Research Article

Anatomical Assessment of Mandibular Buccal-Shelf Area (MBS) on Cone Beam Computed Tomography (CBCT) in the Islamabad/ Rawalpindi Population for Miniscrew Insertion

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Abstract: Background: Extra-alveolar miniscrews exhibit increased advantage over interradicular miniscrews since it does not interfere with constant tooth movement. Total buccal bone thickness in area of mandibular buccal shelf (MBS) area is variable at different sites, depths and also in different ethnicities.

Objective: To assess cortical bone depth (vertical) at horizontal distance of 2, 4 and 6mm and total buccal bone thickness (horizontal) at vertical reference position of 4, 8 and 12mm in mandibular buccal shelf area at distobuccal root of mandibular first molar (DB6), mesiobuccal root of mandibular second molar (MB7) and distobuccal root of second molar (DB7) to determine best site for miniscrew placement.

Materials and Methods: This cross-sectional study was conducted in Department of Orthodontics at Margalla Institute of Health Sciences, Rawalpindi from 1st January 2025 to 31st December 2025 on patients having cone beam computed tomography (CBCT) scans. Prior ethical approval was obtained from the Ethics Review Committee, Margalla Institute of Health Sciences (DM/220/24). SPSS Software (by IBM) version 27.0.1 was used for statistical evaluation. Median with interquartile ranges were tabulated for cortical bone depth (vertical) and total buccal bone thickness (horizontal) .Post-hoc pairwise comparisons following Friedman's test were performed using the Wilcoxon signed-rank test with Bonferroni-adjusted p-values. A p-value of less than 0.05 was considered statistically significant.

Result: Maximum cortical bone depth (vertical) of 14.7 mm (3.0–19.5) was found buccal to the DB6 site at 4mm, followed by MB7 which showed cortical bone depth (vertical) of 12.1mm (0.0–22.7) at 6mm. Maximum total buccal bone thickness (horizontal) of 8mm was found in DB7 at 12mm depth, followed by 7.5mm thickness seen in relation to DB7 at 8mm depth.

Conclusion: Successful placement of TAD in mandibular buccal shelf (MBS) area in Pakistani population can be done buccal to distobuccal root of mandibular second molar at 12mm apical to cementoenamel junction, since this area has maximum total buccal bone thickness (horizontal) and cortical bone depth (vertical) greater than 1mm.

Keywords: Cone beam computed tomography, Cortical bone depth, Mandibular buccal shelf, Miniscrew, Temporary anchorage devices, Total buccal bone thickness.

INTRODUCTION

Miniscrews allow complex dental movement not possible from orthodontics alone [1]. In Orthodontics, miniscrews are temporary anchorage devices (TADs) placed in inter-radicular area and extra-radicular area for various orthodontic purposes. They may be used for various orthodontic mechanics, such as molar intrusion, molar medicalization, whole arch distalization, arch expansion and skeletal anchorage [2]. TADs which were traditionally used for anchorage purpose are now indicated as alternative to surgical treatment to manage borderline surgical cases [3]. Class III malocclusion with mild to moderate skeletal discrepancy can be camouflaged without surgery by orthodontic treatment only to have successful results. Whole arch distalization of mandibular is a viable alternative to regular camouflage treatment for treatment of Class III relationship [4]. Distalization of mandibular arch is difficult due to posterior anatomical limitations [5]. Extra-alveolar implants are preferred in such cases of en-mass distalization, as inter-radicular miniscrews can interfere with constant repositioning of roots [6]. Interradicular miniscrews provide maxillary molar distalization of only 2 mm since it is placed in inter-radicular area. When molar distalization greater than 2 mm is required, TADs in inter radicular area must be relocated. Using extra-alveolar miniscrews in such cases can be beneficial [7].

In maxilla, infra-zygomatic area is the preferred extra-alveolar region for implant placement [8]. In mandible, TADs placed in the mandibular buccal shelf (MBS) are suggested to be a good means of extra-radicular anchorage and it has high success rate than inter-radicular TADs [9].

