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Original Research

Comparative Assessment of Mandibular Buccal Shelf Characteristics in Different Facial Divergence - A Cone Beam Computed Tomography Study

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ABSTRACT:

Introduction: Temporary anchorage devices have expanded orthodontic treatment modalities, particularly in borderline surgical cases. Their stability is primarily dependent on cortical bone characteristics. The mandibular buccal shelf is considered an ideal extra-alveolar anchorage site due to its favourable bone quality. Variations in skeletal growth patterns may influence buccal shelfbone characteristics and thus TADs' stability. **Methods:** This cross-sectional CBCT study included 60 subjects aged 18–25 years, divided into hyperdivergent (Group A, n=30) and normodivergent (Group B, n=30) groups based on lateral cephalometric parameters (Jarabak's ratio, SellaNasion-GonionGnathion angle, and Y-axis). Cortical bone thickness was measured atmesial and distal aspects of first (M6,D6) and second (M7,D7) mandibular molars at 5, 8, and 12 mm from CEJ at insertion angles of 30°, 45°, 60°, and 90° on both sides and compared. Mandibular buccal shelf height was measured at 5 mm from CEJ. **Results:** Statistical analysis included descriptive statistics, Shapiro–Wilk test, Independent*t*-test, and one-way ANOVA with Bonferroni post-hoc test. Across all evaluated sites mean cortical bone thickness was greater in normodivergent subjects compared to hyperdivergent subjects with thickness increasing apically from CEJ and also varying with angulation. Buccal shelf height was also significantly greater in normodivergent group. No significant differences were observed between left and right. **Conclusion:** Buccal shelf bone characteristicsvarieswith growth pattern, site and angulation- increased distally M6<D6<M7<D7, which varied with different heights- 12mm>8mm>5mm. It also varied with different angulations at each height- 60°>45°>30°>90° in both groups.

Keyword: Orthodontics, Mandibular buccal shelf, Facial divergence, CBCT, TADs, Cortical bone thickness, Mandibular buccal shelf height

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INTRODUCTION

In recent years, with Temporary Anchorage Devices (TADs), orthodontic anchorage has been transformed and biomechanics has been simplified. Anatomical characteristics of the insertion site may affect the failure of TADs, along with the influence of factors like amount of bone, cortical bone thickness, bone density,[1] andproximity to vitalstructures, etc.[2-4]

The mandibularbuccal shelf (MBS) region is an innovative site forTADs due to its adequate bone thickness and density.[5]However, stability remains a challenge because TADs are often positioned on movable mucosa that covers the MBS.[6]Cortical bone thickness strongly affects the biomechanics of TADs, suchas insertion torque and stress distribution.[7] Generally, increased cortical bone thickness enhances primary stability and, consequently, a better success rate.[8]

Orthodontistsmust analyze vertical facial patterns and bone characteristics, as these dictate treatment goals and anchorage strategies.[9]Evidence-based studies correlated cortical bone thickness and growth pattern, and showed that subjects with vertical growth pattern had thinner cortical bone than those with average growth. This may suggest that growth pattern might impact the stability and success rate of mini-implants. However, research into this direct association remains limited, and the findings are controversial.[8]

Therefore, the present cross-sectional study is based on correlating craniofacial morphology & mandibular buccal shelf height and cortical bone thickness using CBCT to check various clinical scenarios among subjects with average and vertical facial divergence.

MATERIALS AND METHOD

The present study was carried out in the Department of Orthodontics And Dentofacial Orthopaedics. The ethical approval was obtained from the institutional ethics committee.

Sixty subjects (aged 18-25 years) were selected for Cone Beam Computed Tomography imaging.Table I shows the division of samples. Subjects were included with full set of permanent teeth, healthy periodontium, without apparent facial asymmetry, occlusal cant, or systemic disturbances, and had not undergone previous orthodontic or orthopedic intervention. Subjectswere excluded with endodontic-periodontal diseases, history of trauma, bruxism, attrition, congenital and craniofacial deformities, or Temporomandibular Joint disorders.

CBCT scan of mandible were taken in a VATECH machine. For all scans, scanning time was 18 seconds, with 94 kV, 7.7 mA, 12×10 cm field of view, 0.20 mm voxel size. The CBCT images which were stored in Digital Imaging and Communications in Medicine (DICOM) format were analyzed using CS 3D imaging software (v3.10.21). Measurements were taken for cortical bone thickness and buccal shelf height with a horizontal reference line (cemento-enamel junction) on both sides.

Each mandibular posterior quadrant was visualized in the multiplanar view- the axial plane was positioned tangent to CEJ of each of mandibular first and second molars on right side; the sagittal plane was positioned in center of the buccolingual width of alveolar process of 1st and 2nd molar, and the coronal plane was positioned parallel to long axis of theroot of molar being examined. The subsequent bone measurements were carried out on coronal section and oblique slicing in CBCT.

