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"Evaluating Maxillary Buccal Posterior Cortical Bone Thickness: A Cbct Study of Average and Vertical Growth Patterns in Orthodontics"

[1]Dr. Yati Mehta, [2]Dr. Renuka Patel, [3]Dr. Falguni Mehta, [4]Dr. Jitiksha Dhodi, [5]Dr. Ronit Kumar Tiwari, [6]Dr. Taniya Khandelwal

[1]Post Graduate student – Government Dental College and Hospital – Ahmedabad.

[2]Professor– Government Dental College and Hospital – Ahmedabad.

[3]Professor and Head of the department – Government Dental College and Hospital – Ahmedabad.

[4]Post Graduate student -Government Dental College and Hospital – Ahmedabad.

[5]Post Graduate student –Government Dental College and Hospital – Ahmedabad.

[6]Post Graduate student – Government Dental College and Hospital – Ahmedabad.

Corresponding Author:Dr. Jitiksha Dhodi

Post Graduate student – Government Dental College and Hospital – Ahmedabad.

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KEYWORDS

Skeletal anchorage, TADs, Cortical bone thickness, Maxillary posterior teeth.

ABSTRACT:

Introduction: Orthodontic skeletal anchorage enables the clinician to proceed with absolute anchorage during treatment. Cortical bone thickness is considered a determinant factor for the primary stability of TADs. Vertical facial morphology is important for the orthodontist, since it affects the goals and the approach of orthodontic treatment by having an effect on the growth & anchorage system also. The purpose of this study was to assess and compare the cortical bone thickness in the maxillary buccal posterior region in average and vertical growth pattern subjects for orthodontic implants.

Materials and Methods:

A total of 60 subjects were selected for CBCT images. 30 subjects in group A- Average Growth pattern (14 males and 16 females) & 30 subjects in group B- Vertical Growth pattern (14 males and 16 females). CBCT scans of the maxilla were taken in a VATECH machine. For all scans, the standard protocol was 95 kV, 8 mA, 12 × 10 cm field of view, 0.30 mm voxel size, and scanning time of 11-17 seconds. The CBCT images were analyzed using CS imaging software & bone thickness was measured in the maxillary buccal posterior region. Data were collected and analyzed using independent t test, Shapiro Wilk test, One-way ANOVA test, and Bonferroni post-hoc test.

Results: Both group A and group B showed significant differences on comparing inter-radicular cortical bone thickness between 4&5, 5&6, and 6&7 regions at different heights and different angles, between 5 & 6region had the maximum thickness followed by 6 & 7 region and then 4 & 5 region and group A showed greater values than group B from maxillary occlusal plane.

Conclusion: The desirable site for orthodontic TADs placement, stability & success rate may be between the 2nd premolar & 1st molar then 1st molar & 2nd molar, and 1st premolar & 2nd premolar respectively from maxillary occlusal plane.

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Introduction:

Orthodontic skeletal anchorage enables the clinician to proceed with absolute anchorage during treatment.[1] The growing demand for minimum compliance and maximum curative effects has made temporary anchorage devices (TADs) more promising as an excellent alternative to traditional orthodontic anchorage,[1] which are mostly placed in the palate, retromolar mandibular area, buccal interradicular alveolar areas etc. TADs must be successfully implanted at the intended site in clinical practice. Several studies have investigated & mapped the cortical bone thicknesses at probable sites for TAD placement in patients using CBCT because of its low radiation exposure, short scanning time, and high resolution.[2]

Several local anatomical factors such as age, sex, craniofacial skeletal pattern, site, latent period, loading protocol, TAD dimension and angulation, insertion torque, degree of TAD-bone contact, quality and quantity of the cortical bone, degree of peri-TAD tissue inflammation, thickness and mobility of the soft tissue, and root proximity must be taken into account for TAD stability;[3] a single factor cannot determine the best placement site but an understanding of the cortical bone thickness in the maxilla and mandible has descriptive benefits & clinical implications as well.

Cortical bone thickness is considered a determinant factor for the primary stability of TADs & greater thickness of the cortical bone is suggested to be associated with greater chances of primary stability and, consequently, a better success rate.[4] Researchers have discovered that cortical bone thickness varies across patients with different facial characteristics. Facial morphology plays a key role in orthodontics, influencing growth prediction, anchorage, and treatment goals.[5]

Vertical facial morphology is important for the orthodontist, since it affects the goals and the approach of orthodontic treatment by having an effect on the growth & anchorage system also.[1] Some of the evidence- based studies correlate cortical bone thickness and growth pattern, and showed that subjects with vertical growth pattern present thinner cortical bone than subjects with normal or horizontal growth. These analogues could lead to the speculation that the vertical growth pattern could have some influence on the stability and success rate of mini-implants. However, few studies have evaluated this direct association and the findings are controversial.[4] Therefore, the present cross-sectional study is based on correlating craniofacial morphology & cortical bone thickness in the maxillary buccal posterior region using CBCT to accommodate various clinical scenarios among subjects with average and vertical facial dimensions.

Materials and Methods:

A clinical study was conducted in the institute in the Department of Orthodontics and Dentofacial Orthopedics after getting clearance from the ethical committee of the institute. All ethical guidelines were followed and written informed consent was taken from the patients who were selected for the study.