MBS region is present posteriorly in the mandible bilaterally. It lies buccal to the roots of the 1st and 2nd molars, and anterior in relation to the oblique line of the mandibular ramus [10]. Literature suggests correct technique for insertion of TADs in the

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lower arch is lateral to the 1st and 2nd molars in buccal bone, at an angle of 90 degree to the occlusal plane and parallel to the long axis of tooth, without damaging vital structures such as the inferior alveolar canal [9].

Primary stability is a key factor for successful bone-screw placement. Evidence shows rate of failure of temporary anchorage devices is 13.5%, while extra-radicular TADs showed loss of stability in 7% of the cases [11]. Success of bone screws can be influenced by different anatomic factors related to bone, like density of bone, bone depth, cortical thickness of bone and diameter of miniscrew [12]. Cortical bone depth (vertical) of MBS area is greater compared to other of the mandible and could have contributed to significantly increased primary stability [13]. A study published by Wan-Ping Yu *et al.* evaluated insertion torque values during miniscrew placement to determine the stability of the orthodontic miniscrews. The results indicated that TADs with increased length and increased diameter have higher insertion torque values and increased stability [14].

Many studies have assessed appropriate lengths of miniscrew to be used in mandibular buccal shelf (MBS) area. Finite element study [15], showed miniscrew stability depends not on length but on diameter of miniscrew and TADs with greater diameter provided greater stability ad success. Displacement of miniscrew and pressure on bone reduced, as the TADs diameter and cortex thickness increased. Most of the studies suggest ideal length for the MBS miniscrew is 12mm, but lengths from 10 mm to 14 mm can be used depending on the individual patient's characteristics [16]. In recent randomized clinical trial, Micheal *et al.*, stated that 91% of the 10mm and 75% of the 08 mm length miniscrews were stable [17]. In light of this, adequate assessment of total buccal bone thickness(horizontal) should be known to accommodate TADs of this length. Nucera *et al.*, stated at-least 5mm (1.7 mm of root clearance, 1.6 mm of diameter of screw, and 1.7 mm of clearance of cortical buccal bone) of buccal extension of the mandibular buccal shelf (MBS) for safe miniscrew insertion should be present [6].

Recommended sites for insertion of miniscrew in MBS area are adjacent to the 1st molar, between 1st and 2nd molars, and adjacent to the 2nd molar. However, difference in the depth and thickness of the bone along various sites may affect miniscrew placement [8]. Also, variation in MBS bone width in different ethnicities have also been found in literature [9]. Many studies have assessed MBS using cone beam computed tomography (CBCT) in diverse populations, including Caucasian, Asian, and South Asian adolescents and adults [18].

Sreenivasagan *et al.*, in their study reported maximum total bone thickness of 6.56±0.28mm at the depth of 12 mm with site as distobuccal region of mandibular second molar region (DB2M) [19]. Karim *et al.*, calculated greatest cortical bone depth (vertical) of 6.85±4.27mm at site of distal root of mandibular 1st molar (6D) [20]. A study was conducted by Iqbal *et al.*, [21], on assessment of mandibular buccal shelf (MBS) area for mini-implant insertion in Pakistan, didn't specify around which tooth these variables were measured, since mandibular buccal shelf (MBS) area extends from distobuccal root of mandibular 1st molar to distobuccal root of mandibular 2nd molar.

TAD placement is associated with many complication like instability, fracture risk, and potential root damage. Therefore, a comprehensive understanding of their optimal placement sites is necessary [22]. The aim of the present study is to assess cortical bone depth (vertical) and total buccal bone thickness (horizontal) of mandibular buccal shelf (MBS) area at distobuccal root of mandibular 1st molar (DB6), mesiobuccal root of mandibular 2nd molar(MB7) and distobuccal root of 2nd molar(DB7) at different horizontal and vertical positions in Rawalpindi/Islamabad on CBCT to identify best site for miniscrew placement, since it has not previously been studied in our population. It will be beneficial for the Orthodontist to use standard norms in Pakistani population while using TAD in mandibular buccal shelf (MBS) area.

