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Original Article

Alveolar Bone Plate Measurements of Maxillary Anterior Teeth: A Cone Beam Computed Tomography Study

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ABSTRACT

Objective: To evaluate the crest height and facial alveolar bone thickness of the maxillary anterior teeth within the aesthetic zone among dentate adults in Pakistan.
Study Design: Cross-sectional Analytical study.
Place and Duration of Study: Armed Forces Institute of Dentistry, Rawalpindi Pakistan, from Sep 2024 to Feb 2025.
Methodology: The assessment of alveolar bone thickness was done in 43 patients with use of cone beam computed tomography (CBCT). The thickness of the alveolar bone facial plate was determined for each tooth type (at three different points i.e., A, B, and C) using a CBCT image and an integrated digital caliper. The analysis included bilateral upper canines (UC), upper lateral incisors (UL), and upper central incisors (UCI). Comparative analysis at 0.05 significance level was done using SPSS software (version 20).
Results: Out of the 258 teeth measured, 86 were canines, 86 were lateral incisors and 86 were central incisors. The mean thickness of the alveolar bone facial plates in upper anterior teeth was 1.04±0.09 mm for the lateral incisors, 1.29±0.04 mm for the canines, and 0.98±0.04 mm for the central incisors. These values differed significantly (p<0.001). No significant correlation was observed between age and facial bone plate thickness (p>0.05).
***Conclusion*:** There were significant differences in alveolar bone thickness in maxillary anterior region among Pakistani population. Facial plate thickness is an essential factor in determining optimal strategies for early implant placement in the aesthetic zone**.**

Keywords: Aesthetic Zone, CBCT Analysis, Dental Implant Planning, Facial Plate Measurement, Maxillary Bone Thickness.

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INTRODUCTION

After tooth extraction, changes like resorption and remodeling of alveolar bone are often observed in the region of facial plate.[1] These alterations impact dental implant placements, affecting its success and aesthetics.[2] The increasing use of cone beam computed tomography (CBCT) is attributed to detailed 3D examinations of craniofacial structures and anatomical regions provided as a result.[3] It evaluates bone height, quality and thickness with precision, which helps in treatment planning especially for anterior tooth replacements.[4-5] Alveolar bone thickness varies among diverse population and is influenced by the factors such as incisor inclination and hormonal status.[6-7]

Multiple studies have explored the association between incisor positioning and alveolar bone thickness. Facial plate thickness is an important factor for early implant placement because inadequate bone thickness (<1mm) increases the likelihood of fenestration or dehiscence.[8] According to the literature, around 30% of patients needed bone augmentation prior to implant placement because their facial bone thickness was below the critical value of 1mm. Variations in alveolar bone structure have also been observed in population-based investigations. Zekry *et al.*, conducted a CBCT-based study on a Southeast Asian population and found that the maxillary anterior region's mean facial bone thickness was 1.2±0.3 mm.[9] Zhang *et al.*, observed that participants above 40 years of age had significantly thinner labial bone plates (0.8±0.2 mm) than younger adults (1.2±0.3 mm), emphasizing the effect of aging on alveolar bone morphology.[10]

Despite many studies in the literature focusing on alveolar bone morphology, there are few studies that have examined and reported it in local Pakistani population, more specifically in the context of the aesthetic zone. Therefore, the aim of this study was measuring the thickness of alveolar bone and the height of crest in the aesthetic zone of the maxillary

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anterior teeth using CBCT images and examining its association with age in adult local Pakistani population.

METHODOLOGY

The study design for this study was an analytical cross-sectional. In this study, thickness of alveolar bone in the aesthetic zone of the maxillary anterior teeth, was measured on CBCT scans, which were analyzed using NEWTOM software. The study was carried out during September 2024-February 2025. Research Ethics Committee of AFID reviewed and approved this study after ethical review board (vide letter no.918/Trg/09/Feb/2023). Epi Info StatCal software version 7 (CDC, USA) was used to determine the sample size, with a 95% confidence interval. The expected frequency used was set to 50% to indicate the effect within a representative population and significant difference. CBCT scans of 43 patients visiting Armed Forces Institute of Dentistry (AFID), Rawalpindi, Pakistan was analyzed. These were retrospective scans taken for various clinical indications.

