Anatomical assessment of cortical bone in mandibular buccal shelf in adults for orthodontic bone screw in a sample of population in Erbil city (a CBCT study)

Naz Tariq Karim [(1)]; Omar Fawzi Chawshli [(2)]

Background and objectives: The important factors for placing orthodontic bone screw include thickness of the cortical bone, width of the buccal shelf bone, insertion depth of the screw and the proximity from the inferior alveolar nerve. This study aimed to anatomically assess the mandibular buccal shelf as the insertion site for orthodontic bone screw and determine any differences according to side and gender.

Methods: The study included 20 adult patients (10 males, 10 females; average age, 20-40 years). The measurements were made on cone-beam computed tomography (CBCT) scans of these 20 untreated orthodontic patients. The measurements were taken at mesiobuccal root, distobuccal root of the first molar, mesiobuccal root and distobuccal root of the second molar. The cortical bone thickness was measured at the 4 sites. The buccal shelf bone width was measured 4, 6 and 8 mm below cemento-enamel junction at the 4 sites. The distance between the inferior alveolar nerve canal and the outer surface of the cortical bone at the same 4 sites was measured.

Results: The cortical bone thickness showed the most thickness at the mesiobuccal root area of the first molar and least thickness at the distobuccal root area of the second molar. Regarding the buccal shelf width 4, 6 and 8 mm below cemento-enamel junction the thinnest site was mesiobuccal root of first molar and the thickest site was distobuccal root of second molar. For the distance from nerve the mesiouccal root area of the first molar was the nearest and the mesiobuccal root area of the second molar was the furthest. No significant differences were found between the right and left sides of males and females.

Conclusions: The mesiobuccal side of the mandibular second molar is considered as the most appropriate site for the bone screw placement in the buccal shelf area.

Keywords: CBCT, Orthodontic bone screw, Buccal shelf, Cortical bone.

[(1)]Orthodontics Department, College of Dentistry, Tishk International University
[(2)]POP Department, College of Dentistry, Hawler Medical University
Corresponding author: Naz Tariq Karim
Email: nazamin@gmail.com

Introduction

Temporary anchorage devices are established skeletal anchorage devices routinely used in orthodontic practice.[1] The key factor for successful orthodontic treatment is anchorage stability. The stability of implant is usually divided into two stages. Primary stability is the implant stability during placement of the implant and it is produced by mechanical engagement with cortical bone. Secondary stability arises from regeneration and remodeling of the bone and tissue around the mini-implant after insertion. Secondary stability is affected by various factors like primary stability, bone formation, and remodeling (implant stability after healing). The stability of a mini-implant is determined by the combined effects of primary and secondary stability.[2]

The use of orthodontic bone-screws has widely increased since they provide skeletal anchorage to improve mechanics.[3-5] Bone-screws have demonstrated good patient acceptance and relatively low failure rates, reported at around 13.5%.[6-8] Primary stability is a key factor for successful bone-screw placement.[9] Anatomical factors affecting the stability of bone-screws are bone characteristics (bone density, bone depth and cortical bone thickness), soft tissue characteristics (mucosa vs attached gingiva, tissue thickness, mobility and proximity to the frenum),[2] and the proximity of specific anatomical structures (roots, nerves, vessels and sinus/nasal cavities).[10]

Multiple sites have been used for bone-screw insertion: palatal bone[9,11] the palatal side of the maxillary alveolar process,[12] the mandibular retromolar area,[13] the infrazygomatic crest,[14] the maxillary and mandibular bucco alveolar cortical plate,[15] and the posterior palatal alveolar process.[9] Recently, the mandibular buccal shelf has been proposed as a suitable extra-alveolar bone-screw insertion site. The mandibular buccal shelf is located bilaterally in the posterior part of the mandibular body, buccal to the roots of the first and second molars and anterior to the oblique line of the mandibular ramus.[16]

Bone-screws and mini-implants are classified under temporary anchorage devices. Mini-implants are placed mostly in between the roots of teeth (intra-radicular), while bone screws are placed away from the roots in the infra-zygomatic areas of the maxilla and the buccal shelf areas of the mandible (extra-radicular). The purpose of both of them is skeletal anchorage.[17]