MATERIALS AND METHODS

This cross-sectional study was done in Department of Orthodontics at Margalla Institute of Health Sciences, Rawalpindi from 1st January 2025 to 31st December 2025 on patients having cone-beam -computed-tomography (CBCT) scans. Participants with age of 12-40 years and having lower 1st and 2nd molars erupted were included. This age was selected because of the parameters being measured on CBCT can only be assessed in patients with mature bone having age greater than 12 years. CBCT scan of patients with metabolic bone diseases, craniofacial anomalies and imaging artifacts due to patient's movement were excluded. Prior ethical approval was taken from the Ethics Review Committee, Margalla Institute of Health Sciences to conduct this study, Ethical Approval Number: (DM/220/24). CBCT scans were collected from Margalla Dental Hospital Rawalpindi utilizing non-probability consecutive sampling technique. Sample size of 90 was calculated using WHO calculator with following parameters: confidence interval of 5%, population mean of 6.561 ± 0.28 [19] in relation to distobuccal root of mandibular second molar at 12 mm depth, population standard deviation of 0.2849 and absolute precision of 0.06. For use of CBCT scans, informed consent was taken and identity of patient was maintained. All CBCT images were taken using a standardized procedure with a cone beam machine. The parameters used were: 100 kV, 6 mA, a field of view of 15.5 x 15.5 cm (620 x 620 x 620), voxel size of 0.250 mm, and a scan duration of 12.09 seconds. The CBCT data were saved in DICOM (Digital Imaging Communication in Medicine) files and planmeca Romexis version 6.0 was used for studying these scans.

CBCT Scan Measurements

CBCT Orientation

On Planmeca Romexis, the radiograph was positioned along the three planes (coronal, sagittal and axial). The axial plane was positioned tangentially to the lowest point of the furcation of the lower 1st and 2nd molars on sagittal view (Fig. **1**). The

sagittal plane was positioned in the mid of the alveolar process, parallel to the distal roots of the mandibular 1st molar (M6) and distal root of the 2nd molar (D7) (Fig. **2**); and the frontal plane was positioned parallel to the long axis of the root of the tooth around which total buccal bone thickness (horizontal) is to be measured (Fig. **3**).

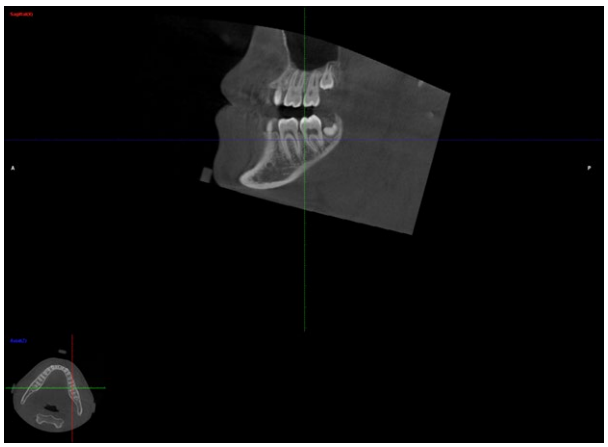

Fig. (1). showing Axial Plane In Blue Line Passing through Furcation Of First And Second Molar on Sagittal View of Cone Beam Computed Tomography.

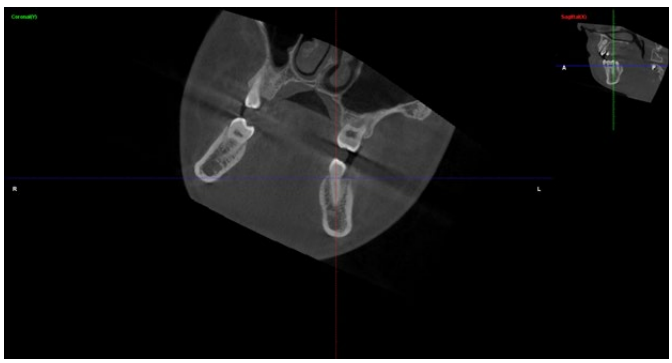

Fig. (2). showing Sagittal Plane in Red Line Passing through Centre of Alveolus Parallel to the Distal Roots of the Lower First Molar (M6) and Distal Root of the Lower Second Molar (D7) on Coronal View of Cone Beam Computed Tomography.

