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ASSESSMENT OF MANDIBULAR BUCCAL SHELF CHARACTERISTICS AS AN OPTIMAL SITE FOR MINI-SCREW INSERTION

Original Research

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ABSTRACT

Background: Orthodontic mini-screw implants have revolutionized anchorage strategies, offering enhanced control during complex tooth movements. The mandibular buccal shelf (MBS) is frequently favored for extra-alveolar mini-screw insertion due to its dense cortical bone and anatomical accessibility. However, most available anatomical data stem from non-South Asian populations, limiting direct application in the Pakistani context. Region-specific CBCT-based evidence is essential to ensure safe and effective mini-screw placement aligned with local anatomical patterns.

Objective: To evaluate mandibular buccal shelf bone thickness and apicoronal depth at clinically relevant points across different vertical skeletal patterns in a Pakistani orthodontic cohort using three-dimensional CBCT imaging.

Methods: This cross-sectional study was conducted at the Department of Orthodontics, Islamic International Dental College, Islamabad, from October 2024 to April 2025. A total of 78 orthodontic patients aged 13–30 years were included. High-resolution CBCT scans were analyzed to measure MBS bone depth at 4 mm and 6 mm apical to the cementoenamel junction (CEJ), and bone thickness at 6 mm and 11 mm below the CEJ, bilaterally. Vertical skeletal pattern was determined via mandibular-maxillary angle (MMA), categorized as low (<21°), normal (21–29°), or high (>29°). Data were statistically analyzed using ANOVA and independent t-tests.

Results: The sample had a mean age of 22.67 ± 4.47 years and a mean BMI of 25.04 ± 1.02 kg/m²; 51.3% were male. At 4 mm from the CEJ, bone depth averaged 17.70 ± 1.95 mm (low angle), 17.42 ± 1.99 mm (normal), and 17.60 ± 1.89 mm (high). At 6 mm, depths were 12.30 ± 1.71 mm, 12.38 ± 1.94 mm, and 12.55 ± 1.79 mm, respectively. Bone thickness at 6 mm was approximately 4.67 ± 1.30 mm across groups, increasing to 5.55 ± 1.07 mm at 11 mm. No statistically significant differences were noted by skeletal pattern, gender, or hemiarch ($p > 0.05$).

Conclusion: The MBS demonstrates consistent bone morphology suitable for mini-screw anchorage in Pakistani patients, regardless of vertical growth pattern or gender. CBCT remains essential for individualized treatment planning and minimizing complications.

Keywords: Cone-Beam Computed Tomography, Dental Implantation, Mandible, Orthodontic Anchorage Procedures, Orthodontics, Skeletal Pattern, South Asian Population.

INTRODUCTION

The advent of absolute anchorage methods has significantly transformed the landscape of orthodontic therapy, with mini-screw implants emerging as a pivotal tool in contemporary treatment planning. These temporary anchorage devices (TADs) offer clinicians the ability to achieve reliable, non-compliant-dependent anchorage, enhancing the predictability and efficiency of tooth movement. However, the clinical success of mini-screws is intricately linked to the characteristics of the insertion site. Among the most crucial determinants of primary stability are the thickness and quality of the cortical bone, which, if insufficient, can lead to compromised retention and a higher risk of failure during active orthodontic forces (1). Current literature underscores that mini-screw stability is governed by a multifaceted interplay of factors, including not only bone density but also anatomical dimensions such as buccolingual width and apicoronal depth, soft tissue biotype, patient-specific variables, screw design, and the insertion protocol employed (2,3). Unlike conventional dental implants that achieve osseointegration, orthodontic mini-screws rely on mechanical interlocking with the surrounding bone. The mandibular buccal shelf (MBS) has gained popularity as a preferred extra-alveolar insertion site due to its typically robust cortical bone structure, particularly adjacent to the distal root of the mandibular second molar, offering favorable conditions for mini-screw placement (4,5). Nevertheless, clinical outcomes can still be affected by technical complications such as heat generation during screw placement and mucosal irritation caused by masticatory forces on the protruding screw heads (6).