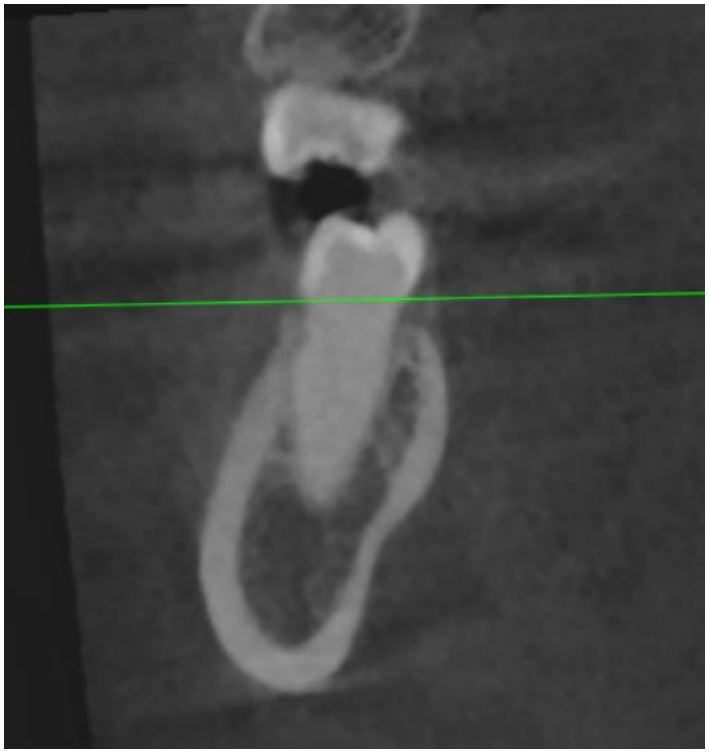

Figure1: Horizontal reference line- Cementoenamel Junction

Vertical reference lines were constructed parallel to long axis of the molars adjacent to the mesial of1st molar (M6), distal of the molar (D6), mesial of 2nd molar (M7), and distal of 2nd molar (D7).

- Cortical Bone Thickness:It was measured perpendicular to the CEJ at vertical heights of 5 mm, 8 mm, and 12 mm and at angulations of 30°, 45°, 60°, and 90°.

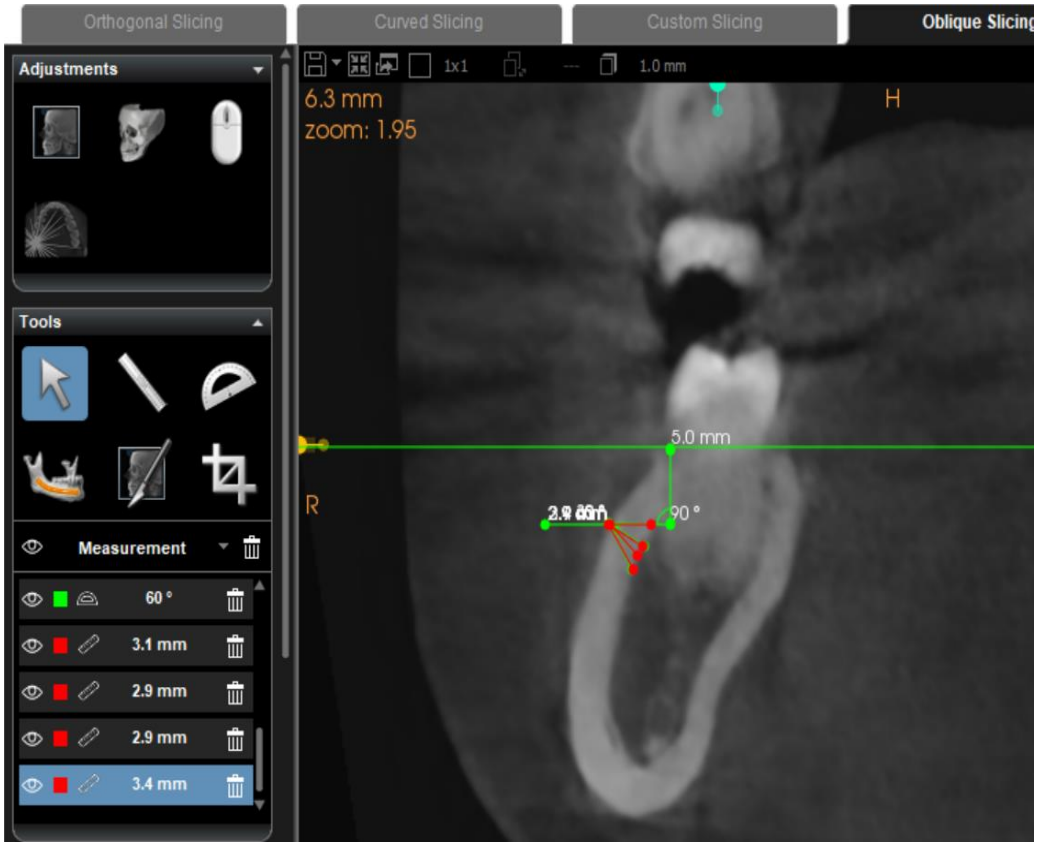

Figure 2: Cortical bone thickness at 5mm perpendicular from cementoenamel junction at angles 30º, 45º, 60º, & 90º.