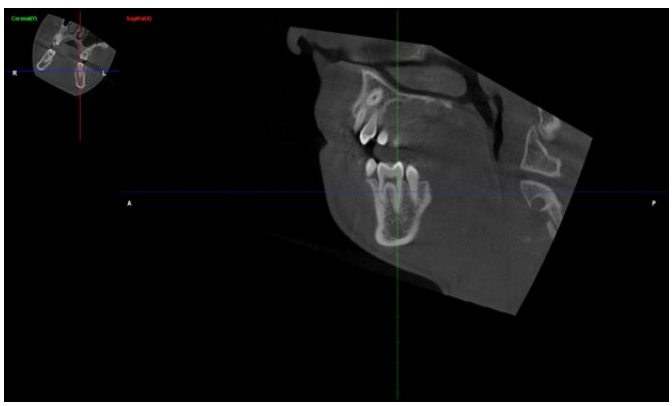

Fig. (3). Sagittal View of Cone Beam Computed Tomography Showing Coronal Plane in Green Line Parallel to the Long Axis of the Root of the Tooth around which Buccal Bone is to be Measured.

Cortical Bone Depth (Vertical) [20]

Cortical bone depth (vertical) was measured in vertical dimension parallel to long axis of root at three reference lines: 2, 4 and 6 mm located buccal to CEJ. All measurements were performed on distobuccal root of the 1st molar (DB6) and 2nd molar (DB7) and mesiobuccal root of the 2nd molar (MB7) in three coronal slices (Fig. **4**).

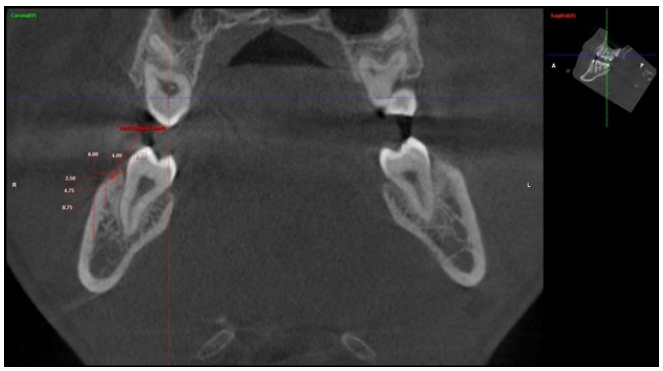

Fig. (4). Cortical Bone Depth Measured in a Vertical Dimension at Horizontal Distance of 2, 4 and 6mm.

Total Buccal Bone Thickness (Horizontal) [19]

Total buccal bone thickness (horizontal) was measured in horizontal dimension perpendicular to long axis of root at 3 vertical reference lines: 4, 8 and 12 mm drawn from the CEJ tangent to each root. All measurements were performed on distobuccal root of the first molar (DB6) and second molar (DB7) and mesiobuccal root of the second molar (MB7) in three coronal (Fig. **5**).

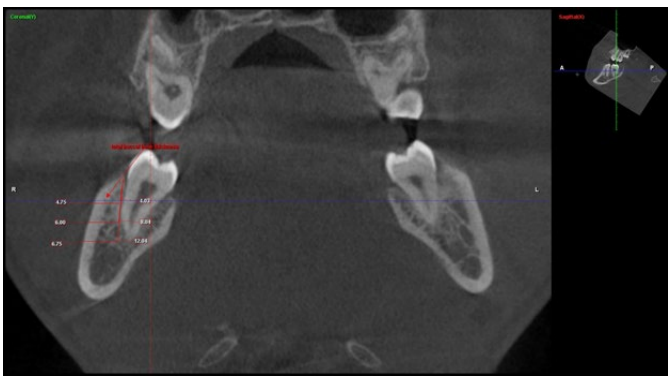

Fig. (5). Total Buccal Bone Thickness Measured in Horizontal Dimension at Vertical Distance of 4, 8 and 12 mm.