Orthodontic bone-screws can be used in almost every clinical situation that a mini-implant is used for, except that they cannot be placed inter-dental purely because of their larger dimension. Bone-screws can be used for molar up-righting, segmental, and full arch distalization, intrusion of single tooth to full arch, protraction and retraction of dentition and for any other anchorage needs. However, two most specific indications would be – full arch distalization of maxillary and mandibular dentition to camouflage a Class II and Class III malocclusion and for distalization of arches in re-treatment cases of anchorage loss, which are otherwise difficult to be done with a regular mini-implant or time-consuming.[17, 18]

The preferred site for placement of bone screws in the maxilla is the infra-zygomatic crest which lies higher and lateral to the first and second molar region.[17,18] While some authors prefer bone screws to be placed in the first and second molar region and others opine a more anterior placement, closer to the MB root of the first molar. The preferred site for placement of bone screws in the mandible is the buccal shelf area, which lies lower and lateral to the second molar region. Buccal shelf bone screws can also be placed in the external oblique ridge of the mandible if the buccal shelf area is found to be too thin or too deep.[19]

For infra zygomatic crest area of the maxilla bone-screws are available in two sizes commonly 12 and 14 mm in length and 2 mm in diameter. When the soft tissue in the buccal vestibule is thick as in most clinical situations, 14 mm bone-screw is the preferred choice which has 7 mm of head and collar area and 7 mm of cutting spiral. Bone -screws of 12 mm length are preferred in cases of thin soft tissue at the vestibule. The length of cutting spiral, head, and collar dimensions may vary according to the choice of manufacturer.[19]

For buccal shelf area of the mandible bone-screws are available in two sizes commonly 10 mm and 12 mm in length and 2 mm in diameter. Buccal shelf area in the Indian population is mostly found to be thin and deep; therefore, the preferred choice will be a 12-mm screw. The head and collar sizes of both the variants (10 and 12 mm) are almost the same but may vary according to the choice of the manufacturer.[17, 18]

Bone-screw placement in the buccal shelf area of mandible (2nd molar region), initial point of insertion is inter-dentally between the 1st and the 2nd molar and 2 mm below the mucogingival junction. The self-drilling screw is directed at 90° to the occlusal plane at this point. After the initial notch in the bone is created after a couple of turns to the driver, the bone screwdriver direction is changed by 60°–75° toward the tooth, upward, which aid in bypassing the roots of the teeth and directing the screw to the buccal shelf area of the mandible. However, in the mandible sometimes pre-drilling or vertical slit in the mucosa may be necessary if the bone density is too thick; though, rising of flap is never required. Immediate loading is possible and a force of up to 300–350 g can be taken up by a single bone-screw.[17,18]

The purpose of this study was to evaluate the cortical bone thickness, buccal shelf width and distance between the screw insertion point and inferior alveolar nerve to determine the most suitable sites of the mandibular buccal shelf at different insertion sites by comparing male with female and right with left side for orthodontic bone screw placement.

Method

In this study 20 adult patients (average age, 20-40 years) were selected. The sample consisted of 20 cone-beam computed tomographic (CBCT) scans of untreated orthodontic patients including 10 males and 10 females. No CBCT was taken for the purpose of research only. The CBCT scans of this study were collected from one of the private dental radiology centers in Erbil city. Inclusion criteria included patients with no periodontal disease, no metallic restoration in the first or second permanent mandibular premolars and molars, no missing teeth except for third molars, no genetic syndromes or craniofacial pathology, no history of facial trauma, no previous orthodontic treatment and no previous orthognathic surgery.

All CBCT images were collected from one of the private dental radiology centers in Erbil city which are taken with NEWTOM GIANO 3D CBCT scanner (Verona , Italy), using 90 kV, 10 mA with emission time (3.6 s ÷ 9.0 s) and scan time (14 s). A field of view (FOV) 11*5 was used for mandible and voxel size was (0.25× 0.25 mm). The images were created in DICOM format. All images were analyzed using the CBCT software NNT V 10.0 (Verona, Italy). The multiplanar reconstruction images of the program included axial, coronal and sagittal views. Coronal (cross-sectional) views were used for evaluation of mandibular parameters with a slice thickness of 0.15 mm. The images were analyzed using 100% zoom and a visual brightness of 60%. A special ruler of the software program was used for measuring the parameters of the mandible.