Inclusion Criteria: CBCT scans from patients of both genders, aged between 18–64 years, who had permanent anterior teeth present bilaterally on the maxilla and had been recommended CBCT imaging for diagnostic purposes in the anterior maxillary region were included.

Exclusion Criteria: Patients who had one or more missing permanent anterior maxillary teeth were excluded if they had implants inserted in the anterior maxillary region, poor quality of CBCT images that did not allow for accurate measurement, or signs of abnormal remodeling of the alveolar bone due to pathological or systemic dento-alveolar disorders.

CBCT images of the patients were analyzed by the author and consultant, who were both independently trained. They used bilateral upper canines (UC), upper lateral incisors (UL), and upper central incisors (UCI) for analysis. For ascertaining reliability, repeated measurements were observed to test the examiners' agreement. For ascertaining the reproducibility and reliability of the repeatedly measured values, intra class correlation coefficients (ICCs) were determined. Throughout this procedure, accuracy of data and minimal observer variability was maintained. This approach ensured precise measurement of alveolar bone and tooth morphology.

Thickness of facial plate of alveolar bone was calculated for each tooth at tooth root using sagittal view of CBCT image. Dividing it into equal halves, a sagittal section was made by pointing the cursor along the tooth's midline.[11] Thickness of alveolar bone was assessed at three distinct points with the help of digital caliper.

In the sagittal view, fixed reference points were created at the midpoint of each third, in order to ensure accuracy. Consistent measurements along the middle, apical and cervical sections were made possible due to these reference points.

All these readings were measured in millimeters (mm). Direct measurements were taken on the images from CBCT, and a built-in digital caliper was used for this purpose. To ensure consistency in assessment, a single monitor was used for analyzing all the images from the patients under proper lighting conditions.[12]

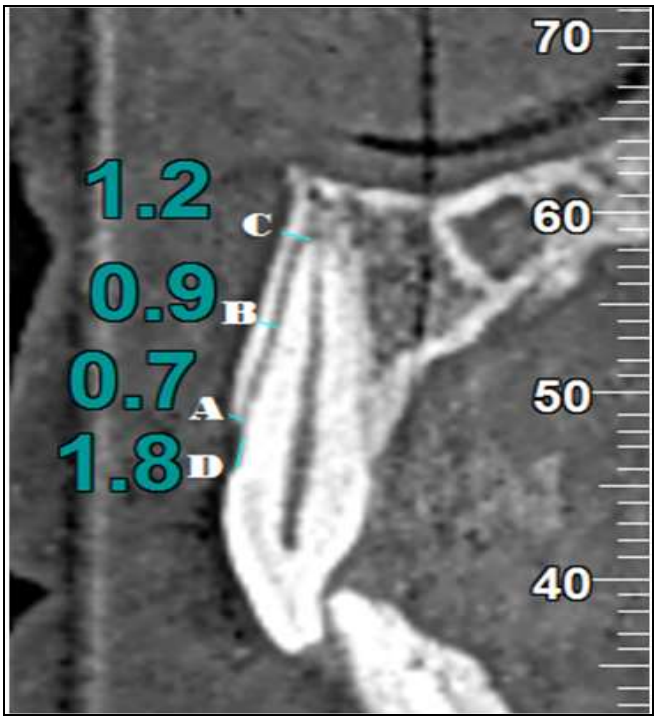

Figure: Measurements of facial plate bone thickness in axial view from facial aspect of tooth root in CBCT

- Point A: Measures the distance from the facial bone plate at the level of the bone crest to the coronal third of the root.
- Point B: Represents the distance from the facial bone plate to the mid-root region.
- Point C: Indicates the measurement from the facial bone plate to the apical third of the root.