Total 60 subjects, aged 18-25 years, were chosen for CBCT images. 30 subjects in group A (14 males and 16 females) & 30 subjects in group B (14 males and 16 females) were divided based on Jarabak's ratio, SN-GoGn angle [sella- nasion to gonion-gnathion] (C. Steiner 1953), Frankfort mandibular plane angle(a line tangent to the lower border of the mandible and the F-H plane) – GROUP A: Participants with average growth pattern growth pattern (FMA -22◦-28°; GoGn-SN-32◦; Jarabak's ratio-62-65%); GROUP B: Participants with vertical growth pattern(FMA >28◦, GoGn-SN>32◦; Jarabak's ratio<62%).

The inclusion criteria were as follows: Subjects between 18-25 years of age with presence of all permanent teeth, without any apparent facial asymmetry, occlusal cant & systemic disturbances for pretreatment lateral cephalogram were selected. The exclusion criteria were subjects who had Endodontic-Periodontal diseases, previous history of trauma, Congenital and Craniofacial deformities, TMJ disorders, history of bruxism and attrition.

CBCT scan of maxilla were taken in a VATECH machine. For all scans, standard protocol was 95 kV, 8 mA, 12 × 10 cm field of view, 0.30 mm voxel size, and scanning time of 11-17 seconds. The CBCT images which were stored in Digital Imaging and Communications in Medicine (DICOM) format were analyzed using **CS imaging software.** A fully reconstructed three-dimensional image with sagittal, coronal and axial planes of the maxilla was generated and the following measurements were taken with different

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horizontal reference plane (maxillary occlusal plane) on both right and left sides to be computed.

On the selected coronal slice, reference lines were drawn to evaluate the cortical bone thickness in the maxillary posterior region. The horizontal reference line corresponded to the maxillary occlusal plane, defined as the plane passing through the mesiobuccal cusps of both maxillary molars and the buccal cusp tips of both premolars. The vertical reference line bisected the interdental space and was aligned parallel to the long axis of the premolars and molars. Cortical bone thickness was measured at heights of 12 mm, 14 mm, and 16 mm from the maxillary occlusal plane, and at angles of 45°, 60°, 70°, and 80°. The Zsigmondy-Palmer notation system was used to designate the measurement sites: between the first and second premolars (4 & 5), between the second premolar and first molar (5 & 6), and between the first and second molars (6 & 7) on both the right and left sides.

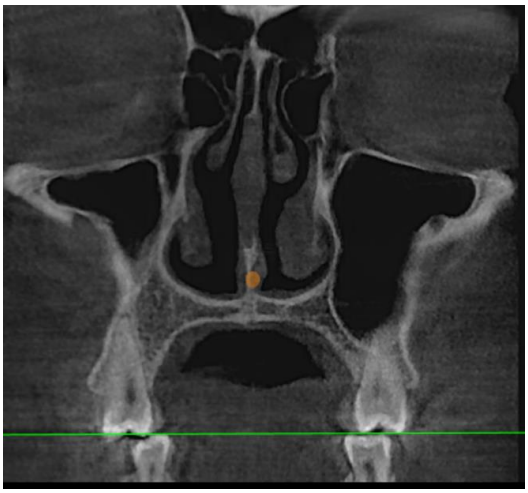


Fig. 1 Horizontal reference line- maxillary occlusal plane

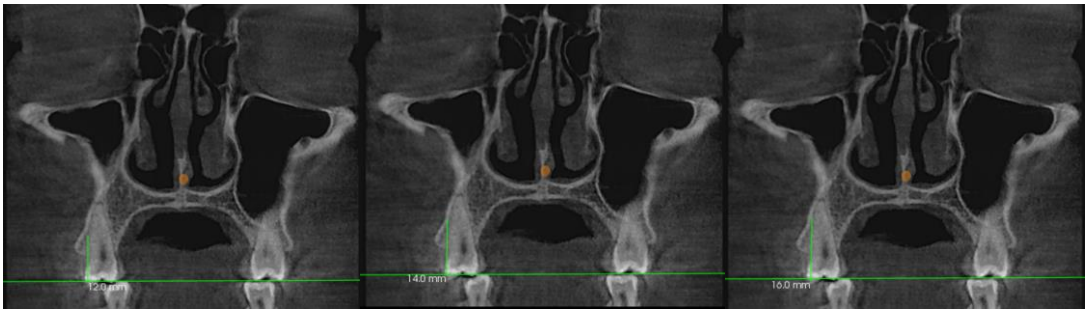
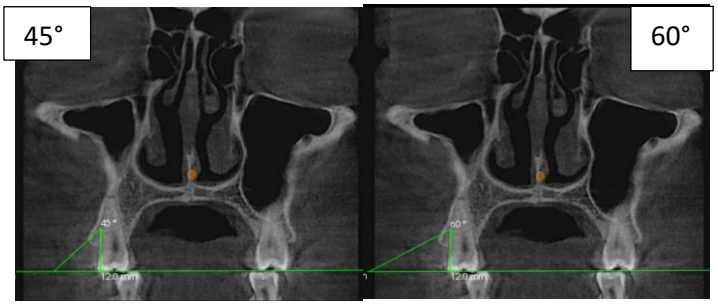


Fig. 2 Cortical bone thickness at 12mm, 14mm, 16mm in coronal view from Maxillary occlusal plane



