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Assessment of mandibular buccal shelf for an ideal miniscrew implantation site using cone-beam computed Tomography

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ABSTRACT

Aims: The aim of the study was to evaluate the cortical bone thickness and bone width of the buccal shelf area and to determine the optimal sites for mini screw-implant placement.

Methods: In this retrospective study, cortical bone thickness and buccal shelf bone width of 20 patients were measured at 3 sites on both right and left sides using cone-beam computed tomography images. The three sites were the measurements were done were areas buccal to the distobuccal cusps of mandibular first molar (6D), and buccal to the mesiobuccal (7M) and distobuccal (7D) cusps of mandibular second molar. Also, buccal shelf bone width was measured at 8 and 4 mm from the cementoenamel junction (CEJ).

Results: The study group included 10 males with the mean age of 24.5 years and 10 females with the mean age of 26.5 years. There was statistically significant difference between the cortical bone thickness, between the left and the right sides in the mesiobuccal cusp of mandibular 2nd molar (MB7) and the distobuccal cusp of mandibular 2nd molar (DB7). The values obtained at MB7 on the right and left sides were 4.74±0.94 and 4.16±0.91 with p value of 0.006, respectively. Similarly, data obtained at DB7 on the right and left sides were 4.13±0.94 and 5.08±1.12 with p value of 15<0.001, respectively.

Conclusions: Maximum bone thickness was found at distal region of the mandibular second molar at 8 mm from the CEJ, hence this is the ideal site for miniscrew placement in buccal shelf area (horizontal bone level at DB7=6.01 mm and vertical bone level at DB7=4.06 mm).

Introduction

The introduction of absolute anchorage in orthodontics has changed the way we see treatment planning of an orthodontic case. It has increased the envelope of tooth movement by fixed orthodontic appliances. The position of these miniscrews is based on the mechanical requirement for a particular case (1-4). The most commonly used sites are the maxillary alveolar process, retromolar area, palate, mandibular and maxillary buccal alveolar processes (2-6).

Thickness of the cortical bone is an important factor to be considered for the stability of miniscrew implant. Inadequate bone thickness leads to diminished primary stability of the miniscrew, which will later lead to its failure during the orthodontic treatment. Less than 1 mm cortical bone thickness can lead to higher rate of failure as compared to 1 mm or more.

Cortical bone with thickness of less than 1 mm is vulnerable to stresses, which further causes bone loss in the nearby area (7-14). The two most important factors for the initial stability of the miniscrew are the quantity and quality of bone. These two factors also have the effect on the long term stability. Stationary anchorage failure occurs mostly due to diminished bone density and the

incidences further increase in case of reduced cortical bone thickness (7-14). The thickness of the bone can be studied with the help of cone-beam computed tomography (CBCT). Hence, it is better to use CBCT in bone screw cases rather than panoramic radiograph and lateral cephalogram as it fails to provide full information about the subject.

Recently, the introduction of bone screws in orthodontics has made full arch distalization and camouflage treatment easier. The buccal shelf area is a site for the placement of such a bone screw for the treatment of class 3 cases (15-18). Despite several CBCT studies, there is inconsistency in the placement site of these implants. Varied bone thickness in these areas has made the standardization difficult as the bone width and thickness change every millimeter. As we go away from the alveolar crestal region, the bone thickness and density increase.

Importance should also be given to the soft tissue and nerve relation with roots of teeth in the neighboring areas (19).

The purpose behind the study was to evaluate the thickness of the cortical bone and bone width of the buccal shelf area and thus to determine the ideal sites for the placement of miniscrew implant in the buccal shelf area of the mandible using CBCT.

Methods

This retrospective study included full field of view (FOV) CBCT records of 20 patients in the age group of 19 to 33 years, including 10 males and 10 females who were admitted to the department of Orthodontics for orthodontic treatment. Full FOV CBCT images were taken for evaluating impacted canines, for assessing sites for zygomatic implants and for the purpose of orthognathic surgeries. Informed consent was also taken from all subjects. Ethical clearance for the study was obtained from AB Shetty Memorial Institute of Dental Sciences Institutional Ethical Committee (Cert. no. ABSM/EC02/2016). The information for each image analyzed was retrieved from the records maintained at the department of oral radiology at the institute. Subjects who had full complement of teeth except for third molars with class 1 molar relation were included in the study. Subjects who had severe skeletal abnormalities and facial anomalies, periodontal disease, systemic illness and endocrinal disorders were not included in the study. The records were analyzed by a single observer.