Anatomical assessment of cortical bone in mandibular buccal shelf:

1. Assessment of bone thickness: Thickness of cortical bone was measured at four different sites on the right and left side: buccal to mesiobuccal cusp of mandibular first molar (6M), buccal to the distobuccal cusp of the mandibular first molar (6D), buccal to the mesiobuccal cusp of mandibular second molar (7M) and buccal to distobuccal cusps of the mandibular second molar (7D), Figure 1.

Cortical bone thickness is defined as the dimension of the cortical bone which was measured from the midpoint of the osseous ledge buccal to the mandibular first and second molars (buccal shelf), parallel to the contour of the buccal root surfaces of the first and second molar.[20]

2. Assessment of bone width: The buccal shelf bone width was measured at three different points 4, 6 and 8 mm below cemento-enamel junction (CEJ). The measurements were taken at the same four sites of right and left side: buccal to mesiobuccal cusp of mandibular first molar (6M), buccal to the distobuccal cusp of the mandibular first molar (6D), buccal to the mesiobuccal cusp of mandibular second molar (7M) and buccal to distobuccal cusps of the mandibular second molar (7D), Figure 2. The buccal shelf bone width is defined as the total amount of

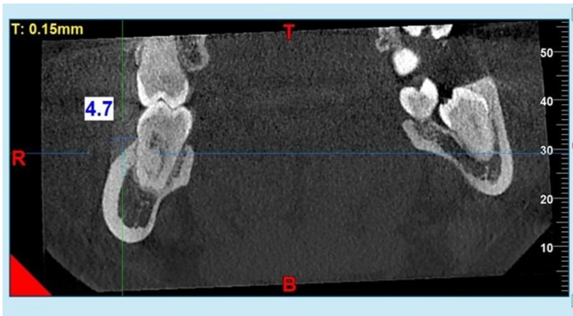

Figure 1. Coronal view showing measurement of the cortical bone thickness.

bone available in the buccolingual direction from the most buccal point of the alveolar bone to the root of the mandibular molars, parallel to the occlusal plane.

3.Assessment of nerve position: Inferioralveolar nerve canal has been traced in the software. The distance between the inferior alveolar nerve canal and outer surface of the cortical bone was measured by a line passing through an angle of ± 60º. The distance was measured for the right and left side at the same four sites: buccal to mesiobuccal cusp of mandibular first molar (6M), buccal to the distobuccal cusp of the mandibular first molar (6D), buccal to the mesiobuccal cusp of mandibular second molar (7M) and buccal to distobuccal cusps of the mandibular second molar (7D), Figure 3.

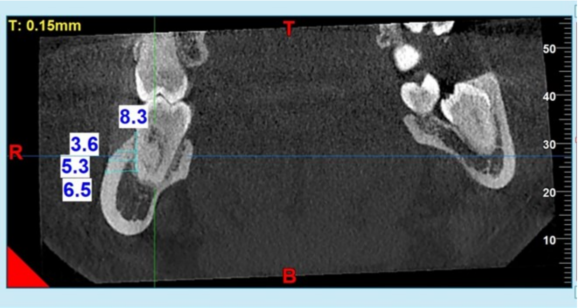

Figure 2. Coronal view showing measurements of the bone width at 4, 6 and 8 mm below CEJ.

Statistical analysis
The data were analyzed using the Statistical Package for Social Sciences (SPSS, version 22). Means and standard deviations were calculated to summarize the numerical variables. A test for normality of data (Shapiro-Wilk test) was done and showed that some of the data sets were not normally distributed. Accordingly, non-parametric tests were used. Mann. Whitney test was used for finding the differences between the mean ranks of males and females, right and left sides. The Kruskal Wallis test was used to evaluate the difference of cortical bone thickness, buccal shelf bone width and distance to the inferior alveolar nerve between the insertion sites. A p value of ≤ 0.05 was considered statistically significant.