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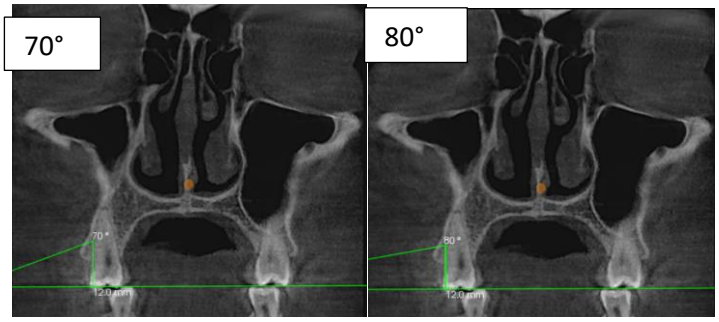

Fig. 3 Cortical bone thickness at 12mm height at angle of 45 º, 60 º, 70 º, 80º from Maxillary occlusal plane

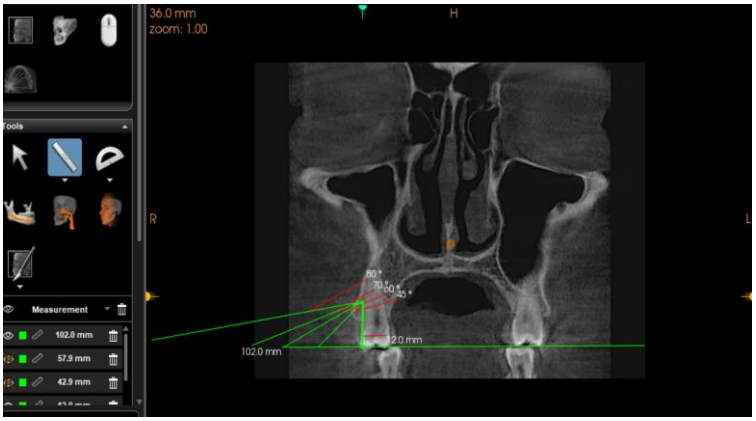

Fig. 4 Cortical bone thickness at 12mm from Maxillary occlusal plane at angle 45º, 60º,70 º& 80 º

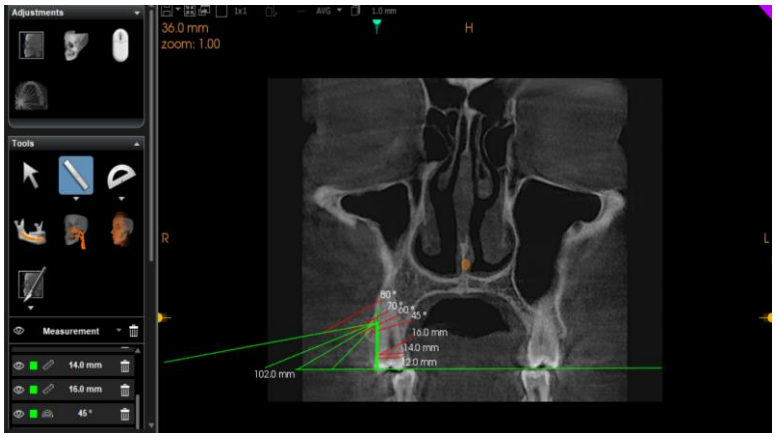

Fig. 5 Cortical bone thickness at 12mm, 14mm & 16mm from Maxillary occlusal plane at different angles 45º, 60 º, 70 º& 80 º

Data was analyzed using the statistical package **SPSS 26.0** (SPSS Inc., Chicago, IL) and level of significance was set at **p<0.05**. **Descriptive statistics** was performed to assess the mean and standard deviation of the respective groups. Normality of the data was assessed using **Shapiro Wilk test**. **Inferential statistics** to find out the difference between the groups was done using **Independent t test** and within group comparison was done using **One way ANOVA test** followed by **Bonferroni posthoc test.**

Results:

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Results showed overall cortical bone thickness of maxillary posterior region across various anatomical sites. Statistically highly significant difference was found on comparing inter-radicular cortical bone thickness between 4&5 (1st premolar & 2nd premolar), 5&6 (2nd premolar & 1st molar), and 6&7(1st molar & 2nd molar) regions at different heights and at different angles, average growth pattern having more values than vertical growth pattern subjects. Furthermore, on comparing at various sites in both the groups, between 5 & 6(2nd premolar & 1st molar) region had the maximum thickness followed by 6 & 7 (1st molar & 2nd molar) region and then 4 & 5(1st premolar & 2nd premolar) region.

Among all angulations, in the 4 & 5 region, Group A exhibited the thickest cortical bone at 16 mm with a 45° angle (1.57 ± 0.09 mm), whereas Group B had the least thickness at 80° at 12 mm (0.30 ± 0.03 mm).

In the 5 & 6 region, Group A demonstrated the thickest cortical bone across all angulations at a 45° angle, with measurements of 16 mm (1.97 ± 0.12 mm), 14 mm (1.72 ± 0.11 mm), and 12 mm (1.57 ± 0.08 mm). Conversely, Group B showed the thinnest cortical bone at 80° at 12 mm (0.64 ± 0.05 mm).

In the 6 & 7 region, Group A also recorded the thickest cortical bone at a 45° angle, with values of 16 mm (1.72 ± 0.11 mm), 14 mm (1.52 ± 0.08 mm), and 12 mm (1.35 ± 0.07 mm). However, in Group B, the cortical bone was thinner at 80°, measuring 12 mm (0.45 ± 0.04 mm), 14 mm (0.60 ± 0.00 mm), and 16 mm (0.84 ± 0.05 mm), respectively.