Statistical Package for the Social Sciences (version 20) was used to evaluate statistically significant differences and normal distribution of the data was assessed by Shapiro-Wilk test. Continuous variables,

i.e., age and facial plate thickness measurements at three reference points A, B, and C for central incisors, lateral incisors, and canines, were reported as Mean±SD. Categorical variables like gender, tooth type, and categories of thickness (<1.5 mm, 1.5–1.9 mm, and 2.0 mm) were presented as frequencies and percentages. Significant differences between alveolar plate measurements between tooth types were evaluated using ANOVA. Pearson correlation was done to find the relationship between age of the patient and thickness of the facial plate of the alveolar bone at three sites (A, B, and C) of measurement for each tooth category (central incisors, lateral incisors, and canines) in the maxillary anterior region. The level of significance was set to 95%, with *p*-values being significant at <0.05. STROBE guidelines were followed during the study.

RESULTS

The study included 43 patients in total, including 20 male (46.5%) and 23 female (53.5%) patients with a mean age of 37.74±9.5 years. A total of 258 teeth were measured, out of which 86 were central incisor, 86 were lateral incisor, and remaining 86 were canines. Table-I shows the frequency and percentage distribution of thickness of facial plate of alveolar bone for central incisors, lateral incisors, and canines. Most teeth in all three groups had a thickness of below 1.5mm, with the highest percentage recorded among canines (94.19%), followed by central incisors (86.05%) and lateral incisors (80.23%). A small proportion measured between 1.5–1.9 mm, while only 3.49% of lateral incisors reached 2.0 mm thickness.

Table-I: Frequency and Percentage Distribution of Facial Plate Thickness of Alveolar Bone in Maxillary Anterior Teeth

Thickness of Facial Plate (mm)	Central Incisor n(%)	Lateral Incisor n(%)	Canines n(%)
<1.5	74(86.05)	69(80.23)	81(94.19)
1.5-1.9	12(13.95)	15(17.44)	5(5.8)
2.0	0(0)	2(2.32)	0(0)

Table-II: Mean Facial Plate Thickness (±SD) at Three Measurement Points (A, B, C) for Central Incisors, Lateral Incisors and Canines in Upper Anterior Maxilla (n=43).

Measure of Distance	Lateral Incisor Mean±SD	*p*-value	Canines Mean±SD	*p*-value	Central Incisor Mean±SD	*p*-value
Point A (mm)	0.96±0.05	<0.001	0.95±0.01	<0.001	0.95±0.02	<0.001
Point B (mm)	1.01±0.04		0.94±0.02		0.96±0.08	
Point C (mm)	1.38±0.16		1.06±0.08		1.21±0.19	
Mean thickness (mm)	1.29±0.04		0.98±0.04		1.04±0.09	

Table-II presents the mean facial plate thickness of alveolar bone at three points of reference (A, B, and C) for canines, lateral incisors, and central incisors. Lateral incisors showed highest overall mean thickness (1.29±0.04 mm), followed by central incisors (1.04±0.09 mm) and canines (0.98±0.04 mm). The thickest values were found at Point C, and Points A and B showed relatively thinner bone. Statistically significant differences (p<0.001) were found between the tooth types at Point A.

Table-III shows the comparison of the mean facial plate thickness of the right and left sides of maxillary anterior teeth. The measurement of all three types of teeth (lateral incisors, canines, and central incisors) was symmetrical with the same or very close mean values on both sides. The most significant thickness was that of Point C, while Points A and B had comparatively lower values.