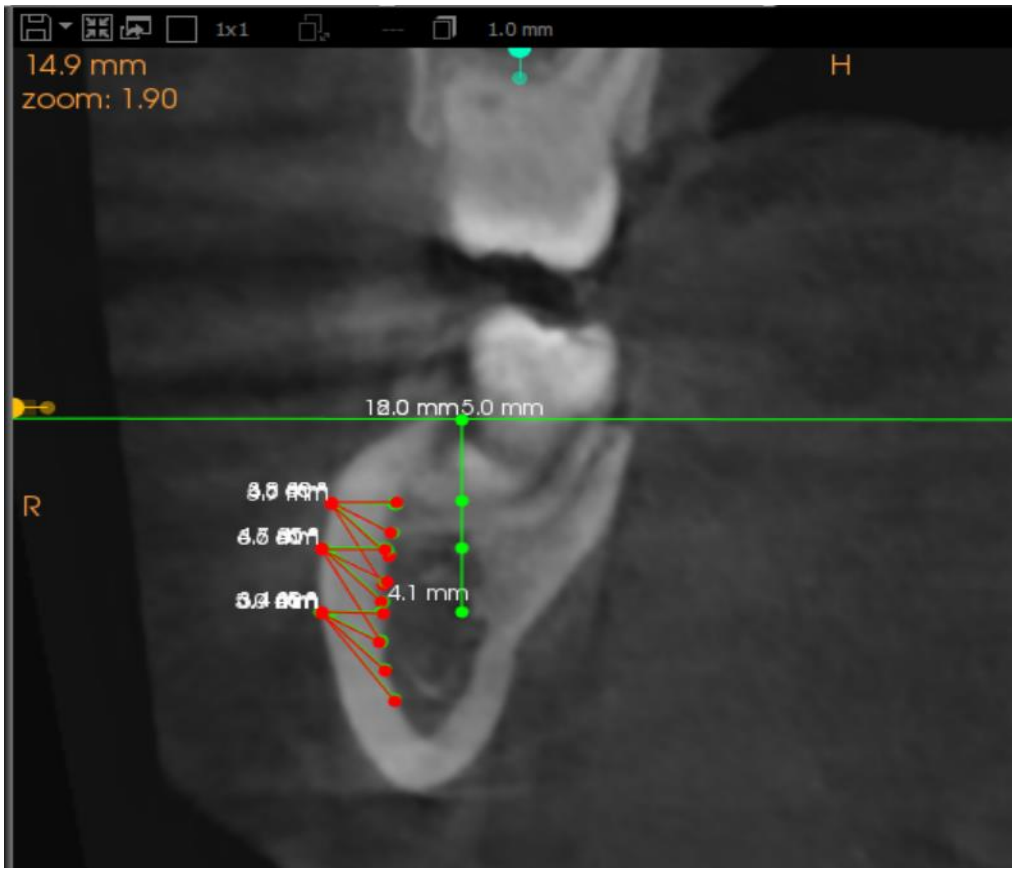

Figure 3: Cortical bone thickness at 5mm, 8mm and 12mm perpendicular from Cementoenamel Junction at different angles 30°, 45º, 60 º, & 90º.

- Buccal Shelf Height: The mandibular buccal shelf height was measured on same CBCT scans using CEJ as the horizontal reference line at 5 mm. A vertical line was drawn from the outer-most curvature ofcortex to the lower-most part of the mandibular cortex to determine the height.

Figure 4: Mandibular buccal shelf depth at 5mm from CEJ.

RESULTS

Statistical analysis done using SPSS 26.0(SPSS Inc., Chicago, IL) with significance set at $p<0.05$. Descriptive statistics assessed the mean and standard deviation of each group,while datanormality 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.

Independent t-test revealed statistically significant higher values of cortical bone thickness in Group B than Group A across all sites at each depth and angulation. In M6 region significant thickness of cortical bone was found in Group Bin relation to 90° at 12mm, 30° at 8mm and 45°, 60° at 5mm but highly significant in 90° at 5mm on both sides, as seen in **Table II**.Similarly, in**Table III**,(D6 region)reveals significantly greater thickness in Group B. In M7 region, Group B showed greater values at 12mm and 8mm in 45°/60°/90°, while differences at 5mm were not significant**(Table IV).**The analysis of D7 region in **Table V** demonstrated significant values with greater bone thickness in Group B compared to Group A across all angulations, except 30° and 45° at 8mm and 30° at 5mm.

Using the Bonferroni posthoc test, most pair groups showed significance ($p<0.05$), except 30° vs 90° in few instances.One-way ANOVA for comparison of bone thickness within group showed statistically significant difference amongst all the different angulations in both group A & group B.