Results
According to the descriptive statistics that was done for the data including the total number of the patients, mean and the standard deviation, the cortical bone thickness presented the least thickness at 7D site (4.9 ± 1.7 mm) and most thickness at 6M site (6.98 ± 4.22 mm). The buccal shelf bone width showed the thinnest at the 6M (0.82 ± 0.25 mm) and the thickest at 7D (4.82 ± 1.83 mm) when it is measured 4 mm below the CEJ. When the bone width was measured 6 mm below the CEJ the thickest site that was found was the 7D (5.9 ± 1.66 mm) and the thinnest site was the 6M (1.01 ± 0.44 mm). The final measurements 8 mm below the CEJ for the bone width showed the thickest site as 7D (6.47 ± 1.68 mm) and the thinnest site as 6M (1.45 ± 0.69 mm).The nearest distance to the inferior alveolar nerve was found to be at 6M (4.94 ± 1.37 mm) and the furthest distance was at 7M (6.19 ± 1.27 mm), Table 1.
The Mann Whitney test indicated in table 2 that there were no significant differences between the right side and left side of each of the males and females regarding the cortical bone thickness, buccal shelf bone width 4, 6, and 8 mm below the CEJ, and the distance to nerve (Table 2).
The right side showed no significant differences between males and females regarding the cortical bone thickness,

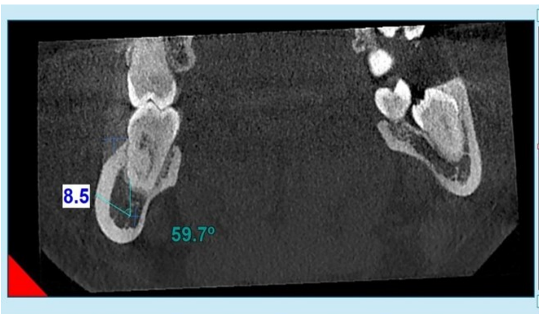

Figure 3. Coronal view showing the distance between inferior alveolar nerve canal and outer surface of the cortical bone.

The non-parametric test Kruskal-Wallis was used to compare the cortical bone thickness, buccal shelf bone width and distance to nerve between the 4 different sites. The results showed no significant association between the sites regarding the cortical bone thickness (p = 0.156). However, the buccal shelf bone width 4, 6, and 8 mm below the buccal shelf bone width, and distance from nerve except that the bone thickness at 7D site indicated that mean rank (and hence the mean) is more in the right side of males than females (p = 0.011). On the left side, again no significant differences were noted except that the bone width at 6M site when 6 mm below CEJ where the mean rank of males was significantly (p = 0.023) higher than females Table 3.

Table 1. Descriptive statistics for cortical bone thickness, bone width 4, 6 and 8 mm below CEJ and distance to nerve.

	Site	N (right + left)	Mean (mm)	(±SD)	SE	95% C.I. for Mean Lower Bound	95% C.I. for Mean Upper Bound	Min.	Max.
Bone thickness	6M	40	6.98	(4.22)	0.67	5.63	8.33	1.8	16.1
	6D	40	6.85	(4.27)	0.68	5.48	8.21	1.8	23.8
	7M	40	5.41	(1.58)	0.25	4.9	5.92	2.4	8.9
	7D	40	4.9	(1.7)	0.27	4.35	5.44	2.4	9.9
Bone width 4mm from CEJ	6M	40	0.82	(0.25)	0.04	0.74	0.9	0.3	1.4
	6D	40	1.28	(0.55)	0.09	1.11	1.45	0.5	3
	7M	40	3.02	(1.39)	0.22	2.58	3.47	0.5	7.1
	7D	40	4.82	(1.83)	0.29	4.23	5.41	1.4	8.9
Bone width 6mm from CEJ	6M	40	1.01	(0.44)	0.07	0.87	1.15	0.3	2.3
	6D	40	1.93	(0.96	0.15	1.62	2.23	0.6	4.5
	7M	40	4.34	(1.71)	0.27	3.79	4.88	0.6	7.4
	7D	40	5.9	(1.66)	0.26	5.37	6.43	2.3	9
Bone width 8mm from CEJ	6M	40	1.45	(0.69)	0.11	1.23	1.67	0.3	3
	6D	40	2.92	(1.28)	0.2	2.51	3.32	0.5	5.6
	7M	40	5.23	(1.71)	0.27	4.68	5.77	1.8	8.3
	7D	40	6.47	(1.68)	0.27	5.94	7.01	3	9.5
Distance to nerve	6M	40	4.94	(1.37)	0.22	4.51	5.38	2.3	9.9
	6D	40	5.72	(1.47)	0.23	5.25	6.19	3.1	10.4
	7M	40	6.19	(1.27)	0.2	5.78	6.6	3.4	10
	7D	40	5.71	(1.13)	0.18	5.35	6.07	3.3	7.9

Table 2. Mean ranks for bone thickness, bone width, and distance to nerve by sides for each of the males and females.