The CBCT images were taken using Planmeca ProMax™ Machine (230-240 V, 50 Hz, 16 A) manufactured by PLANMECA OY (Helsinki Finland). Full FOV images were retrieved from already existing CBCT images. The images were analyzed using Planmeca Romexis Viewer (version 4.1.2). 2 mm cross sections of the mandible were obtained. The 3D images were reconstructed around the axial plane. These measurements were made from 4 mm and 8 mm from the cementoenamel junction (CEJ). The CEJ was customized by tracing the CEJ of each tooth individually on the coronal view.

Thickness of the cortical bone and the width of the buccal shelf bone were measured at 3 sites on both right and left sides. Measurements were done at areas buccal to the distobuccal cusps of mandibular first molar (6D), and buccal to the mesiobuccal (7M) and distobuccal (7D) cusps of mandibular second molar. Cortical bone thickness was measured (parallel to buccal root surface) from the midpoint of the osseous ledge buccal to first and second mandibular molars (buccal shelf area) (Figure 1).

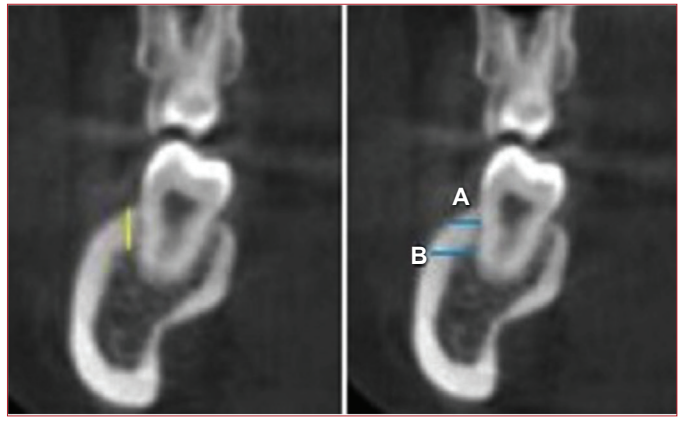

Figure 1. Measurement of horizontal and vertical cortical bone thickness

Buccal shelf bone width was the total bone width present in buccolingual direction (parallel to occlusal plane) from the root of the mandibular molars to the most buccal point of the alveolar bone at 8 and 4 mm from the CEJ. These measurements were recorded at 3 sites at 4 mm and 8 mm: buccal to the distobuccal cusp of mandibular first molar (6D4, 6D8), and buccal to the mesiobuccal (7M4, 7M8) and distobuccal (7D4, 7D8) cusps of mandibular second molar (Figure 1).

All measurements were made on the reconstructed axial plane using the “Measure Length” Tool. (Planmeca Romexis V. 4.1.2™).

Statistical Analysis

The data collected were entered in Microsoft Excel work sheet and analyzed using IBM SPSS version 22. The descriptive statistics were represented in the form of mean and standard deviation.

A paired Student’s t-test was used for additional preliminary data analysis to test the differences between the left and right sides in the cortical bone width. Analysis of variance was used to evaluate the importance of the site and measurement level on cortical bone thickness and buccal shelf bone width. The post-hoc Tukey test was used to further evaluate interactions of the different variables. Intraclass correlation was also evaluated.

Results

This retrospective study included 20 patients comprising of 10 males with the mean age of 24.5 years and 10 females with

the mean age of 26.5 years (Table 1). The horizontal and vertical bone levels between right and left sides at different sites were compared (Table 2) and there was no statistically significant difference between the left and the right sides of the cortical bone width at 4 and 8 mm from CEJ. There was statistically significant difference between the cortical bone thickness between the left and the right sides in MB7 and DB7. The values obtained at MB7 on the right and left sides were 4.74±0.94 and 4.16±0.91 with p value of 0.006, respectively. Similarly, data obtained at DB7 on the right and left sides were 4.13±0.94 and 5.08±1.12 with p value of 101<0.001, respectively.

The horizontal bone levels (cortical bone width) between different sites at 4 mm were compared (Tables 3, 4) and statistically significant difference was found among DB6, MB7 and DB7.

The maximum bone width was seen at DB7 (with average thickness of 4.79 mm) followed by MB7 (3.80 mm) and minimum levels at DB6 (1.81 mm).

Table 1. Basic data of participants

Gender	Number	Mean age (years)
Males	10	24.5
Females	10	26.5

It was also seen that when the horizontal bone levels between different sites at 8 mm (Tables 3, 4) were compared, there was statistically significant difference among the DB6, MB7 and DB7. The maximum bone width was seen at DB7 (with average thickness of 6.01 mm) followed by MB7 (4.85 mm) and minimum levels at DB6 (2.27 mm).