With the evolution of cone-beam computed tomography (CBCT), clinicians now have access to precise three-dimensional imaging, enabling meticulous assessment of bone morphology and site-specific evaluation prior to TAD placement. CBCT has become the gold standard for evaluating the buccal shelf region and identifying optimal zones for mini-screw installation (7). Despite these advancements, most studies to date have been conducted on non-South Asian populations, limiting their applicability in regions with distinct craniofacial patterns. Given the documented anatomical variability across ethnicities, extrapolating data from international studies may not yield optimal results for South Asian patients, particularly those in Pakistan. Emerging evidence suggests that the structural characteristics of the MBS differ across various vertical facial growth patterns, influencing the selection of safe and effective insertion zones. Standardized distances from the cementoenamel junction (CEJ) have been proposed to guide mini-screw placement; however, these recommendations may not hold true in all populations (3,8). In the context of Pakistan, no previous study has comprehensively explored these variations using CBCT imaging, leaving a critical gap in localized orthodontic guidelines. Therefore, this study seeks to address this void by employing high-resolution CBCT to analyze the three-dimensional architecture of the mandibular buccal shelf in a Pakistani orthodontic cohort. By evaluating mean bone thickness and apicoronal depth at clinically significant sites across different vertical skeletal patterns, the objective is to identify optimal insertion locations for mini-screw implants and provide evidence-based, region-specific recommendations that account for local anatomical diversity.

METHODS

This cross-sectional study was conducted in the Department of Orthodontics at Islamic International Dental College, Islamabad, spanning from October 30th, 2024, to April 30th, 2025. Ethical approval was obtained prior to the commencement of the study from the Institutional Review Board, and written informed consent was secured from all participants or their legal guardians before enrollment. The study aimed to evaluate the three-dimensional characteristics of the mandibular buccal shelf (MBS) using cone-beam computed tomography (CBCT) in relation to vertical skeletal patterns among orthodontic patients. Participants were recruited through a non-probability sequential sampling technique. All patients presenting for orthodontic consultation during the study period who fulfilled the eligibility criteria were invited to participate. Inclusion criteria encompassed individuals aged 13 to 30 years, presenting with fully erupted mandibular second premolar, first molar, and second molar, and those for whom CBCT imaging was clinically indicated during initial orthodontic evaluation. Exclusion criteria included CBCT images of poor quality or those containing artifacts, presence of large coronal restorations or prostheses on the mandibular molars, and any signs of periapical or peri-radicular pathology due to endodontic or periodontal causes. Additionally, patients with osseous or odontogenic tumors, hypodontia, supernumerary teeth, orofacial clefts, or any diagnosed craniofacial syndromes were excluded to minimize confounding anatomical variability. Demographic and clinical information, including age, gender, body mass index (BMI), and skeletal pattern based on the mandibular-maxillary angle (MMA), were documented using a standardized data collection proforma. Lateral cephalograms were used to determine the vertical skeletal pattern, categorized as low angle (MMA < 21°), normal angle (MMA 21°–29°), and high angle (MMA > 29°) (9,10).

