickness tends to decrease posteriorly and laterally. Our results support the advantage of using the anterior palate and the median region as potential sites for placement of miniscrews.

In our study, the buccal cortical bone was greatest in the posterior region (between the molars and second premolar) and decreased progressively toward the anterior region (between the incisors). This is also in line with previous findings and consistent with the recommendation that the optimal position for placing miniscrews is between the second premolar and first molar and between the first and second molars.[10,39] Borges et al[41] found that the highest density in the buccal cortical bone was in the area between the maxillary first and second premolars. Their study had a small sample size (n=11) and they only measured the bone density (Hounsfield units) and not the bone width.

The infrazygomatic crest bone thickness varies according to the miniscrew insertion angle. Liou et al[21] found that the mean infrazygomatic crest bone thickness was 5.2 mm with 40 degree insertion angle and 8.8 mm at 75 degrees insertion angle. Murugesan et al.[22] also reported a mean bone thickness of 4.6 mm at an insertion angle of 45° and 7.9 mm at a 70° insertion angle. In contrast, we found that the mean thickness of the infrazygomatic crest bone at a 45 degree inser-

Table 3. Comparisons of buccal bone thickness at the different locations (n=100).

Location number	Location between	Mean (SD)
1	Central / lateral incisors	7.53 (0.52)
2	Lateral incisor / canine	7.54 (0.46)
3	Canine / 1st premolar	9.90 (0.48)
4	1st / 2nd premolars	9.84 (0.55)
5	2nd premolar / 1st molar	11.96 (1.40)
6	1st / 2nd molars	11.69 (1.28)
	***P* value**	<.001

Data are presented as mean (standard deviation) in millimeters.

Table 4. Comparison of buccal bone thickness between males and females.

Location between	Males (n=50)	Females (n=50)	Diff.	*P* value
Central / Lateral Incisors	7.66 (0.51)	7.41 (0.52)	0.24	.021
Lateral Incisor / Canine	7.53 (0.43)	7.56 (0.50)	0.03	.730
Canine / 1st Premolar	9.98 (0.49)	9.84 (0.48)	0.14	.162
1st Premolar / 2nd Premolar	9.98 (0.57)	9.71 (0.51)	0.28	.011
2nd Premolar / 1st Molar	12.07 (1.41)	11.86 (1.42)	0.20	.477
1st Molar / 2nd Molar	11.84 (1.38)	11.54 (1.17)	0.30	.248

Data are presented as mean (standard deviation) in millimeters.

Table 5. Comparisons of infrazygomatic crest bone thickness at different insertion angles between males and females.

Insertion angle	All subjects (n=100)	Males (n=50)	Females (n=50)
45°	4.94 (0.73)	4.96 (0.65)	4.93 (0.80)
55°	3.73 (0.41)	3.72 (0.43)	3.75 (0.38)
70°	3.90 (0.31)	3.88 (0.29)	3.92 (0.32)
***P* value**	<.001	<.001	<.001

Data are presented as mean (standard deviation) in millimeters. Differences between males and females were not statistically significant by the *t* test.

tion angle to be 4.9 mm, and 3.90 mm at a 70 degree insertion angle. The available bone in this area is not optimal and the risk of sinus perforation could be high, which is in line with Jia et al.25 The differences in the infrazygomatic crest bone width between various studies could be attributed to ethnic background, maxillary sinus and palatal morphology, or the individual's physical built.

In the present study, even though there were statistically significant differences in bone thickness between males and females in some measurements (mean difference range 0.09-0.28 mm), these differences were not considered clinically significant.[42] Our results are in agreement with previous studies.[7,22,43] However, Fayed et al[39] found that males had significantly thicker bone in the maxilla than females. This could be attributed to the sample selection.

In several previous studies, no correlation was found between age and bone thickness even though the studied samples had an age range between 10 to 52 years.[23,40,43] This is in line with the present findings that included an age range between 18 to 42 years. One could speculate that there is no major change in bone thickness after the age of 10. However, Fayed et al[39] found a significant difference in bone thickness between their studied age groups (13-18 versus 19-27 years). The difference in results between Fayed et al[39] and our study could be attributed to differences in age group selection and ethnic background.

Factors contributing to the success of miniscrews include interradicular distance, soft-tissue anatomy, and buccolingual bone depth. To avoid any complications that may arise during miniscrew placement, it is important to study the placement site and be familiar with anatomical structures such as soft tissue, nerve and blood supply, root, nasopalatine canal and its accessory canalis sinuosus, and maxillary sinus morphologies to avoid root injury or perforation of either the maxillary sinus or nasal cavity.[1,14,19,20,32-36,44] The present study used CBCT imaging as it provides accurate clinical guidance for placement of orthodontic miniscrews especially in areas where the maxillary sinus or nasal cavity are predicted to be in close proximity.[15] However, CBCT use in orthodontics is still debatable due to the increased dose of radiation. When selecting the imaging modality for any orthodontic patient, proper principles that weigh the risk versus benefit should always be followed.[45]

The findings of the present study further improve our understanding regarding maxillary bone thickness in relation to the maxillary sinus and nasal cavity. Even though the current findings may provide clinical guidelines, this does not minimize the need for accurate radiographic imaging prior to the insertion of orthodontic miniscrews. A limitation of our study is that this was retrospective and from one center. The results of this study cannot be generalized to the Saudi population due to the multiracial background of the population. Thus, multi-center studies with larger sample sizes from different centers in Saudi Arabia are warranted.