Cortical bone thickness increases as height increases and decreases as angle increases from the maxillary occlusal plane (more at 16mm than 14mm and 12mm) as reference plane. Inter-radicular maxillary buccal cortical bone thickness appears to vary in a distinctive pattern. Non-significant differences were observed when the right and left sides were compared.

TABLE I(a)-COMPARING CORTICAL BONE THICKNESS BETWEEN 4&5 AT 12 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A (mm)	GROUP B (mm)	MEAN DIFFERENCE	**P VALUE (T TEST)**	GROUP A	GROUP B	MEAN DIFFERENCE	**P VALUE (T TEST)**
45^0	**1.20±0.04**	**0.75±0.12**	**0.45±0.10**	**0.0001*(t=19.48)**	**1.20±0.04**	**0.75±0.12**	**0.45±0.08**	**0.0001*(t=19.48)**
60^0	**1.09±0.07**	**0.52±0.09**	**0.57±0.08**	**0.0001*(t=27.38)**	**1.09±0.07**	**0.52±0.09**	**0.57±0.08**	**0.0001*(t=27.38)**
70^0	**1.05±0.07**	**0.49±0.09**	**0.56±0.08**	**0.0001*(t=26.90)**	**1.05±0.07**	**0.49±0.09**	**0.56±0.08**	**0.0001*(t=26.90)**
80^0	**0.90±0.12**	**0.30±0.03**	**0.60±0.06**	**0.0001*(t=26.56)**	**0.90±0.12**	**0.30±0.03**	**0.60±0.06**	**0.0001*(t=26.56)**
P VALUE (ONE WAY ANOVA TEST)	**0.0001***	**0.0001***			**0.0000**	**-0.0000**		
45^0 vs 60^0	**0.0001***	**0.0001***	**POST HOC TEST(BONFERRONI TEST) P VALUE**		**0.0001***	**0.0001***		
45^0 vs 70^0	**0.0001***	**0.0001***			**0.0001***	**0.0001***		
45^0 vs 80^0	**0.0001***	**0.0001***			**0.0001***	**0.0001***		
60^0 vs 70^0	**0.22**	**0.55**			**0.22**	**0.55**		

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60^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		

TABLE I(b)- COMPARING CORTICAL BONE THICKNESS BETWEEN 4&5 AT 14 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.40±0.08	0.85±0.04	0.55±0.06	0.0001*(t=33.68)	1.40±0.08	0.85±0.04	0.55±0.06	0.0001* (t=33.68)
60^0	1.28±0.09	0.69±0.04	0.59±0.6	0.0001*(t=32.81)	1.28±0.09	0.69±0.04	0.59±0.07	0.0001* (t=6.79)
70^0	1.24±0.10	0.65±0.04	0.59±0.08	0.0005*(t=3.67)	1.24±0.10	0.65±0.05	0.59±0.08	0.0001* (t=28.90)
80^0	1.08±0.04	0.45±0.06	0.63±0.05	0.0001*(t=12.62)	1.08±0.04	0.44±0.06	0.64±0.05	0.0001* (t=12.62)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.22	0.005*			0.22	0.005*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE I(c)- COMPARING CORTICAL BONE THICKNESS BETWEEN 4&5 AT 16 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.57±0.09	1.01±0.03	0.56±0.07	0.0001*(t=32.33)	1.57±0.08	1.01±0.03	0.56±0.05	0.0001*(t=35.89)
60^0	1.49±0.09	0.91±0.06	0.58±0.08	0.0001*(t=29.36)	1.49±0.09	0.91±0.06	0.58±0.07	0.0001*(t=29.36)

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70^0	1.40±0.06	0.88±0.04	0.52±0.05	0.0001*(t=39.49)	1.40±0.06	0.88±0.04	0.52±0.05	0.0001*(t=39.49)
80^0	1.17±0.08	0.65±0.05	0.52±0.07	0.0001*(t=30.19)	1.17±0.08	0.65±0.05	0.52±0.07	0.0001*(t=39.49)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0012*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.0002*	0.06			0.0002*	0.06		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE II(a)- COMPARING CORTICAL BONE THICKNESS BETWEEN 5&6 AT 12 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.57±0.08	1.01±0.10	0.56±0.09	0.0001*(t=23.95)	1.57±0.08	1.00±0.10	0. 56±0.09	0.0001*(t=23.95)
60^0	1.45±0.14	0.94±0.06	0.51±0.10	0.0001*(t=18.33)	1.45±0.14	0.94±0.06	0.51±0.10	0.0001*(t=18.33)
70^0	1.35±0.05	0.84±0.06	0.51±0.05	0.0001*(t=35.76)	1.35±0.05	0.84±0.06	0.51±0.05	0.0001*(t=35.76)
80^0	1.13±0.06	0.64±0.05	0.49±0.05	0.0001*(t=34.36)	1.13±0.06	0.64±0.05	0.49±0.05	0.0001*(t=34.36)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.0002*	0.0001*			0.0002*	0.0001*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