STATISTICAL EVALUATION

All the statistical calculations were performed using the SPSS Software (by IBM) version 27.0.1. The analysis involved both descriptive and inferential statistics. For the only categorical variable in the study, frequency and percentage was tabulated. For continuous variables in the study, median with interquartile ranges were tabulated. Normality of the data was evaluated using the Shapiro–Wilk test. All variables were non-normal so to find out differences between them, Friedman test was applied.

Post-hoc pairwise comparisons following Friedman's test were performed using the Wilcoxon signed-rank test with Bonferroni-adjusted p-values. Intra-examiner reliability was assessed on 20 re-measured scans using the intraclass correlation coefficient (ICC). A p-value of less than 0.05 was considered statistically significant. The null hypothesis was that there is no difference of cortical bone depth (vertical) and total buccal bone thickness (horizontal) among different sites.

RESULT

A total of 90 participants, comprising 46 males (51.1%) and 44 females (48.9%). At the DB6 site, cortical bone depth (vertical) differed significantly across depths ($p = 0.002$). The median cortical bone depth (vertical) was 11.5 mm (IQR: 4.3–15.0) at 2 mm, 14.7 mm (3.0–19.5) at 4 mm, and 1.6 mm (0.0–18.5) at 6 mm, with significant differences between 2 mm vs 4 mm and 2 mm vs 6 mm. At the MB7 site, cortical bone depth(vertical) also showed significant variation ($p < 0.001$), with median values of 8.0 mm (5.1–11.8) at 2 mm, 9.5 mm (4.8–16.5) at 4 mm, and 12.1 mm (0.0–22.7) at 6 mm. Significant differences were observed between 2 mm vs 4 mm and 2 mm vs 6 mm. Similarly, at the DB7 site, cortical bone depth (vertical) increased significantly with depth ($p < 0.001$), from 6.0 mm (3.0–8.0) at 2 mm to 6.5 mm (3.3–9.6) at 4 mm and 9.4 mm (6.3–13.5) at 6 mm, with all pairwise comparisons showing statistical significance. Maximum cortical bone depth (vertical) of 14.7 mm (3.0–19.5) was found buccal to DB6 site at 4mm, followed by MB7 which showed cortical bone depth (vertical) of 12.1mm (0.0–22.7) at 6mm. Least cortical bone depth (vertical) of 1.6 mm(0.0–18.5) was found buccal to DB6 at 6mm (Table **1**). Intraclass correlation coefficient (ICC) to assess intra-examiner reliability showed values ranging from 0.999 to 1.000, suggesting excellent agreement between values.

Table 1. Showing Gender in Percentage, Median and Inter-quartile Ranges of Cortical Bone Depth at DB6,MB7 and DB7 at Horizontal Position of 2,4 and 6mm and Total Buccal Bone Thickness at Vertical Reference Position of 4,8 and 12mm and Comparison of these Variables using Friedman Test along with Post-hoc pair-wise Comparisons.

Gender, N (%)	**Male**	**46 (51.1%)**			
	Female	**44 (48.9%)**			
		Median (IQR)	**Friedman χ^2**	**P value**	**Post-Hoc Significant Results**
DB6 – Cortical Bone Depth	2 mm	11.5 (4.3–15.0)	12.58	0.002*	2mm vs 4mm
	4 mm	14.7 (3.0–19.5)			2mm vs 6mm
	6 mm	1.6 (0.0–18.5)			
MB7 – Cortical Bone Depth	2 mm	8.0 (5.1–11.8)	16.8	<0.001*	2mm vs 4mm
	4 mm	9.5 (4.8–16.5)			2mm vs 6mm
	6 mm	12.1 (0.0–22.7)			
DB7 – Cortical Bone Depth	2 mm	6.0 (3.0–8.0)	44.53	<0.001*	2mm vs 4mm
	4 mm	6.5 (3.3–9.6)			2mm vs 6mm
	6 mm	9.4 (6.3–13.5)			4mm vs 6mm
DB6 – Total Buccal Bone Thickness	4 mm	2.5 (1.8–3.5)	151.94	<0.001*	4mm vs 8mm
	8 mm	4.5 (2.9–5.3)			4mm vs 12mm
	12 mm	5.8 (4.3–7.4)			8mm vs 12mm
MB7 – Total Buccal Bone Thickness	4 mm	2.8 (1.3–4.5)	113.63	<0.001*	4mm vs 8mm
	8 mm	5.8 (4.5–6.5)			4mm vs 12mm
	12 mm	6.4 (6.1–7.5)			8mm vs 12mm
DB7 – Total Buccal Bone Thickness	4 mm	6.5 (3.3–7.8)	45.96	<0.001*	4mm vs 8mm
	8 mm	7.5 (5.3–8.8)			4mm vs 12mm
	12 mm	8.0 (6.0–9.3)			