CONCLUSIONS

Within the study limitations, the conclusions are: in the palate, the distance to the nasal cavity and maxillary sinus was greatest in the region mesial to the first premolar, then the distance starts to decrease significantly. In the buccal area, a 90° miniscrew insertion angle was safe with minimal risk of sinus/nasal cavity injury. In the infrazygomatic crest area, bone thickness at a 45° insertion angle was greatest, but this does not exclude the risk of maxillary sinus perforation due to the limited available bone.

REFERENCES

1. Chang HP, Tseng YC. Miniscrew implant applications in contemporary orthodontics. Kaohsiung J Med Sci. 2014;30:111-115.
2. Costello BJ, Ruiz RL, Petrone J, Sohn J. Temporary skeletal anchorage devices for orthodontics. Oral Maxillofac Surg Clin North Am. 2010;22:91-105.
3. Reynders R, Ronchi L, Bipat S. Mini-implants in orthodontics: a systematic review of the literature. Am J Orthod Dentofacial Orthop. 2009;135:564 e561-519; discussion 564-565.
4. Al-Fraidi AA, Zawawi KH. Clinical showcase. Selective intrusion of overerupted upper first molars using a temporary anchorage device: case report. J Can Dent Assoc. 2010;76:a9.
5. Aljhani A, Zawawi KH. The use of mini-implants in en masse retraction for the treatment of bimaxillary dentoalveolar protrusion. Saudi Dent J. 2010;22:35-39.
6. Zawawi KH. Acceptance of orthodontic miniscrews as temporary anchorage devices. Patient Prefer Adherence. 2014;8:933-937.
7. Kim HJ, Yun HS, Park HD, Kim DH, Park YC. Soft-tissue and cortical-bone thickness at orthodontic implant sites. Am J Orthod Dentofacial Orthop. 2006;130:177-182.
8. Abbassy MA, Bakry AS, Zawawi KH, Hassan AH. Long-term durability of orthodontic mini-implants. Odontology. 2018;106:208-214.
9. Laursen MG, Melsen B, Cattaneo PM. An evaluation of insertion sites for mini-implants: a micro - CT study of human autopsy material. Angle Orthod. 2013;83:222-229.
10. Baumgaertel S, Hans MG. Buccal cortical bone thickness for mini-implant placement. Am J Orthod Dentofacial Orthop. 2009;136:230-235.
11. Baumgaertel S, Jones CL, Unal M. Miniscrew biomechanics: Guidelines for the use of rigid indirect anchorage mechanics. Am J Orthod Dentofacial Orthop. 2017;152:413-419.
12. Baumgaertel S. Cortical bone thickness and bone depth of the posterior palatal alveolar process for mini-implant insertion in adults. Am J Orthod Dentofacial Orthop. 2011;140:806-811.
13. Bittencourt LP, Raymundo MV, Mucha JN. The optimal position for insertion of orthodontic miniscrews. Revista Odonto Ciência. 2011;26:133-138.
14. Wang Y, Qiu Y, Liu H, He J, Fan X. Quantitative evaluation of palatal bone thickness for the placement of orthodontic miniscrews in adults with different facial types. Saudi Med J. 2017;38:1051-1057.
15. Abbassy MA, Sabban HM, Hassan AH, Zawawi KH. Evaluation of mini-implant sites in the posterior maxilla using traditional radiographs and cone-beam computed tomography. Saudi Med J. 2015;36:1336-1341.
16. Iijima M, Takano M, Yasuda Y, Muguruma T, Nakagaki S, Sakakura Y, et al. Effect of the quantity and quality of cortical bone on the failure force of a miniscrew implant. Eur J Orthod. 2013;35:583-589.
17. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2006;130:18-25.
18. Chen YJ, Chang HH, Huang CY, Hung HC, Lai EH, Yao CC. A retrospective analysis of the failure rate of three different orthodontic skeletal anchorage systems. Clin Oral Implants Res. 2007;18:768-775.
19. Kang S, Lee SJ, Ahn SJ, Heo MS, Kim TW. Bone thickness of the palate for orthodontic mini-implant anchorage in adults. Am J Orthod Dentofacial Orthop. 2007;131:S74-81.
20. Mannchen R, Schatzle M. Success rate of palatal orthodontic implants: a prospective longitudinal study. Clin Oral Implants Res. 2008;19:665-669.
21. Liou EJ, Chen PH, Wang YC, Lin JC. A computed tomographic image study on the thickness of the infrazygomatic crest of the maxilla and its clinical implications for miniscrew insertion. Am J Orthod Dentofacial Orthop. 2007;131:352-356.
22. Murugesan A, Sivakumar A. Comparison of bone thickness in infrazygomatic crest area at various miniscrew insertion angles in Dravidian population - A cone beam computed tomography study. Int Orthod. 2020;18:105-114.