The vertical bone levels between different sites (Tables 3, 4) were also compared and statistically significant difference was found among the DB6, MB7 and DB7. The maximum bone width was seen at DB7 (with average thickness of 4.60 mm) followed by MB7 (4.45 mm) and minimum levels at DB6 (3.42 mm). Intraclass correlation was also evaluated for horizontal and vertical bone levels at different sites (Tables 5, 6).

Discussion

The decision for placing the miniscrew is dependent on the bio-mechanics and the local anatomy of that particular region. Local anatomy varies with different individuals, but some sites are more reliable and show more bone thickness than others (1,5,20). The two most important factors for the primary stability of the implant are the quality and quantity of bone. CBCT may be used to study this, though the gold standard for studying the quality of bone is biopsy.

Table 2. Comparison of horizontal and vertical bone levels between right and left side at different sites

Site			N	Mean	Standard deviation	Mean difference	95% confidence interval of the difference		t	df	p value
							Lower	Upper			
DB6	H-4 mm	Right	20	1.78	0.46	-0.07	-0.36	0.22	-0.50	19	0.63 (NS)
		Left	20	1.85	0.50						
	H-8 mm	Right	20	2.29	0.76	0.03	-0.49	0.55	0.13	19	0.90 (NS)
		Left	20	2.25	0.90						
	Vertical	Right	20	3.53	0.98	0.22	-0.27	0.71	0.93	19	0.36 (NS)
		Left	20	3.31	0.58						
MB7	H-4 mm	Right	20	3.58	1.15	-0.44	-1.04	0.15	-1.57	19	0.13 (NS)
		Left	20	4.02	1.45						
	H-8 mm	Right	20	4.85	1.09	0.01	-0.90	0.93	0.03	19	0.98 (NS)
		Left	20	4.84	1.84						
	Vertical	Right	20	4.74	0.94	0.57	0.18	0.96	3.07	19	0.006*
		Left	20	4.16	0.91						
DB7	H-4 mm	Right	20	4.92	0.94	0.26	-0.36	0.87	0.88	19	0.39 (NS)
		Left	20	4.66	1.51						
	H-8 mm	Right	20	5.89	0.88	-0.24	-0.78	0.30	-0.91	19	0.37 (NS)
		Left	20	6.13	1.29						
	Vertical	Right	20	4.13	0.94	-0.95	-1.40	-0.51	-4.46	19	<0.001*
		Left	20	5.08	1.12						

Paired t-test, *p<0.05 statistically significant, p>0.05.
NS: Non-significant

Table 3. Comparison of horizontal bone levels between different sites at 4 mm and 8 mm, comparison of vertical bone levels between different sites

4 mm	Sites	N	Mean	Standard deviation	ANOVA	
					F	p value
Right	DB6	20	1.78	0.46	61.82	<0.001*
	MB7	20	3.58	1.15		
	DB7	20	4.92	0.94		
Left	DB6	20	1.85	0.50	28.32	<0.001*
	MB7	20	4.02	1.45		
	DB7	20	4.66	1.51		
Average	DB6	20	1.81	0.36	53.37	<0.001*
	MB7	20	3.80	1.14		
	DB7	20	4.79	1.07		
8 mm	**Sites**	**N**	**Mean**	**Standard deviation**	**ANOVA**	
					F	**p value**
Right	DB6	20	2.29	0.76	81.35	<0.001*
	MB7	20	4.85	1.09		
	DB7	20	5.89	0.88		
Left	DB6	20	2.25	0.90	39.98	<0.001*
	MB7	20	4.84	1.84		
	DB7	20	6.13	1.29		
Average	DB6	20	2.27	0.62	84.62	<0.001*
	MB7	20	4.85	1.16		
	DB7	20	6.01	0.94		
Vertical	**Sites**	**N**	**Mean**	**Standard deviation**	**ANOVA**	
					F	**p value**
Right	DB6	20	3.53	0.98	7.97	0.001*
	MB7	20	4.74	0.94		
	DB7	20	4.13	0.94		
Left	DB6	20	3.31	0.58	19.44	<0.001*
	MB7	20	4.16	0.91		
	DB7	20	5.08	1.12		
Average	DB6	20	3.42	0.61	13.10	<0.001*
	MB7	20	4.45	0.83		
	DB7	20	4.60	0.91		

*p<0.05 statistically significant, p>0.05.
NS: Non-significant

Mandibular buccal shelf area is the area between the buccal frenum and anterior border of masseter muscle. It extends medially from the crest of the ridge, laterally to the external oblique ridge and distally up to the retromolar pad. There is significant amount of bone present in this area and thus permits clinicians to place miniscrews in a direction parallel to the long axes of the molar roots. With this mode of insertion, screw-to-root contact can be avoided during the procedure of insertion and also during retraction of the posterior tooth (21). Buccal shelf area is one of the areas which are most favorable insertion sites for the placement of miniscrew especially in class 3 cases.