All subjects underwent high-resolution CBCT imaging and lateral cephalometry prior to orthodontic treatment. CBCT scans were evaluated for MBS parameters using standardized anatomical landmarks and orientations. Bone depth was measured 4 mm and 6 mm apical to the cementoenamel junction (CEJ), parallel to the Y-axis. Bone thickness was measured at 6 mm and 11 mm below the CEJ, parallel to the Z-axis, representing the buccolingual cortical breadth. Measurements were recorded bilaterally from both right and left hemiarches (11). All radiographic evaluations were performed by a single calibrated observer blinded to the clinical data. To ensure reliability, 10% of the CBCT scans were randomly re-evaluated after a two-week interval, and intra-examiner reliability was assessed using the intraclass correlation coefficient (ICC), with values above 0.80 interpreted as indicating strong agreement. The collected data were entered and analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables such as age, BMI, bone depth, and thickness were reported as means with standard deviations, while categorical variables such as gender, hemiarch, and skeletal pattern were summarized as frequencies and percentages. Data normality was assessed using the Shapiro-Wilk test. Comparative analyses between two groups (e.g., gender, hemiarch) were performed using independent samples t-tests. Differences among the three skeletal pattern groups were examined using one-way analysis of variance (ANOVA), with post-hoc Bonferroni correction applied for multiple pairwise comparisons. Stratified analyses were conducted to assess the modifying effects of age, gender, and side (hemiarch). A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study analyzed data from 78 orthodontic patients with a mean age of 22.67 ± 4.47 years and a mean body mass index (BMI) of 25.04 ± 1.02 kg/m². Males comprised 51.3% (n = 40) and females 48.7% (n = 38) of the sample. A majority of participants (64.1%) were over 20 years of age, while 39.7% had a BMI exceeding 25.0 kg/m². Regarding vertical skeletal pattern distribution, 23.1% of participants were classified as low angle, 44.9% as normal angle, and 32.1% as high angle. The right hemiarch was more frequently assessed (56.4%) compared to the left (43.6%). Evaluation of mandibular buccal shelf (MBS) bone depth and thickness revealed no statistically significant differences among the three vertical skeletal pattern groups. At 4 mm apical to the cementoenamel junction (CEJ), the mean bone depth was 17.70 ± 1.95 mm in low angle, 17.42 ± 1.99 mm in normal angle, and 17.60 ± 1.89 mm in high angle individuals (p = 0.88). Similarly, at 6 mm from the CEJ, the corresponding depths were 12.30 ± 1.71 mm, 12.38 ± 1.94 mm, and 12.55 ± 1.79 mm, respectively (p = 0.91). Bone thickness measured 6 mm below the CEJ was 4.68 ± 1.20 mm in the low angle group, 4.66 ± 1.35 mm in the normal angle group, and 4.67 ± 1.32 mm in the high angle group (p = 0.99). At 11 mm from the CEJ, bone thicknesses were 5.59 ± 1.02 mm, 5.52 ± 1.09 mm, and 5.53 ± 1.11 mm across the respective groups (p = 0.98). Stratification by gender revealed no statistically significant differences in bone depth or thickness at any measurement point (all p > 0.05). Bone depth at 4 mm was 17.43 ± 2.02 mm in males and 17.71 ± 1.81 mm in females (p = 0.52), and at 6 mm it was 12.43 ± 1.81 mm and 12.42 ± 1.85 mm, respectively (p = 0.99). Bone thickness at 6 mm was 4.75 ± 1.32 mm in males and 4.58 ± 1.29 mm in females (p = 0.56), while at 11 mm it was 5.50 ± 1.11 mm versus 5.58 ± 1.03 mm (p = 0.75). Hemiarch comparisons also yielded no significant differences between right and left sides for all parameters (all p > 0.05). However, paired comparisons of measurement sites demonstrated statistically significant differences. Bone depth at 4 mm was significantly greater than at 6 mm apical to the CEJ, with a mean difference of 5.14 ± 2.56 mm (95% CI: 4.56–5.71, p < 0.001). Likewise, bone thickness at 11 mm was significantly higher than at 6 mm from the CEJ, with a mean difference of 0.87 ± 1.76 mm (95% CI: -1.27 to -0.47, p < 0.001), suggesting an apically increasing trend in cortical bone thickness and a coronal decline in bone depth.

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Table 1: Demographic and basic characteristics of population

Variable	n	Mean ± SD / n (%)
Age (years)	78	22.67 ± 4.47
BMI (kg/m²)	78	25.04 ± 1.02
Age >20 years	50	64.1%
Gender		
Male	40	51.3%
Female	38	48.7%
BMI >25.0 kg/m²	31	39.7%
Hemiarch		
Right	44	56.4%
Left	34	43.6%
Vertical Pattern		
Low angle	18	23.1%
Normal angle	35	44.9%
High angle	25	32.1%