N: Frequency, %: Percentage, IQR: Interquartile Range, *p<0.05, significant.

For total buccal bone thickness (horizontal) a consistent increase with depth was observed at all sites. At DB6, median thickness increased from 2.5 mm (1.8–3.5) at 4 mm to 4.5 mm (2.9–5.3) at 8 mm and 5.8 mm (4.3–7.4) at 12 mm ($p < 0.001$), with all pairwise comparisons significant. At MB7, corresponding values were 2.8 mm (1.3–4.5), 5.8 mm (4.5–6.5), and 6.4 mm (6.1–7.5) ($p < 0.001$), with all pairwise comparisons significant. At the DB7 site, total buccal bone thickness(horizontal) increased from 6.5 mm (3.3–7.8) at 4 mm to 7.5 mm (5.3–8.8) at 8 mm and 8.0 mm (6.0–9.3) at 12 mm ($p < 0.001$), with significant differences

between 4 mm vs 8 mm and 4 mm vs 12 mm. Maximum total buccal bone thickness(horizontal) of 8mm was found in DB7 at 12mm depth, followed by 7.5mm thickness seen in relation to DB7 at 8mm depth. DB6 showed least total buccal bone thickness (horizontal) of 2.5mm at 4mm depth (Table **1**).

DISCUSSION

The results of this study found, that cortical bone depth (vertical) changes according to different sites and different horizontal positions. This study found maximum cortical bone depth (vertical) in relation to distobuccal root of mandibular first molar site, followed by mesiobuccal root of mandibular second molar area. These results are similar to the previous study in which cortical bone depth (vertical) was thickest at mandibular first molar area and thinnest at mandibular second molar area [20]. However, in contrary to this, a study conducted by Abhijith *et al.*, [10], maximum cortical bone depth (vertical) was found with respect to the distobuccal cusp of the 2nd molar. The difference of results from this study might be because of ethnic variability. Cortical bone depth (vertical) is significantly related to the stability of miniscrew and its thickness greatly effects insertion torque. Areas of bone with reduced depth of cortical bone is associated with loss of stability and miniscrew failure, whereas very thick bone will have good initial stability but have increased insertion torque [10]. In case where there is excessive bone thickness, predrilling is required as it will produce lesser heat at miniscrew-bone surface. A study done by Iqbal *et al.*, [21] on sample size of 78, in Pakistan, showed findings of bone thickness and bone depth of MBS area, but didn't mention around which tooth these variables were measured, since mandibular buccal shelf (MBS) area extends from distobuccal root of mandibular first molar to distobuccal root of mandibular second molar. On contrary, our study of increased sample size of 90, assessed cortical bone depth (vertical) and total buccal bone thickness (horizontal) at all sites: distobuccal root of mandibular first molar, mesiobuccal root of mandibular second molar and distobuccal root of mandibular second molar. Previously published study [11], discussed that miniscrews should be inserted where cortical bone depth (vertical) is greater than 1mm to obtain reasonable primary stability and high success rate. Our study found wide variation of cortical bone depth (vertical) values across all sites and all three horizontal positions, with median value of cortical bone depth(vertical) > 1mm at each site. We don't suggest CBCT for evaluation of cortical bone depth (vertical) for every patient since at least 1 mm depth should be available for primary stability of miniscrew.