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70^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE II(b)- COMPARING CORTICAL BONE THICKNESS BETWEEN 5&6 AT 14 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.72±0.11	1.17±0.14	0.55±0.12	0.0001*(t=16.91)	1.72±0.11	1.17±0.14	0.55±0.12	0.0001*(t=16.91)
60^0	1.58±0.13	1.03±0.06	0.55±0.09	0.0001*(t=21.04)	1.58±0.13	1.03±0.06	0.55±0.10	0.0001*(t=21.04)
70^0	1.50±0.07	0.95±0.08	0.55±0.07	0.0001*(t=28.33)	1.50±0.07	0.95±0.08	0.55±0.07	0.0001*(t=28.33)
80^0	1.16±0.10	0.75±0.05	0.41±0.08	0.0001*(t=20.08)	1.16±0.10	0.75±0.05	0. 41±0.08	0.0001*(t=20.08)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.01*	0.0042*			0.01*	0.004*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE II(c)- COMPARING CORTICAL BONE THICKNESS BETWEEN 5&6 AT 16 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.97±0.12	1.44±0.13	0.53±0.12	0.0001*(t=16.40)	1.97±0.12	1.44±0.13	0.53±0.12	0.0001*(t=16.40)
60^0	1.84±0.17	1.28±0.10	0.56±0.14	0.0001*(t=15.55)	1.84±0.17	1.28±0.10	0.56±0.14	0.0001*(t=15.55)

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70^0	1.71±0.11	1.25±0.08	0.46±0.10	0.0001*(t=18.52)	1.71±0.11	1.25±0.08	0.46±0.09	0.0001*(t=18.52)
80^0	1.37±0.12	1.04±0.05	0.33±0.08	0.0001*(t=13.90)	1.37±0.12	1.05±0.05	0.33±0.09	0.0001*(t=13.90)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.001*	0.61			0.001*	0.61		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE III(a)- COMPARING CORTICAL BONE THICKNESS BETWEEN 6&7 AT 12 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.35±0.07	0.84±0.08	0.51±0.07	0.0001*(t=26.27)	1.35±0.07	0.84±0.08	0.51±0.07	0.0001*(t=26.27)
60^0	1.24±0.09	0.78±0.04	0.46±0.06	0.0001*(t=25.58)	1.24±0.09	0.78±0.03	0.46±0.07	0.0001*(t=26.55)
70^0	1.20±0.08	0.66±0.05	0.54±0.07	0.0001*(t=31.35)	1.20±0.08	0.66±0.05	0.54±0.07	0.0001*(t=31.35)
80^0	1.00±0.01	0.45±0.04	0.55±0.02	0.0001*(t=73.06)	1.00±0.01	0.45±0.04	0.55±0.02	0.0001*(t=73.06)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		

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45^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		
60^0 vs 70^0	0.12	0.0001*		0.12	0.0001*		
60^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE III(b)- COMPARING CORTICAL BONE THICKNESS BETWEEN 6&7 AT 14 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.52±0.08	0.96±0.07	0.56±0.07	0.0001*(t=28.85)	1.52±0.08	0.96±0.07	0.56±0.07	0.0001*(t=28.85)
60^0	1.45±0.09	0.80±0.02	0.65±0.04	0.0001*(t=38.61)	1.45±0.09	0.80±0.02	0.65±0..07	0.0001*(t=38.61)
70^0	1.33±0.10	0.79±0.01	0.54±0.05	0.0001*(t=29.43)	1.33±0.10	0.79±0.01	0.54±0.05	0.0001*(t=29.43)
80^0	1.06±0.11	0.6±0	0.46±0.05	0.0001*(t=22.90)	1.06±0.11	0.6±0	0.46±0.05	0.0001*(t=22.90)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.02*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.02*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.0001*	0.71			0.0001*	0.71		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE III(c)- COMPARING CORTICAL BONE THICKNESS BETWEEN 6&7 AT 16 mm FROM OCCLUSAL PLANE

	LEFT				RIGHT			
	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)	GROUP A	GROUP B	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.72±0.11	1.22±0.11	0.49±0.11	0.0001*(t=17.25)	1.71±0.11	1.22±0.11	0.49±0.11	0.0001*(t=17.25)
60^0	1.62±0.16	1.13±0.12	0.49±0.14	0.0001*(t=13.41)	1.62±0.16	1.13±0.12	0.49±0.14	0.0001*(t=13.41)

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70^0	1.54±0.10	1.04±0.06	0.5±0.07	0.0001*(t=23.48)	1.54±0.10	1.04±0.06	0.5±0.07	0.0001*(t=23.48)
80^0	1.22±0.16	0.84±0.05	0.38±0.10	0.0001*(t=12.41)	1.22±0.16	0.84±0.04	0.38±0.10	0.0001*(t=12.62)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.05	0.001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.05	0.001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.10	0.001*			0.10	0.001*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE VII(a)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 4&5 REGION AT 12 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE(T TEST)
45^0	1.20±0.04	1.20±0.04	0±0.04	1(t=0)	0.75±0.12	0.75±0.12	0±0.12	1(t=0)
60^0	1.09±0.07	1.09±0.07	0±0.07	1(t=0)	0.52±0.09	0.52±0.09	0±0.09	1(t=0)
70^0	1.05±0.07	1.05±0.07	0±0.07	1(t=0)	0.49±0.09	0.49±0.09	0±0.09	1(t=0)
80^0	0.90±0.12	0.90±0.12	0±0.12	1(t=0)	0.30±0.03	0.30±0.03	0±0.03	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.22	0.22			0.55	0.55		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