		Mean rank			Mean rank		
	Site	Right Male	Left Male	*P**	Right Female	Left Female	*P**
Bone thick-ness	6M	10.00	11.00	0.739	11.35	9.65	0.529
	6D	10.35	10.65	0.912	9.65	11.35	0.529
	7M	9.70	11.30	0.579	10.60	10.40	0.971
	7D	10.60	10.40	0.971	9.70	11.30	0.579
Bone width 4mm from CEJ	6M	9.85	11.15	0.631	9.70	11.30	0.579
	6D	9.20	11.80	0.353	10.20	10.80	0.853
	7M	9.75	11.25	0.579	10.65	10.35	0.912
	7D	9.50	11.50	0.481	11.15	9.85	0.631
Bone width 6mm from CEJ	6M	9.55	11.45	0.481	11.10	9.90	0.684
	6D	9.85	11.15	0.631	10.10	10.90	0.796
	7M	10.85	10.15	0.796	12.25	8.75	0.190
	7D	10.80	10.20	0.853	11.50	9.50	0.481
Bone width 8mm from CEJ	6M	9.95	11.05	0.684	11.35	9.65	0.529
	6D	11.85	9.15	0.315	10.75	10.25	0.853
	7M	10.60	10.40	0.971	10.60	10.40	0.971
	7D	9.75	11.25	0.579	10.35	10.65	0.912
Dis-tance to nerve	6M	10.10	10.90	0.796	9.10	11.90	0.315
	6D	10.90	10.10	0.796	9.35	11.65	0.393
	7M	10.60	10.40	0.971	9.00	12.00	0.280
	7D	9.05	11.95	0.280	10.50	10.50	>0.999

*By Mann Whitney test

Table 3. Mean ranks for bone thickness, bone width, and distance to nerve by gender on the right and left sides.

		Mean rank			Mean rank		
	Site	Right Male	Right Female	*P**	Left Male	Left Female	*P**
Bone thickness	6M	10.65	10.35	0.912	12.35	8.65	0.165
	6D	11.35	9.65	0.529	10.50	10.50	>0.999
	7M	11.35	9.65	0.529	11.75	9.25	0.353
	7D	13.80	7.20	0.011	11.80	9.20	0.353
Bone width 4mm from CEJ	6M	12.10	8.90	0.247	13.05	7.95	0.052
	6D	12.75	8.25	0.089	13.45	7.55	0.023
	7M	11.95	9.05	0.280	12.65	8.35	0.105
	7D	9.05	11.95	0.280	10.95	10.05	0.739
Bone width 6mm from CEJ	6M	10.20	10.80	0.853	11.05	9.95	0.684
	6D	10.55	10.45	0.971	10.60	10.40	0.971
	7M	9.25	11.75	0.353	11.10	9.90	0.684
	7D	10.65	10.35	0.912	11.25	9.75	0.579
Bone width 8mm from CEJ	6M	10.90	10.10	0.796	11.60	9.40	0.436
	6D	11.45	9.55	0.481	10.35	10.65	0.912
	7M	10.95	10.05	0.739	11.55	9.45	0.436
	7D	10.55	10.45	0.971	11.50	9.50	0.481
Distance to nerve	6M	12.40	8.60	0.165	11.65	9.35	0.393
	6D	11.25	9.75	0.579	9.90	11.10	0.684
	7M	12.20	8.80	0.218	11.30	9.70	0.579
	7D	10.85	10.15	0.796	12.25	8.75	0.190

*By Mann Whitney test.

Table 4. Means and standard deviation of bone thickness, bone width, and distance to nerve.