Table 2: Mean MBS Bone Depth and Thickness by Vertical Skeletal Pattern

Measurement Site	Low Angle (n=18)	Normal Angle (n=35)	High Angle (n=25)	ANOVA p-value
Bone Depth 4 mm (mm)	17.70 ± 1.95	17.42 ± 1.99	17.60 ± 1.89	0.88
Bone Depth 6 mm (mm)	12.30 ± 1.71	12.38 ± 1.94	12.55 ± 1.79	0.91
Thickness 6 mm (mm)	4.68 ± 1.20	4.66 ± 1.35	4.67 ± 1.32	0.99
Thickness 11 mm (mm)	5.59 ± 1.02	5.52 ± 1.09	5.53 ± 1.11	0.98

Table 3: Comparison of MBS Parameters by Gender and Hemiarch

Measurement	Male (n=40)	Female (n=38)	p-value	Right Hemiarch (n=44)	Left Hemiarch (n=34)	p-value
Depth 4 mm (mm)	17.43 ± 2.02	17.71 ± 1.81	0.52	17.86 ± 2.04	17.18 ± 1.70	0.12
Depth 6 mm (mm)	12.43 ± 1.81	12.42 ± 1.85	0.99	12.41 ± 1.86	12.44 ± 1.80	0.94
Thickness 6 mm (mm)	4.75 ± 1.32	4.58 ± 1.29	0.56	4.77 ± 1.40	4.53 ± 1.16	0.42
Thickness 11 mm(mm)	5.50 ± 1.11	5.58 ± 1.03	0.75	5.57 ± 1.04	5.50 ± 1.11	0.78

Table 4: Paired Differences in MBS Parameters at Different Measurement Sites

Parameter	Mean Difference (mm)	SD	95% CI	p-value
Depth (4 mm vs 6 mm)	5.14	2.56	4.56–5.71	<0.001
Thickness (6 mm vs 11 mm)	0.87	1.76	-1.27– -0.47	<0.001