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TABLE VII(b)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 4&5 REGION AT 14 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE(T TEST)
45^0	1.40±0.08	1.40±0.08	0±0.08	1(t=0)	0.85±0.04	0.85±0.04	0±0.04	1(t=0)
60^0	1.28±0.09	1.28±0.09	0±0.09	1(t=0)	0.69±0.04	0.69±0.04	0±0.04	1(t=0)
70^0	1.24±0.10	1.24±0.10	0±0.10	1(t=0)	0.65±0.04	0.65±0.05	0±0.05	1(t=0)
80^0	1.08±0.04	1.08±0.04	0±0.04	1(t=0)	0.45±0.06	0.44±0.06	0.01±0.06	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.22	0.22			0.005*	0.005*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE VII(c)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 4&5 REGION AT 16 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE(T TEST)
45^0	1.57±0.09	1.57±0.09	0±0.09	1(t=0)	1.01±0.03	1.01±0.03	0±0.03	1(t=0)
60^0	1.49±0.09	1.49±0.09	0±0.09	1(t=0)	0.91±0.06	0.91±0.06	0±0.06	1(t=0)
70^0	1.40±0.06	1.40±0.06	0±0.06	1(t=0)	0.88±0.04	0.88±0.04	0±0.04	1(t=0)
80^0	1.17±0.08	1.17±0.08	0±0.08	1(t=0)	0.65±0.05	0.65±0.05	0±0.05	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.001*	0.001*			0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		

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45^0 vs 80^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE	0.0001*	0.0001*		
60^0 vs 70^0	0.0002*	0.0002*		0.06	0.06		
60^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*		0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE VIII(a)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 5&6 REGION AT 12 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.57±0.08	1.57±0.08	0±0.08	1(t=0)	1.01±0.10	1.00±0.10	0.01±0.10	1(t=0)
60^0	1.45±0.14	1.45±0.14	0±0.14	1(t=0)	0.94±0.06	0.94±0.06	0±0.06	1(t=0)
70^0	1.35±0.05	1.35±0.05	0±0.05	1(t=0)	0.84±0.06	0.84±0.06	0±0.06	1(t=0)
80^0	1.13±0.06	1.13±0.06	0±0.06	1(t=0)	0.64±0.05	0.64±0.05	0±0.05	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.0002*	0.0002*			0.0001*	0.0001*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE VIII(b)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 5&6 REGION AT 14 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE(T TEST)
45^0	1.72±0.11	1.72±0.11	0±0.11	1(t=0)	1.17±0.14	1.17±0.14	0±0.14	1(t=0)
60^0	1.58±0.13	1.58±0.13	0±0.13	1(t=0)	1.03±0.06	1.03±0.06	0±0.06	1(t=0)

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70^0	1.50±0.07	1.50±0.07	0±0.07	1(t=0)	0.95±0.08	0.95±0.08	0±0.08	1(t=0)
80^0	1.16±0.10	1.16±0.10	0±0.10	1(t=0)	0.75±0.05	0.75±0.05	0±0.05	1(t=0)
P VALUE (FRIEDMAN TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.01*	0.01*			0.004*	0.004*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE VIII(c)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE IN 5&6 REGION AT 16 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE(T TEST)
45^0	1.97±0.12	1.97±0.12	0±0.12	1(t=0)	1.44±0.13	1.44±0.13	0±0.13	1(t=0)
60^0	1.84±0.17	1.84±0.17	0±0.17	1(t=0)	1.28±0.10	1.28±0.10	0±0.10	1(t=0)
70^0	1.71±0.11	1.71±0.11	0±0.11	1(t=0)	1.25±0.08	1.25±0.08	0±0.08	1(t=0)
80^0	1.37±0.12	1.37±0.12	0±0.12	1(t=0)	1.04±0.05	1.05±0.05	0.01±0.05	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.001*	0.001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.001*	0.001*			0.61	0.61		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

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TABLE IX(a)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE 6&7 REGION AT 12 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.35±0.07	1.35±0.07	0±0.7	1(t=0)	0.84±0.08	0.84±0.08	0±0.08	1(t=0)
60^0	1.24±0.09	1.24±0.09	0±0.09	1(t=0)	0.78±0.04	0.78±0.03	0±0.03	1(t=0)
70^0	1.20±0.08	1.20±0.08	0±0.08	1(t=0)	0.66±0.05	0.66±0.05	0±0.05	1(t=0)
80^0	1.00±0.01	1.00±0.01	0±0.01	1(t=0)	0.45±0.04	0.45±0.04	0±0.04	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.0001*	0.0001*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0003*	0.0003*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.12	0.12			0.0001*	0.0001*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE IX(b)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE 6&7 REGION AT 14 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.52±0.08	1.52±0.08	0±0. 08	1(t=0)	0.96±0.07	0.96±0.07	0±0.07	1(t=0)
60^0	1.45±0.09	1. 45±0.09	0±0.09	1(t=0)	0.80±0.02	0.80±0.02	0±0.02	1(t=0)
70^0	1.33±0.10	1.33±0.10	0±0.10	1(t=0)	0.79±0.01	0.79±0.01	0±0.01	1(t=0)
80^0	1.06±0.11	1.06±0.11	0±0.11	1(t=0)	0.6±0	0.6±0	0±0	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.02*	0.02*	POST HOC TEST(BONFERRONI TEST) P VALUE		0.0001*	0.0001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.0001*	0.0001*			0.71	0.71		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