Analysis of cortical bone thickness at 5mm, 8mm, and 12mm from the CEJ across sites M6, D6, M7, and D7 showed no significant differences between Group A and Group B, though one-way ANOVA confirmed highly significant variations within groups. Post-hoc testing revealed that bone thickness consistently increases posteriorly (M6<D6<M7<D7), with the thickest bone found at D7 and highly significant differences ($p<0.001$) occurring specifically when comparing M6 to M7 and D7. Data demonstrated substantial variations between the Group A and B, when comparing mesial site measurements (M6) to distal sites (M7 and D7) shown in **Table VI**.

Comparison of mandibular buccal shelf height by Independent T-test at 5mm from CEJ between Group A & B **(Table VII)** showed statistically high significant difference ($p<0.0001$*) for all sites (M6, D6, M7, D7) on both sides, with Group B having greater height. Within-site comparison reveals highly significant differences, especially in D6 and D7 sites. However, on comparing within sites for each group revealed highly significant differences increasing from M6<D6<M7<D7, with more height in the D7.

Comparison of cortical bone thickness and mandibular buccal shelf height by Independent T-test in M6, D6, M7 and D7 region at 12mm, 8mm & 5mm from CEJ and did not report statistically significant

difference between left & right sides with respect to both groups(p>0.05) in relation to all the angulations (30°/45°/60°/90°).

TABLE I–DISTRIBUTION OF SAMPLES

Parameters (Lateral Cephalogram)	Group A- Hyperdivergence (n=30)	Group B- Normodivergence (n=30)
Y axis	53-66º	>66º
Mandibular Plane Angle (Go-Gn to SN)	27-36º	>36º
Jarabak's Ratio	62-65%	<62%

Go-Gn to SN: Angulation between Gonion-Gnathion plane to Sella-Nasion plane

TABLE II - COMPARING CORTICAL BONE THICKNESS IN M6 AT 12,8,5mm WITH DIFFERENT ANGULATION FROM CEJ

Height	Angulation	LEFT: Group A	LEFT: Group B	P Value (t value)	RIGHT: Group A	RIGHT: Group B	P Value (t value)
12 mm	30°	2.47±0.39 mm	2.62±0.36 mm	0.12 (t=1.54)	2.51±0.48 mm	2.64±0.35 mm	0.23 (t=1.19)
	45°	3.06±0.39 mm	3.19±0.44 mm	0.23 (t=1.21)	3.16±0.46 mm	3.25±0.42 mm	0.43 (t=0.79)
	60°	3.93±0.45 mm	4.01±0.53 mm	0.53 (t=0.63)	3.96±0.55 mm	3.96±0.50 mm	0.99(t=0.001)
	90°	2.13±0.40 mm	2.34±0.27 mm	0.02* (t=2.38)	2.16±0.51 mm	2.35±0.28 mm	0.07 (t=1.78)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.008*	0.04*		0.03*	0.02*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
8 mm	30°	2.26±0.40 mm	2.54±0.32 mm	0.004* (t=2.99)	2.24±0.44 mm	2.43±0.36 mm	0.07 (t=1.83)
	45°	2.87±0.39 mm	2.94±0.41 mm	0.50 (t=0.67)	2.95±0.35 mm	2.9±0.40 mm	0.60 (t=0.51)
	60°	3.61±0.32 mm	3.74±0.54 mm	0.26 (t=1.13)	3.71±0.39 mm	3.70±0.53 mm	0.93 (t=0.08)
	90°	2.06±0.65 mm	2.15±0.23 mm	0.47 (t=0.71)	1.99±0.36 mm	2.03±0.19 mm	0.59 (t=0.53)
	30° vs 45°	0.0001*	0.0008*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.003*	0.001*		0.002*	0.001*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.00001*		0.0001*	0.0001*	
5 mm	30°	2.03±0.37 mm	2.13±0.31 mm	0.26 (t=1.13)	2.03±0.52 mm	2.15±0.37 mm	0.30 (t=1.02)
	45°	2.48±0.43 mm	2.7±0.31 mm	0.02* (t=2.27)	2.63±0.44 mm	2.73±0.28 mm	0.29 (t=1.05)
	60°	3.08±0.39 mm	3.30±0.48 mm	0.05* (t=1.94)	3.22±0.51 mm	3.26±0.33 mm	0.71 (t=0.36)
	90°	1.57±0.32 mm	1.98±0.20 mm	0.0001* (t=5.95)	1.46±0.30 mm	1.92±0.21 mm	0.0001* (t=6.88)
	30° vs 45°	0.0001*	0.0001*	(Post Hoc)	0.0001*	0.0001*	(Post Hoc)
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.001*	0.32		0.001*	0.001*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects
M6: Mesial sites of 1st molar