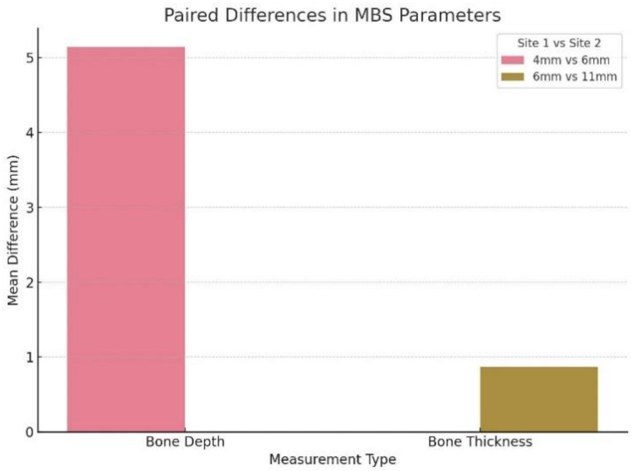

Figure 1 Paired Differences in MBS Parameters

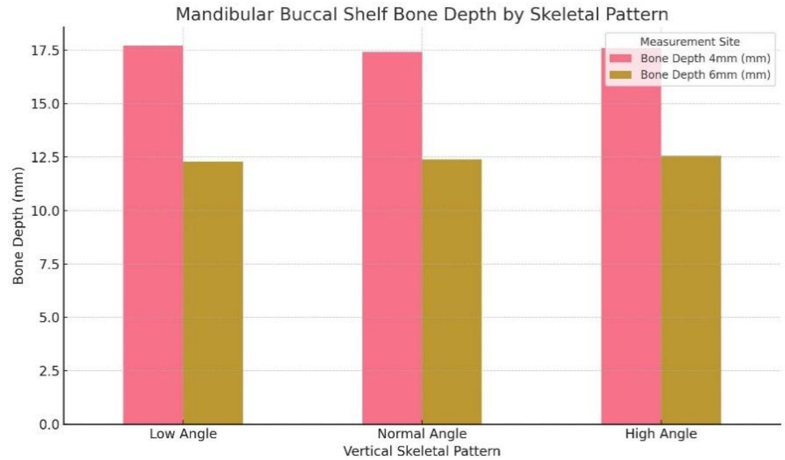

Figure 2 Mandibular Buccal Shelf Bone Depth by Skeletal Pattern

DISCUSSION

This study provides a comprehensive and regionally relevant analysis of the mandibular buccal shelf (MBS) as a viable site for orthodontic mini-screw anchorage in the Pakistani population, using high-resolution three-dimensional CBCT imaging. The findings demonstrated that both bone thickness and apicoronal depth at the MBS were consistently adequate across different vertical skeletal patterns, genders, and hemiarchs. These observations strengthen the clinical premise that the MBS can serve as a reliable and anatomically favorable location for mini-screw insertion, particularly when absolute anchorage is essential for complex orthodontic mechanics. The results were in alignment with existing literature from international cohorts, confirming sufficient cortical bone thickness at both 6 mm and 11 mm apical to the cementoenamel junction (CEJ), with a notable increase in thickness observed at the 11 mm level. This apical increment supports previously reported findings indicating that deeper mini-screw placement may enhance primary stability by engaging denser cortical bone and reducing the risk of mobility under orthodontic loading forces (12–14). Moreover, the lack of significant differences across skeletal morphologies echoes findings from other population-based studies, reinforcing the reproducibility of the MBS as a site with consistent anatomical architecture conducive to mini-screw anchorage (15,16). One of the distinct strengths of this study lies in the utilization of calibrated examiners and standardized CBCT protocols, which ensured measurement precision and minimized examiner-related bias. CBCT imaging remains instrumental in preoperative planning for mini-screw placement, offering detailed visualization of cortical bone, adjacent roots, and neurovascular structures. This approach significantly reduces the likelihood of procedural complications, such as root perforation or nerve injury, both of which carry significant clinical implications if overlooked (17,18).

The relevance of this study is further amplified by its focus on a South Asian population. Variations in craniofacial structure based on ethnicity, dietary influences, and growth patterns are well documented, yet the literature remains sparse for South Asian groups. By contributing normative anatomical data specific to Pakistani patients, this study addresses a critical knowledge gap and enhances the contextual applicability of global best practices within local orthodontic settings (19-21). These findings align well with those reported in related South Asian cohorts, suggesting a broader regional consistency in MBS morphology and anchorage suitability. Despite its contributions, the study is not without limitations. Being conducted at a single institution, the sample, although adequately powered, may not fully reflect the broader demographic or ethnic variability across Pakistan. The cross-sectional design inherently restricts the ability to evaluate real-world outcomes, such as mini-screw survival, failure rates, or the impact of orthodontic forces over time. Furthermore, bone density—an integral factor for mechanical interlocking and long-term stability—was not directly measured, which limits a more nuanced assessment of primary stability. Inter-examiner reliability, although mitigated through single-observer calibration, was not statistically tested, which may influence the reproducibility of measurements in broader clinical settings. Future research should prioritize multicenter collaboration to enhance the generalizability of findings and include longitudinal follow-up to evaluate the clinical success of mini-screws placed at MBS sites. Quantitative bone density analysis through voxel-based CBCT measurement or Hounsfield unit standardization would provide further clarity on cortical quality. Moreover, comparative trials assessing mini-screw performance in relation to insertion depth, angulation, and torque application could offer valuable insights into optimization strategies for enhanced clinical outcomes (22-24). Overall, this study reinforces the MBS as a structurally consistent and clinically promising site for orthodontic mini-screw insertion in the Pakistani population, with findings that support its application across diverse skeletal patterns and patient demographics. When combined with CBCT-guided planning and individualized assessment, these insights can significantly streamline treatment protocols and enhance anchorage reliability in contemporary orthodontic practice.

CONCLUSION

In conclusion, this study confirms the anatomical consistency and clinical suitability of the mandibular buccal shelf as a reliable site for orthodontic mini-screw insertion within the Pakistani population, regardless of skeletal pattern, gender, or side of placement. By providing region-specific evidence aligned with international standards, the findings support the safe integration of global skeletal anchorage techniques into local orthodontic practice. Importantly, individualized assessment through CBCT remains essential to ensure precision, minimize risks, and enhance treatment outcomes, reinforcing the value of tailored, image-guided planning in modern orthodontic care.

AUTHOR CONTRIBUTION

Author	Contribution
Rida Iqbal*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Ulfat Bashir Raja	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Kanwal Zulfikar	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Obaid Ullah	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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