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*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

TABLE IX(c)- CORTICAL BONE THICKNESS DIFFERENCES BETWEEN RIGHT AND LEFT SIDE 6&7 REGION AT 16 mm FROM OCCLUSAL PLANE

	GROUP A				GROUP B			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
45^0	1.71±0.11	1.71±0.11	0±0.11	1(t=0)	1.22±0.11	1.22±0.11	0±0.11	1(t=0)
60^0	1.62±0.16	1.62±0.16	0±0.16	1(t=0)	1.13±0.12	1.13±0.12	0±0.12	1(t=0)
70^0	1.54±0.10	1.54±0.10	0±0.10	1(t=0)	1.04±0.06	1.04±0.06	0±0.06	1(t=0)
80^0	1.22±0.16	1.22±0.16	0±0.16	1(t=0)	0.84±0.05	0.84±0.04	0±0.04	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 60^0	0.05	0.05	POST HOC TEST(BONFERRONI TEST) P VALUE		0.001*	0.001*		
45^0 vs 70^0	0.0001*	0.0001*			0.0001*	0.0001*		
45^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
60^0 vs 70^0	0.10	0.10			0.001*	0.001*		
60^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		
70^0 vs 80^0	0.0001*	0.0001*			0.0001*	0.0001*		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

Table X(a)- GROUP A- OCCLUSAL (OVERALL SITES)

	OCCLUSAL PLANE			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
4&5	1.37±0.22	1.14±0.14	0.23±0.20	0.0001*(t=4.84)
5&6	1.53±0.23	1.43±0.16	0.10±0.19	0.04*(t=1.95)
6&7	1.35±0.25	1.35±0.21	0±0.23	1(t=0)
P VALUE (ONE WAY ANOVA TEST)	0.01*	0.0001*		
4& 5 vs 5&6	0.02*	0.0001*		
4&5 vs 6&7	0.94	0.0001*		
5&6 vs 6&7	0.01*	0.17		

*P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

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Table X(b)- GROUP B-OCCLUSAL (OVERALL SITES)

	OCCLUSAL PLANE			
	LEFT	RIGHT	MEAN DIFFERENCE	P VALUE (T TEST)
4&5	**0.68±0.20**	**0.68±0.19**	**0±013**	**1(t=0)**
5&6	**1.03±0.28**	**1.03±0.15**	**0±0.12**	**1(t=0)**
6&7	**0.84±0.30**	**0.84±0.19**	**0±0.16**	**1(t=0)**
P VALUE (ONE WAY ANOVA TEST)	**0.0001***	**0.0001***		
4& 5 vs 5&6	**0.0001***	**0.0001***		
4&5 vs 6&7	**0.0001***	**0.0001***		
5&6 vs 6&7	**0.17**	**0.17**		

***P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)**

Discussion:

Skeletal anchorage with mini-implant screws is widely used in orthodontic practice today because it provides *absolute anchorage*. Orthodontic treatment may be simplified without complex appliances for preserving anchorage. Better control of tooth movement is available with skeletal anchorage appliances by combining biomechanical principles (Sugawara et al. 1998; Erverdi et al. 2002; Giancotti et al. 2002; Maino et al. 2002; Park et al. 2002, 2005).[6] The primary implant stability of orthodontic implants can be assessed by CBCT for cortical bone thickness and density before treatment.

Some studies focused on posterior sites in the maxilla and mandible where TADs are generally placed, the safest zone in the inter-radicular space of the posterior maxilla was between the second premolar and the first molar at all heights for all facial growth patterns.[7] Kim stated that the stability of miniscrew implants depends on the quality (bone density) and quantity (bone volume) of the cortical bone. [8] The main objective of an orthodontic screw is to gain maximum retention by placing the screw in an area with the thinnest soft tissue and the thickest cortical bone. Previous studies have examined the relationship between facial divergence and cortical bone thickness.[8]

In addition, most of the studies showed associations between cortical bone thickness and vertical growth pattern, that subjects with vertical growth pattern present thinner cortical bone, when compared with normal or horizontal growth.[1,4,7,8] However, only a few studies have evaluated this direct association and the findings are controversial.[9] Therefore, more studies are needed to confirm this association. The same results were found by Tsunori M et al., and by Turkyilmaz I et al., that the cortical bone thickness is associated with the facial type.[10] Based on this controversy and because cortical bone thickness could depend on the growth pattern, and it is considered an important factor related to mini-implant stability. For this reason, the primary objective of this present cross-sectional study was to evaluate the influence of the growth patterns on cortical bone thickness in the maxillary posterior region at different heights and angles using CBCT in average and vertical growth pattern subjects, which has been grouped based on cephalometric parameters from pre-treatment lateral cephalogram.