23. Bernhart T, Vollgruber A, Gahleitner A, Dortbudak O, Haas R. Alternative to the median region of the palate for placement of an orthodontic implant. Clin Oral Implants Res. 2000;11:595-601.
24. Poggio PM, Incorvati C, Velo S, Carano A. "Safe zones": a guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod. 2006;76:191-197.
25. Jia X, Chen X, Huang X. Influence of orthodontic mini-implant penetration of the maxillary sinus in the infrazygomatic crest region. Am J Orthod Dentofacial Orthop. 2018;153:656-661.
26. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods. 2009;41:1149-1160.
27. Ryu JH, Park JH, Vu Thi Thu T, Bayome M, Kim Y, Kook YA. Palatal bone thickness compared with cone-beam computed tomography in adolescents and adults for mini-implant placement. Am J Orthod Dentofacial Orthop. 2012;142:207-212.
28. Sabban H, Mahdian M, Dhingra A, Lurie AG, Tadinada A. Evaluation of linear measurements of implant sites based on head orientation during acquisition: An ex vivo study using cone-beam computed tomography. Imaging Sci Dent. 2015;45:73-80.
29. Araghbidikashani M, Golshah A, Nikkerdar N, Rezaei M. In-vitro impact of insertion angle on primary stability of miniscrews. Am J Orthod Dentofacial Orthop. 2016;150:436-443.
30. Petrey JS, Saunders MM, Kluemper GT, Cunningham LL, Beeman CS. Temporary anchorage device insertion variables: effects on retention. Angle Orthod. 2010;80:446-453.
31. Motoyoshi M, Sanuki-Suzuki R, Uchida Y, Saiki A, Shimizu N. Maxillary sinus perforation by orthodontic anchor screws. J Oral Sci. 2015;57:95-100.
32. Chen Y, Kyung HM, Zhao WT, Yu WJ. Critical factors for the success of orthodontic mini-implants: a systematic review. Am J Orthod Dentofacial Orthop. 2009;135:284-291.
33. Er K, Bayram M, Tasdemir T. Root canal treatment of a periradicular lesion caused by unintentional root damage after orthodontic miniscrew placement: a case report. Int Endod J. 2011;44:1170-1175.
34. Ghislanzoni LH, Berardinelli F, Ludwig B, Lucchese A. Considerations Involved in Placing Miniscrews Near the Nasopalatine Bundle. J Clin Orthod. 2016;50:321-328.
35. Gracco A, Tracey S, Baciliero U. Miniscrew insertion and the maxillary sinus: an endoscopic evaluation. J Clin Orthod. 2010;44:439-443.
36. Kuroda S, Tanaka E. Risks and complications of miniscrew anchorage in clinical orthodontics. Jap Dent Sci Rev. 2014;50:79-85.
37. Baumgaertel S. Quantitative investigation of palatal bone depth and cortical bone thickness for mini-implant placement in adults. Am J Orthod Dentofacial Orthop. 2009;136:104-108.
38. Bourassa C, Hosein YK, Pollmann SI, Galil K, Bohay RN, Holdsworth DW, et al. In-vitro comparison of different palatal sites for orthodontic miniscrew insertion: Effect of bone quality and quantity on primary stability. Am J Orthod Dentofacial Orthop. 2018;154:809-819.
39. Fayed MM, Pazera P, Katsaros C. Optimal sites for orthodontic mini-implant placement assessed by cone beam computed tomography. Angle Orthod. 2010;80:939-951.
40. Marquezan M, Nojima LI, Freitas AO, Baratieri C, Alves Junior M, Nojima Mda C, et al. Tomographic mapping of the hard palate and overlying mucosa. Braz Oral Res. 2012;26:36-42.
41. Borges MS, Mucha JN. Bone density assessment for mini-implants position. Dental Press J Orthod. 2010;15:58-60.
42. Ranganathan P, Pramesh CS, Buyse M. Common pitfalls in statistical analysis: Clinical versus statistical significance. Perspect Clin Res. 2015;6:169-170.
43. Gracco A, Lombardo L, Cozzani M, Siciliani G. Quantitative cone-beam computed tomography evaluation of palatal bone thickness for orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop. 2008;134:361-369.
44. Gurler G, Delilbasi C, Ogut EE, Aydin K, Sakul U. Evaluation of the morphology of the canalis sinuosus using cone-beam computed tomography in patients with maxillary impacted canines. Imaging Sci Dent. 2017;47:69-74.
45. American Academy of O, Maxillofacial R. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. [corrected]. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013;116:238-257.