The purpose of this study was to investigate the cortical bone thickness and cortical bone width at 3 sites (DB6 MD7 DB7) and two levels (4 mm and 8 mm) from the CEJ using CBCT technology in Indian population.

The findings of this study show different bone thickness and bone width in different region of buccal shelf area. The width of bone increased from the first molar region to the second molar region, which was statistically significant (p=0.006). The minimum bone width was measured with respect to first molar region (at 4 mm site=1.86 mm and at 8 mm site=2.27 mm), hence it is not suitable for miniscrew placement. The maximum

Table 4. Pairwise comparison of horizontal bone levels between different sites at 4 mm and 8 mm, pairwise comparison of vertical bone levels between different sites

4 mm	(I) Site	(J) Site	Mean difference (I-J)	Standard error	p value	95% confidence interval	
						Lower bound	Upper bound
Right	DB6	MB7	-1.80	0.28	<0.001*	-2.48	-1.12
		DB7	-3.14	0.28	<0.001*	-3.82	-2.46
	MB7	DB7	-1.34	0.28	<0.001*	-2.02	-0.66
Left	DB6	MB7	-2.18	0.39	<0.001*	-3.12	-1.23
		DB7	-2.81	0.39	<0.001*	-3.76	-1.87
	MB7	DB7	-0.64	0.39	0.24 (NS)	-1.58	0.31
Average	DB6	MB7	-1.99	0.29	<0.001*	-2.69	-1.28
		DB7	-2.98	0.29	<0.001*	-3.68	-2.27
	MB7	DB7	-0.99	0.29	0.004*	-1.69	-0.28
8 mm	**(I) Site**	**(J) Site**	**Mean difference (I-J)**	**Standard error**	**p value**	**95% confidence interval**	
						Lower bound	**Upper bound**
Right	DB6	MB7	-2.57	0.29	<0.001*	-3.27	-1.87
		DB7	-3.61	0.29	<0.001*	-4.31	-2.91
	MB7	DB7	-1.04	0.29	0.002*	-1.74	-0.34
Left	DB6	MB7	-2.59	0.44	<0.001*	-3.65	-1.53
		DB7	-3.88	0.44	<0.001*	-4.94	-2.81
	MB7	DB7	-1.29	0.44	0.01*	-2.35	-0.23
Average	DB6	MB7	-2.58	0.29	<0.001*	-3.29	-1.87
		DB7	-3.74	0.29	<0.001*	-4.45	-3.03
	MB7	DB7	-1.16	0.29	0.001*	-1.87	-0.46
Vertical	**(I) Site**	**(J) Site**	**Mean difference (I-J)**	**Standard error**	**p value**	**95% confidence interval**	
						Lower bound	**Upper bound**
Right	DB6	MB7	-1.21	0.30	0.001*	-1.93	-0.48
		DB7	-0.60	0.30	0.13 (NS)	-1.32	0.13
	MB7	DB7	0.61	0.30	0.12 (NS)	-0.12	1.33
Left	DB6	MB7	-0.85	0.28	0.01*	-1.54	-0.17
		DB7	-1.77	0.28	<0.001*	-2.45	-1.09
	MB7	DB7	-0.91	0.28	0.006*	-1.60	-0.23
Average	DB6	MB7	-1.03	0.25	<0.001*	-1.63	-0.42
		DB7	-1.18	0.25	<0.001*	-1.79	-0.58
	MB7	DB7	-0.15	0.25	0.82 (NS)	-0.76	0.45

Tukey post-hoc test, *p<0.05 statistically significant, p>0.05.
NS: Non-significant

width of bone was witnessed with respect to distobuccal cusp of second molar (at 4 mm site=4.79 mm and at 8 mm site=6.01 mm) hence it is the best region for the placement of miniscrew.