TABLE III - COMPARING CORTICAL BONE THICKNESS IN D6 AT 12,8,5mm WITH DIFFERENT ANGULATION FROM CEJ

Height	Angulation	LEFT: Group A	LEFT: Group B	P Value (t value)	RIGHT: Group A	RIGHT: Group B	P Value (t value)
12 mm	30°	2.93±0.42 mm	3.33±0.38 mm	0.0003* (t=3.86)	2.96±0.51 mm	3.11±0.36 mm	0.19 (t=1.31)
	45°	3.63±0.34 mm	3.85±0.33 mm	0.01* (t=2.54)	3.62±0.48 mm	3.84±0.31 mm	0.03* (t=2.10)
	60°	4.43±0.43 mm	4.83±0.42 mm	0.0006* (t=3.64)	4.47±0.48 mm	4.74±0.38 mm	0.78 (t=0.26)
	90°	2.59±0.46 mm	2.81±0.24 mm	0.02* (t=2.32)	2.63±0.48 mm	2.80±0.37 mm	0.12 (t=1.53)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.01*	0.0001*		0.04*	0.005*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
8 mm	30°	2.44±0.42 mm	3.07±0.24 mm	0.0001* (t=7.13)	2.48±0.38 mm	3.01±0.26 mm	0.0001* (t=6.30)
	45°	3.09±0.41 mm	3.57±0.22 mm	0.0001* (t=5.65)	3.15±0.39 mm	3.61±0.17 mm	0.0001* (t=5.92)
	60°	3.95±0.35 mm	4.26±0.20 mm	0.0001* (t=4.21)	4.08±0.42 mm	4.36±0.29 mm	0.003* (t=3.00)
	90°	2.23±0.35 mm	2.71±0.28 mm	0.0001* (t=5.86)	2.17±0.38 mm	2.64±0.25 mm	0.0001* (t=5.65)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.15	0.0001*		0.01*	0.0001*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
5 mm	30°	2.06±0.41 mm	2.53±0.34 mm	0.0001* (t=4.83)	2.04±0.38 mm	2.46±0.36 mm	0.0001* (t=4.39)
	45°	2.59±0.48 mm	2.90±0.39 mm	0.008* (t=2.74)	2.46±0.45 mm	2.92±0.41mm	0.0001* (t=4.13)
	60°	3.37±0.44 mm	3.40±0.40 mm	0.78 (t=0.27)	3.21±0.44 mm	3.58±0.40 mm	0.001* (t=3.40)
	90°	1.79±0.24 mm	2.21±0.37 mm	0.0001* (t=5.21)	1.81±0.31 mm	2.16±0.30 mm	0.0001* (t=4.44)
	30° vs 45°	0.0001*	0.001*	Post Hoc Analysis	0.0005*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.04*	0.007*		0.12	0.01*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05).
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects.
D6: Distal sites of 1st molar.

TABLE IV - COMPARING CORTICAL BONE THICKNESS IN M7 AT 12,8,5mm WITH DIFFERENT ANGULATION FROM CEJ

Height	Angulation	LEFT: Group A	LEFT: Group B	P Value (t value)	RIGHT: Group A	RIGHT: Group B	P Value (t value)
12 mm	30°	3.25±0.31 mm	3.35±0.46 mm	0.32 (t=0.98)	3.33±0.34 mm	3.34±0.43 mm	0.92 (t=0.09)
	45°	3.93±0.28 mm	4.14±0.47 mm	0.03* (t=2.10)	4.06±0.41 mm	4.14±0.49 mm	0.49 (t=0.68)
	60°	4.79±0.31 mm	5.60±0.53 mm	0.0001* (t=7.22)	5.06±0.57 mm	5.52±0.50 mm	0.001* (t=3.32)
	90°	2.85±0.38	2.98±0.35	0.17	2.82±0.37	2.98±0.34	0.08

		mm	mm	(t=1.37)	mm	mm	(t=1.74)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0001*	0.0001*		0.0001*	0.01*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
8 mm	30°	3.15±0.36 mm	3.17±0.23 mm	0.79 (t=0.25)	3.06±0.38 mm	3.17±0.32 mm	0.23 (t=1.21)
	45°	3.54±0.36 mm	3.84±0.35 mm	0.001* (t=3.27)	3.59±0.31 mm	3.80±0.46 mm	0.04* (t=2.07)
	60°	4.36±0.43 mm	4.67±0.49 mm	0.01* (t=2.60)	4.62±0.31 mm	4.57±0.48 mm	0.63 (t=0.47)
	90°	2.74±0.31 mm	3.06±0.29 mm	0.0001* (t=4.12)	2.60±0.30 mm	2.95±0.34 mm	0.0001* (t=4.22)
	30° vs 45°	0.0004*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0002*	0.62		0.0001*	0.16	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
5 mm	30°	2.84±0.35 mm	2.86±0.25 mm	0.79 (t=0.25)	2.79±0.34 mm	2.76±0.31 mm	0.72 (t=0.35)
	45°	3.26±0.29 mm	3.25±0.54 mm	0.92 (t=0.08)	3.14±0.35 mm	3.28±0.50m m	0.21 (t=1.25)
	60°	3.89±0.29 mm	3.98±0.44 mm	0.35 (t=0.93)	3.81±0.33 mm	3.93±0.40 mm	0.21 (t=1.26)
	90°	2.50±0.37 mm	2.65±0.32 mm	0.09 (t=1.67)	2.55±0.41 mm	2.52±0.34 mm	0.75 (t=0.30)
	30° vs 45°	0.0001*	0.001*	Post Hoc Analysis	0.001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0006*	0.18		0.05*	0.09	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects
M7: Mesial sites of 2nd molar