In Average growth pattern (Group A), in 4&5, 5&6 and 6&7 region, cortical bone thickness was more at 45° and less at 80° at 12mm, 14mm and 16mm height, but it varied with different heights and angles and it was observed that as height increases from occlusal plane, thickness was gradually increasing. Ono et al. in 2008 showed similar findings that the greater the height, the thicker the cortical bone tended to be.[11] Liou et al. and Baungaertel and Hans in their studies also reported that thickness decreases as the distance from the occlusal plane increases.[12,13]

Likewise, in Vertical growth pattern (Group B), for all sites, cortical bone thickness was more at 45° and less at 80° at 12mm, 14mm and 16mm height from occlusal plane. Qinxuan Song et al. in 2022 also found that the CBT was similar among different insertion sites in all insertion angles except 40, 50 and 70 degrees with reference to maxillary occlusal plane.[14] *Deguchi et al.*

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in 2006 also found that in the buccal region of the maxilla, average cortical thicknesses were 2.0 ± 0.8 mm, 1.5 ± 0.6 mm, and 1.2 ± 0.5 mm at 30°, 45°, and 90°, respectively. Significantly more cortical thickness was observed at 30° than at 45° ($p < 0.0001$) and 90° ($p < 0.0001$).[15] *Liou et al. in 2007* found that the clinical implication for miniscrew insertion in the IZ crest of adults is 14 to 16 mm above the maxillary occlusal plane and the maxillary first molar, and at an angle of 55° to 70° to the maxillary occlusal plane.[13] *Saif et al. in 2022* concluded that for minimum bone support of 3mm at infrazygomatic bone crest & safe placement of screw without injuring distobuccal root, the miniscrew should be inserted at an angle of 55° to 70° at distances of 16mm to 18mm from maxillary occlusal plane.[16] *Arathi et al. in 2020* derived the conclusion that the best possible site for miniscrew insertion is 12 to 17 mm above the occlusal plane at an angle of 65° to 70°, with no injury to the adjacent anatomical structures, no mucosal irritation and adequate stability for the miniscrew.[17] *Dangal et al. in 2022* concluded that infrazygomatic crest thickness increases with the increase in insertion angle and the decrease in height. The optimal site for miniscrew placement in IZC of an adult is at an angle of 70° and 13 mm from the occlusal plane.[18]

Another clinically related important fact is that high angle subjects had more sites with cortical bone thickness less than 1 mm, which can increase the risk of failure of mini-implants placed at these sites according to *Motoyoshi et al*.[19]

On comparing cortical bone thickness between average and vertical growth pattern subjects, group A (average growth pattern) had higher values at all heights and at all sites however, it was found more between 5&6 region then 6&7 region and 4&5 region respectively when considering maxillary occlusal plane as reference plane. Fransworth et al in 2011 showed that with the vertical level of 4mm apical to the crest of the alveolar bone; the 2-3 site was significantly thinner than the 4-5 and 5-6 sites; the 5-6 site were significantly thicker than the 4-5 and 6-7 sites.[20] *Deguchi et al* in 2006 found similar findings that thicker cortical bone at the 5-6 site than at the 6-7 site or at Point A.[15] *Mais et al.* in 2016 observed similar results that inter-radicular cortical bone was thinner in high-angle subjects, compared to the low- and normal-angle groups, at the vertical height from alveolar crest in which mini-implants are commonly inserted for skeletal anchorage.[9] *Gaffuri et. al in 2021* also found similar findings that in the anterior maxilla and practically everywhere else in the jaw, the alveolar bone of the hyperdivergent patients was thinner.[21] Clinicians should be aware of the likelihood of thinner cortical bone in high angle patients than to normal and low angle patients to reduce the risk of trauma or mini-implant failure.[15] *Ozdemir et al. in 2013* showed that with reference to alveolar crest, measured at 4mm; maximum thickness was observed in low angle patients between 6 & 7 region (1.62 ± 0.29mm) and minimum thickness was observed in high angle patients between 5 & 6 region (1.27±0.15mm). They found that cortical bone thickness of the jaws is closely related to vertical facial type. In all measurement sites, mandibular buccal, maxillary buccal, and maxillary palatal alveolar bones, cortical bone thickness in the low-angle subjects was significantly higher than in the high-angle subjects.[1]

In Average and Vertical Growth pattern, non-significant differences were found between right and left sides in cortical bone thickness in 4&5, 5&6 & 6&7 region at 5mm, 7mm & 9mm from maxillary occlusal plane.

The maxillary buccal alveolar area is the region where the orthodontist would face stability concerns in the high-angle group.[9] Clinicians should be aware of the likelihood of thin cortical bone in high-angle patients, as well as the risk of TAD failures.[9] The cortical bone thickness should be at least 1 mm for a mini-implant to be successful but some studies discovered less than 1mm of cortical bone in various areas across the maxilla.[19] One cause or reason for this is that in both adolescents and adults, the vertical growth pattern individuals have weak masticatory muscles which produce lesser biting forces, exerting less tension on the corresponding bones.[7] Knowledge of this pattern can aid clinicians in implant site selection and proper site preparation.

In our study, average and vertical growth pattern individuals were taken which should be considered when interpreting its findings thus reducing the relative distinctiveness of the groups and not considering the gender differences.

Conclusion:

The results demonstrated the desirable position for orthodontic implants. Thus, it suggested that the desirable site for orthodontic TADs placement, stability

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& success rate may be between 2nd premolar & 1st molar followed by 1st molar & 2nd molar, and 1st premolar & 2nd premolar respectively from maxillary occlusal plane at height of 16mm at 45º irrespective of different facial pattern. Statistically highly significant difference was found on comparing inter-radicular cortical bone thickness at different heights and different angles, with average growth pattern having more values than vertical growth pattern subjects. Non-significant differences were found between right and left sides in cortical bone thickness.

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