	Site	N	Mean rank	*P**
Bone thickness	6M	40	85.56	0.156
	6D	40	88.39	
	7M	40	81.40	
	7D	40	66.65	
Bone width 4mm from CEJ	6M	40	30.60	< 0.001
	6D	40	56.39	
	7M	40	104.35	
	7D	40	130.66	
Bone width 6mm from CEJ	6M	40	29.11	< 0.001
	6D	40	58.51	
	7M	40	105.13	
	7D	40	129.25	
Bone width 8mm from CEJ	6M	40	27.15	< 0.001
	6D	40	62.23	
	7M	40	106.24	
	7D	40	126.39	
Distance to nerve	6M	40	54.70	< 0.001
	6D	40	82.19	
	7M	40	100.40	
	7D	40	84.71	

*By Kruskal Wallis test.

Discussion

The anatomy of the bone and the biomechanics are the factors that affect the bone screw placement. Certain insertion sites show high successful rates even though the anatomy of the bone is changing among the individuals.[9,15,21] CBCT is considered as a reliable source for giving the accurate information about the anatomy of the bone. A good primary stability is achieved by having a good bone quality.[22] Due to the importance of cortical bone thickness and buccal shelf bone width many studies have used the CBCT to evaluate the anatomy of the bone and assess the important structures in this area when placing a bone screw.[9,15,21]

The mandibular buccal shelf which is the extension of the external oblique ridge is considered as a good insertion site for the bone screw placement because of the good bone density present in this area. Chang et al reported high success rate for insertion of the bone screw at the buccal shelf area.[23]

The purpose of this study was to evaluate the mandibular buccal shelf area in a sample of population of Erbil city by measuring the cortical bone thickness, buccal shelf bone width and finding the distance to the inferior alveolar nerve by using CBCT. Another purpose of the study was to compare the measurements between males and females, right and left sides.

The findings of this study suggested that the cortical bone thickness changes according to the different insertion sites. A cortical bone thickness of more than 1 mm is needed at the insertion site for placing a bone screw to gain a good stability.[24] According to a study done by Miyawaki[25] increased failure rate of bone screw placement is associated with thin cortical bone.[26] In our study, the bone thickness was obviously thinner at the mandibular second molar areas than the mandibular first molar areas.

Overall, buccal to the mesial root of first molar the cortical bone thickness was the thickest and buccal to distal root of second molar it was the thinnest. However, according to a study done by Elshebiny et al.[20] the cortical bone showed the most thickness at the distal of second molar. Another study indicated the same results that the bone thickness increased toward the distal site.[15]

The buccal shelf on the 3D images showed an increased width buccal to distal of second molars while decreased width buccal to mesial of first molars. Statistically, the buccal bone shelf widths showed no differences when it was measured 4, 6 and 8 mm below the CEJ. So, there was no difference between the bone widths regarding all levels from CEJ. A previous study showed the same results as ours that the bone width was the thickest at the distal of second molar region when measured at different levels from CEJ.[20]

Our findings conducted that the distance between the inferior alveolar nerve canal and outer surface of cortical bone was the least at mesial of first molar. However, the longest available distance was found to be at the mesial of second molar. The results from Elshebiny et al. suggested that the longest available distance was at the distal to first molar.[20] The digitally traced inferior alveolar nerve canal in the software is helpful for the clinician for finding the proximity from the nerve for the insertion of bone screw. In our study there were no significant differences between males and females, right and left sides in the findings.

Finally, the results of this study showed different findings among the bone thickness, bone width and the distance to nerve. The sites for each parameter was different, the cortical bone thickness showed the greatest thickness buccal to the mesial root of the first molar. The buccal shelf bone showed the greatest width at the distal of second molar at the three different levels from CEJ 4, 6 and 8 mm. While, the distance to nerve showed the longest distance at mesial of the second molar.

So according to the findings of our study the best insertion site for bone screw placement in the mandibular buccal shelf area is considered at the buccal side of the mesial root of second molar. We should depend on the findings of cortical bone prior to the bone width and distance to the nerve since the cortical bone thickness is the most important factor of the anatomy that we should rely on for placement of the bone screw. The results of this study can be used for conducting future studies about bone screw placement in the mandibular buccal shelf. Further to this study other steps should be taken to find differences among different malocclusions and ethnic groups.

Conclusion

The mandibular buccal shelf area is considered as a good insertion site for the placement of bone screw in the sample of population in Erbil city. The most favorable site is found to be near the buccal of mesial root of the second molar regarding the bone thickness, bone width and the distance to nerve.

Conflicts of interest

The authors report no conflicts of interest.

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