TABLE V - COMPARING CORTICAL BONE THICKNESS IN D7 AT 12,8,5mm WITH DIFFERENT ANGULATION FROM CEJ

Height	Angulation	LEFT: Group A	LEFT: Group B	P Value (t value)	RIGHT: Group A	RIGHT: Group B	P Value (t value)
12 mm	30°	3.48±0.53 mm	3.83±0.36 mm	0.004* (t=2.99)	3.64±0.67 mm	3.77±0.32 mm	0.34 (t=0.95)
	45°	4.49±0.56 mm	4.82±0.36 mm	0.008* (t=2.71)	4.42±0.60 mm	4.79±0.34 mm	0.004* (t=2.93)
	60°	5.56±0.38 mm	6.82±0.54 mm	0.0001* (t=10.45)	5.71±0.53 mm	6.7±0.52 mm	0.0001* (t=7.30)
	90°	2.98±0.41 mm	3.30±0.24 mm	0.0005* (t=3.68)	2.93±0.43 mm	3.28±0.22 mm	0.0002* (t=3.96)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0005*	0.0001*		0.0001*	0.0001*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
8 mm	30°	3.54±0.45 mm	3.48±0.28 mm	0.53 (t=0.62)	3.54±0.37 mm	3.46±0.25 mm	0.33 (t=0.98)
	45°	4.39±0.52 mm	4.22±0.41 mm	0.16 (t=1.40)	4.26±0.39 mm	4.22±0.35 mm	0.67 (t=0.41)
	60°	5.15±0.40	5.55±0.48	0.0009*	5.12±0.44	5.49±0.41	0.001*

		mm	mm	(t=3.50)	mm	mm	(t=3.36)
	90°	2.91±0.34 mm	3.15±0.19 mm	0.001* (t=3.37)	2.94±0.32 mm	3.05±0.25 mm	0.14 (t=1.48)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0001*	0.002*		0.0001*	0.0001*	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
5 mm	30°	3.19±0.27 mm	3.29±0.36 mm	0.22 (t=1.21)	3.4±0.40 mm	3.26±0.27 mm	0.11 (t=1.58)
	45°	3.90±0.42 mm	4.21±0.34 mm	0.002* (t=3.14)	4.03±0.51 mm	3.89±0.30 mm	0.20 (t=1.29)
	60°	4.71±0.41 mm	5.00±0.44 mm	0.01* (t=2.64)	4.67±0.46 mm	4.8±0.30 mm	0.19 (t=1.29)
	90°	2.77±0.33 mm	3.21±0.34 mm	0.0001* (t=5.08)	2.95±0.48 mm	3.11±0.28 mm	0.12 (t=1.57)
	30° vs 45°	0.0001*	0.0001*	Post Hoc Analysis	0.0001*	0.0001*	Post Hoc Analysis
	30° vs 60°	0.0001*	0.0001*		0.0001*	0.0001*	
	30° vs 90°	0.0001*	0.83		0.001*	0.18	
	45° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	
	60° vs 90°	0.0001*	0.0001*		0.0001*	0.0001*	

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects
D7: Distal sites of 2nd molar

TABLE VI - COMPARING CORTICAL BONE THICKNESS AT 12, 8, 5mm WITH FROM CEJ BETWEEN SITES (M6,D6,M7,D7)

12mm		**LEFT**		**RIGHT**	
		GROUP A	GROUP B	GROUP A	GROUP B
	M6 vs D6	0.06	0.04*	0.06	0.09
	M6 vs M7	0.0006*	0.0004*	0.0007*	0.001*
	M6 vs D7	0.0001*	0.0001*	0.0001*	0.0001*
	D6 vs M7	0.41	0.45	0.46	0.43
	D6 vs D7	0.002*	0.0008*	0.01*	0.0004*
	M7 vs D7	0.16	0.06	0.35	0.04*
8mm	M6 vs D6	0.59	0.07	0.47	0.4
	M6 vs M7	0.0003*	0.0001*	0.0007*	0.0001*
	M6 vs D7	0.0001*	0.0001*	0.0001*	0.0001*
	D6 vs M7	0.06	0.40	0.06	0.62
	D6 vs D7	0.0001*	0.0009*	0.0001*	0.003*
	M7 vs D7	0.15	0.09	0.5	0.09
5mm	M6 vs D6	0.73	0.34	0.98	0.25
	M6 vs M7	0.0001*	0.0001*	0.0001*	0.0003*
	M6 vs D7	0.0001*	0.0001*	0.0001*	0.0001*
	D6 vs M7	0.0002*	0.02*	0.0001*	0.09
	D6 vs D7	0.0001*	0.0001*	0.0001*	0.0001*
	M7 vs D7	0.6	0.16	0.45	0.34

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects
M6, M7: Mesial sites of 1st and 2nd molar; D6, D7: Distal sites of 1st and 2nd molar

TABLE VII -COMPARING MANDIBULAR BUCCAL SHELF HEIGHT BETWEEN GROUP A & B AT 5mm WITH FROM CEJ.