There was variation in the width of bone seen from 4 mm from CEJ to 8 mm from CEJ. The width of the bone was more on the 8 mm site compared to 4 mm site. The result of the bone width was in correlation with the studies performed by Elshebiny et al. (19) and Nucera et al (22). Bone thickness is one of the essential factors for primary stability of miniscrew and it correlates directly to the placement torque, which in turn influences the stability of the screw. Baumgaertel (23,24) confirmed the importance of cortical bone thickness in implant site preparation. Lim et al. (25) also mentioned the significant role of cortical bone thickness in the evaluation of maximum insertion torque value as it determines the stability of the implant. Various studies have proven that extreme values of cortical bone thickness can affect the insertion outcome. Areas of very thin bone will lead to stress in the bone and later lead to implant failure whereas very thick bone will have good initial stability but later will lead to implant failure due to compression of the bone. In case where there is excessive bone thickness, predrilling is recommended as it will produce lesser heat at the implant bone surface. The thickness

Table 5. Intraclass correlation coefficient-horizontal bone level

Tooth	mm	Side	Intraclass correlation	95% confidence interval	
				Lower bound	Upper bound
DB6	4	Left	0.99	0.99	1.00
		Right	0.99	0.99	1.00
	8	Left	1.00	0.99	1.00
		Right	1.00	0.99	1.00
MB7	4	Left	1.00	1.00	1.00
		Right	1.00	0.99	1.00
	8	Left	1.00	1.00	1.00
		Right	1.00	1.00	1.00
DB7	4	Left	1.00	1.00	1.00
		Right	1.00	0.99	1.00
	8	Left	1.00	1.00	1.00
		Right	1.00	0.99	1.00
Tooth	mm	Intraclass correlation Lower bound		95% confidence interval	
				Upper bound	
DB6	4	0.99		0.99	1.00
	8	1.00		0.99	1.00
MB7	4	1.00		1.00	1.00
	8	1.00		1.00	1.00
DB7	4	1.00		1.00	1.00
	8	1.00		1.00	1.00

Table 6. Intraclass correlation coefficient-vertical bone level

Tooth	mm	Side	Intraclass correlation	95% confidence interval	
				Lower bound	Upper bound
DB6	4	Left	0.99	0.99	1.00
		Right	1.00	0.99	1.00
MB7	4	Left	1.00	0.99	1.00
		Right	1.00	1.00	1.00
DB7	4	Left	1.00	0.99	1.00
		Right	1.00	0.99	1.00
Tooth	mm	Intraclass correlation Lower bound		95% confidence interval	
				Upper bound	
DB6	4	1.00		0.99	1.00
MB7	4	1.00		1.00	1.00
DB7	4	1.00		1.00	1.00

of the bone increases from mesial site to the distal as shown by other studies as well. The maximum thickness was found with respect to the distobuccal cusp of the second molar and there was a statistically significant difference among the three sites. It was in accordance with studies done by Elshebiny et al. (19) and Nucera et al. (22). The torque values used in the buccal shelf area is generally higher than other areas as the cortical bone thickness is more, but care should be taken not to exceed the recommended torque levels as it might fracture the implant. In case of excessive bone thickness, drilling should be done and then the implant should be placed.

The cortical bone thickness in the present retrospective study was done on full FOV rather than small FOV, which could provide a better image quality and smaller voxel size.

Ethnicity does play a role in the morphology of bone as the values found in this study were different from the values found in the study done by Elshebiny et al. (19) and Nucera et al. (22). This might be dependent on the facial type of patients and the skeletal malocclusion of the patient. Also, comparison of cortical bone thickness between adults and adolescent groups can be studied. Hence, it is recommended that further research in this area will give a better picture of the bone in the buccal shelf region.

Conclusion

The mandibular buccal shelf area is a suitable site for bone screw placement. With the limitation of the study, the bone buccal to the mandibular second molar region appears to be the most favorable site for the miniscrew placement. The maximum bone thickness was found at distal region of the mandibular second molar at 8 mm from the CEJ, hence this is the ideal site for miniscrew placement. The insertion of the miniscrew at the first molar region would require further investigation.

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Ethics

Ethics Committee Approval: Ethical clearance for the study was obtained from AB Shetty Memorial Institute of Dental Sciences Institutional Ethical Committee (Cert. no. ABSM/EC02/2016).

Informed Consent: Retrospective study.

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Authorship Contributions

Surgical and Medical Practices: V.K., Concept: M.P., Design: M.P., Data Collection or Processing: V.K., Analysis or Interpretation: R.S., C.R.S., S.A., Literature Search: V.K., R.S., C.R.S., S.A., Writing: V.K., S.A.

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