According to our findings, total buccal bone thickness(horizontal) increased as we increased depth from CEJ at 4,8 and 12mm. Maximum total buccal bone thickness (horizontal) was found at depth of 12mm followed by 8mm buccal to distobuccal root of second molar. Minimum total buccal bone (horizontal) was present buccal to distobuccal root of first molar at vertical depth of 4mm. These results are in accordance to the results found by *et al* Sreenivasagan [19] that found greatest total buccal bone thickness (horizontal) at DB2M region at 12mm depth. Abhijith *et al* also stated that maximum total buccal bone thickness (horizontal) was found around distal root of second molar [10]. A study conducted by Xing Fan *et al.*, [12], stated that best site for mini-implant insertion at MBS is the buccal site corresponding to the second molar with the maximum insertion length of ≤ 12 mm. Eto *et al.*, [23] also found ideal site for mandibular buccal shelf (MBS) TAD insertion around distal root of the second molar, regardless of vertical pattern, age, or gender. Results of another study also stated optimal location for MI insertion in the MBS, in the absence of impacted third molars, is the area buccal to the distal surface of the mandibular second molar [24]. Findings of martina *et al.*, [25], are also in line with our study, that also found optimal site at distal root of the second molar at 4 mm buccal to the cementoenamel junction (CEJ). Many studies have indicated that mandibular buccal shelf (MBS) bone thickness increases distally from the first to the second molar but there is less consensus on depth measurements since some authors find that they increase [8] with increase in depth, while others find the opposite results [26]. In light of this, our study evaluated bone thickness at different depths. At all three sites, greatest bone was present at 8 and 12 mm, while least bone was measured at 4mm. Bone thickness is greater apically because of the muscle attachment that is present in this area, which is associated with increased bone thickness. Since cut off value of bone width is 5mm as stated by Nucera *et al.*, [6], successful insertion of MBS miniscrew can be done only at 8 and 12 mm horizontal distance for MB7 and DB7 sites, as these sites in our study has bone width greater than 5 mm.

CONCLUSION

According to the results of this study, cortical bone depth (vertical) was maximum at distobuccal root of mandibular 1st molar but this area didn't show maximum total buccal bone thickness(horizontal), which was found at distobuccal root of mandibular 2nd molar. Since DB7 site had maximum total buccal bone thickness (horizontal) and had cortical bone depth (vertical) greater than 1mm, this site can successfully be used for miniscrew placement in our population.

LIMITATIONS

One limitation of this study was it didn't measure soft tissue thickness around mandibular buccal shelf (MBS) area which can vary according to different sites. Effect of sagittal and vertical skeletal pattern on bone thickness in MBS area was also not studied. Future studies should be done to evaluate relationship of bone density with MBS bone thickness.

ABBREVIATIONS

CBCT: Cone beam computed tomography.

DB6: Distobuccal root of mandibular first molar.

DB7: Distobuccal root of mandibular second molar.

MBS: Mandibular buccal shelf.

MB7: Mesiobuccal root of mandibular second molar.

TAD: Temporary anchorage device.

AUTHORS' CONTRIBUTION

Muteen Fatima: Conceptualization, Study design, Methodology, data analysis and interpretation and Writing draft.

Amjad Mahmood and **Kausar Ilyas**: Critical review and revision the manuscript, Final approval, final proof to be published.

Mehwish Shaheed: Final approval, final proof to be published.

Amna Saeed: Methodology, data analysis and interpretation.

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Declared none.

ETHICAL DECLARATIONS

Data Availability Statement

Data gathered during this study is available with corresponding author.

Ethical Approval

Ethical approval was obtained from the Ethics Review Committee, Margalla Institute of Health Sciences (DM/220/24).

Consent to Participate

Consent form to participate in the study is available with the corresponding author.

Consent for Publication

All the authors provided the consent for publication.

Conflict of Interest

Declared none.

Competing Interest/Funding

Declared none.

Use of AI-Assisted Technologies

The authors declare that NO generative artificial intelligence (AI) or AI-assisted technologies were utilized in the writing of this manuscript, in the creation of images/graphics/tables/captions, or in any other aspect of its preparation.

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