	LEFT			**RIGHT**		
	GROUP A	**GROUP B**	**P VALUE (T TEST)**	**GROUP A**	**GROUP B**	**P VALUE (T TEST)**
M6	0.41±1.35 mm	7.19±2.10 mm	0.0001* (t=14.87)	0.37±1.19 mm	7.24±1.58 mm	0.0001* (t=19.02)

D6	7.50±1.79 mm	15.08±1.30 mm	0.0001* (t=18.76)	7.39±1.82 mm	14.51±1.97 mm	0.0001* (t=14.54)
M7	10.94±2.30 mm	17.97±1.92 mm	0.0001* (t=12.85)	10.68±2.44 mm	18.14±1.96 mm	0.0001* (t=13.05)
D7	15.07±2.18 mm	21.57±2.26 mm	0.0001* (t=11.33)	14.74±2.25 mm	21.98±2.63mm	0.0001* (t=11.45)
P VALUE (ONE WAY ANOVA TEST)	0.0001*	0.0001*	POST HOC TEST(BONE FERRONI TEST) P VALUE	0.0001*	0.0001*	
M6 vs D6	0.0001*	0.0001*		0.0001*	0.0001*	
M6 vs M7	0.0001*	0.0001*		0.0001*	0.0001*	
M6 vs D7	0.0001*	0.0001*		0.0001*	0.0001*	
D6 vs M7	0.0001*	0.0001*		0.0001*	0.0001*	
D6 vs D7	0.0001*	0.0001*		0.0001*	0.0001*	
M7 vs D7	0.0001*	0.0001*		0.0001*	0.0001*	

*p<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)
Group A: Hyperdivergent subjects; Group B: Normodivergent subjects
M6, M7: Mesial sites of 1st and 2nd molar; D6, D7: Distal sites of 1st and 2nd molar.

DISCUSSION

TADs provide skeletal anchorage by transferring forces to bone, enabling nonsurgical correction of complex cases. The Mandibular Buccal Shelf offers an extra-alveolar site with superior bone quality and less interference with tooth movement, though its success depends on cortical bone characteristics, which are influenced by facial divergence.

Unlike occlusal plane, which is susceptible to incisal wear, or alveolar crest, which can be altered by periodontal disease, CEJ remains a stable and consistent landmark;thus, in this study, it was chosen asreference point for accurate data collection in adult patients. Measurements were taken at apical heights of 5 mm, 8 mm, and 12 mm from CEJ to reflect clinical standards for extra-alveolar miniscrews. To better simulate actual insertion, bone thickness was assessed at various angulations rather than horizontal planes alone. The objective was to use CBCT imaging to compare MBS height and cortical bone thickness between hyperdivergent and normodivergent growth patterns to optimize anchorage strategies.

Our study reveals that normodivergent subjects (Group B) consistently possess significantly thicker cortical bone than hyperdivergent subjects (Group A) across all evaluated sites, including mesial and distal aspects of first and second molars (M6,D6, M7, D7). In both groups, cortical thickness increased as we moved apically from CEJ (12mm>8mm>5mm) and varied significantly with insertion angle, with 60° showing the greatest thickness and 90° the least. These findings carry significant clinical importance; while nearly all sites met the 1 mm threshold suggested by Motoyoshi et al. for primary stability,[10] the D7 region at 12 mm depth and 60° angle in Group B emerged as the most suitable site for extra-alveolar TAD placement (6.82±0.54mm). Conversely, the hyperdivergent group showed minimal thickness at the M6 region at 90°and 5 mm depth (1.46±0.32mm), highlighting the need for careful site selection in hyperdivergent subjects to avoid stability failure.

Fulya Ozdemir et al. (2013), Sadek et al. (2016), and Vargas et al. (2020) similarly reported that hyperdivergent subjects exhibit thinner cortical bone and that thickness increases distally and apically.[9,11,12]Uysal et al. (2014) and Monnerat et al. corroborated that thickness increases from the CEJ to the apex.[13,14] Niwlikar et al. (2018) and Nookala et al. (2023) both confirmed that normodivergent or hypodivergent subjects possess thicker bone than hyperdivergent ones. [15,16]

Conversely, some studies, such as Swasty et al. (2011)[17] and García-Gonzales & Ruiz-García (2022),[18] found no significant differences between different growth patterns, likely due to small sample sizes and smaller CBCT FOV used. Deguchi et al (2012) analyzed mandibular cortical bone thickness and found no overall significant difference except at mesial to first molar and distal to second molar. Significantly greater cortical thickness was observed at 30° than at 45° and 90°, which is different from our findings because they took the measurements relative to long axis of individual molars while we measured from outer buccal cortex.[19] Matias et al. (2021) even found mesofacial subjects had less bone than other groups, possibly due to population differences.[20] Regarding angulation, Inaba et al. (2009),[10] Chang et al. (2016),[5] Trivedi et al. (2020),[21]all emphasized that angulated insertion significantly increases cortical bone contact compared to a 90° approach, hence, optimizing site, depth, and angle is critical for TADs' stability.

Comparison of cortical bone thickness at 12 mm, 8mm, and 5mm from CEJ between sites- M6, D6, M7, and D7 demonstrated substantial differences between the Group A and B, when comparing mesial site

measurements (M6) to distal sites (M7 and D7). Cortical bone thickness at 12mm,8mm, 5mm from CEJ, irrespective of growth pattern, increased from M6<D6<M7<D7, being thickest at D7, with statistically significant differences. Veli et al., Vargas et al., Patla et al., Eto et al., alsorevealed that the buccal cortical bone thicknesses in all groups increased towards the posterior of the mandible.[13,12,22,23] Although Gandhi et al. reported decrease in thickness due to a different reference point-roof of Inferior Alveolar Canal.[24]

Comparison in both groups showed no significant differences in cortical bone thickness and MBS height between the right and left sides. This symmetry is attributed to the exclusion of patients with posterior crossbites, dental asymmetries, and severe crowding. These results are consistent with Veli et al. (2014),[13] Escobar-Correa et al. (2021),[25] and Abhijith et al. (2024),[26] who found no significant side-dependent variation in mandibular cortical thickness.

Comparative analysis of MBS height at 5 mm from CEJ revealed highly significant differences between growth patterns, with Group Bexhibiting greater mean values than Group A which was most significant at D6 and D7 sites. Intra-group analysis demonstrated a progressive increase in height from anterior to posterior (M6<D6<M7<D7), with the D7 site having the maximum bone height.These findings corroborate research by Patla et al. (2021)[22] and García-Gonzales & Ruiz-García de Chacón (2022)[18] regarding site-specific height variation. The observation that vertical facial patterns influence bone depth aligns with Reshma Mohan et al. (2023),[27] who noted superior bone depth in hypodivergent subjects. Furthermore, the distal root of the second molar, having the greatest bone height (23.94 ± 3.57 mm), is consistent with the findings of Abhijith et al. (2024) and Nucera et al. (2017).[26,28]

This study highlights a clear correlation between facial divergence and cortical bone characteristics. Hyperdivergent patients exhibited significantly thinner cortical bone, potentially compromising TAD stability in the Mandibular Buccal Shelf. This deficiency is likely due to weaker masticatory muscle function and reduced occlusal forces, which exert less physiological tension on the alveolar bone.

Consequently, clinicians must remain cautious when selecting sites for high-angle patients, as thinner bone increases the risk of TAD failure. While CBCT offers precise morphometric data, clinical success also depends on variables such as soft tissue thickness, insertion torque, and loading protocols. Furthermore, the cross-sectional design and lack of control for age, gender, and ethnicity may limit the generalizability of these findings.

CONCLUSION

- On comparing cortical bone thickness at 12mm, 8mm, and 5mm from CEJ Group B exhibited significantly thicker cortical bone than Group A across most sites.
- Within-group, on comparing cortical bone thickness in M6, D6, M7, D7 at 12mm, 8mm, 5mm with different angles- 30°, 45°, 60°, and 90° showed highly significant differences ($p<0.0001$), except between 30° vs 90° in Group A as well as Group B on both sides.
- Statistically significant difference was noted in cortical bone thickness in M6, D6, M7, and D7 sites, which varied with different heights but was found to be more at 12mm than at 8mm and 5mm. It also varied with different angulations at each height, with more cortical bone thickness at 60° than at 45° and 30°, and least at 90° in both groups on both sides.
- On comparing within sites in Group A, highly significant differences were revealed between M6 vs M7, M6 vs D7 and significant differences at D6 vs D7. And in Group B, highly significant differences were revealed at M6 vs M7, M6 vs D7, and D6 vs D7.
- Differences between mesial and distal sites of the 1st molar and 2nd molar were less pronounced; however, both cortical bone thickness and buccal shelf height increased from M6<D6<M7<D7, being thickest at D7 in both groups.
- Mandibular buccal shelf height at 5mm from CEJ in M6, D6, M7, and D7 sites between Group A and B showed statistically highly significant differences with more mean in Group B.
- For mandibular buccal shelf height and cortical bone thickness in Group A as well as B, non-significant differences were observed between right and left sides.
- Orthodontists should have to consider cortical bone thickness at different heights and angles in different growth patterns along with sagittal jaw discrepancy in conjunction with bone density and soft tissue parameters for TADs placement, stability & success rate. Future research should explore longitudinal studies of TADs' success based on growth pattern-related anatomical differences and incorporating clinical variables.

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