Table-III: Comparison of Mean Facial Plate Thickness (± SD) between Right and Left Sides for Central Incisors, Lateral Incisors and Canines (n=43)

Measure of Distance	Lateral Incisor Mean±SD		Canines Mean±SD		Central Incisor Mean±SD	
	Left	Right	Left	Right	Left	Right
Point A (mm)	0.96±0.05	0.96±0.04	0.95±0.01	0.95±0.01	0.94±0.02	0.95±0.01
Point B (mm)	1.01±0.04	1.01±0.04	0.94±0.02	0.94±0.01	0.96±0.07	0.96±0.08
Point C (mm)	1.38±0.13	1.38±0.13	1.06±0.08	1.06±0.08	1.21±0.18	1.21±0.20
Mean thickness (mm)	1.12±0.07	1.12±0.07	0.98±0.04	0.98±0.03	1.04±0.09	1.04±0.13

Table-IV: Correlation between Age and Facial Plate Thickness of Alveolar Bone in Aesthetic Zone of Maxillary Anterior Teeth

Facial plate thickness of alveolar bone according to teeth		Age	
		r	*p*-value
Central Incisor	Point A	-0.059	0.708
	Point B	-0.162	0.299
	Point C	0.090	0.564
Lateral Incisor	Point A	-0.113	0.472
	Point B	0.078	0.619
	Point C	-0.115	0.464
Canines	Point A	0.067	0.671
	Point B	0.120	0.444
	Point C	-0.035	0.822

Table-IV depicts the correlation between facial plate thickness and patient age at three measurement locations for every type of anterior maxillary tooth. Statistical non-significant (p>0.05) and weak correlation coefficients (r) were observed in all comparisons.

DISCUSSION

The results indicated that the greatest thickness of the facial plates was of lateral incisors, with a mean measurement of 1.29±0.04 mm, followed by central incisors (1.04±0.09 mm), and the thinnest of the facial plate was that of canines, with mean facial plate measurement of 0.98±0.04 mm. The smallest mean thickness recorded was at point B of the right canine, which was approximately 0.64 mm. On the contrary, the maximum mean thickness was recorded at point C of the lateral incisors, which was 1.78 mm. The facial

plate thickness of alveolar bone showed no significant correlation with age for all patients considered in the study (p>0.05).

Several national and international studies have reported findings on facial plate thickness, allowing for a comparative evaluation of our results. In a study conducted by Januario *et al.,* the mean thickness of the facial plate of alveolar bone for maxillary central incisors was about 1.06mm,[13] which concurs with this study's reports of approximately 1.04±0.09 mm. In a similar study conducted by Sun *et al.,* the mean thickness for lateral incisors was reported to be 1.2mm,[14] which is marginally different from that reported in the present study (1.29±0.04 mm). This minor variation could be attributed to differences in sample populations, measurement methodologies, or imaging techniques. Internationally, a CBCT-based study by Ghassemian *et al.,* in a European population reported thinner facial bone plates, particularly in canines, averaging around 0.85mm.[15] This is consistent with the present study, in which canines exhibited the lowest mean thickness (0.98±0.04 mm). However, the slight difference might be due to genetic variation, dietary factors, or environmental influences affecting bone density. Pradhan *et al.,* examined 186 adult patients with CBCT and found an average facial alveolar bone thickness of 1.14±0.31 mm for maxillary lateral incisors and concluded that facial bone thickness in the anterior maxilla is overall thin, with the majority of measurements less than 1.5mm, consistent with the findings of the current study.[16] The present study also indicated no significant association between age and facial plate thickness, consistent with observations from Sheerah *et al.,* which reported that alveolar bone thickness remained constant throughout life except in cases of periodontal disease or other diseases.[17] However, other studies, for example, Zhao *et al.,* indicate a mild decline in bone thickness as a result of aging along with patterns of bone resorption.[18] The lack of significant correlation in the present study could be attributed to the relatively narrow age range of study sample (mean age: 37.74±9.5 years), which may not adequately reflect age-related changes effectively. Li *et al.,* found that older individuals had significantly thinner facial bone plates compared to younger individuals and attributed this difference to age-related bone resorption and reduced osteogenic activity.[19] This contrasts with the present study's findings of no association between age and facial plate thickness.

Ahmad *et al.,* noted an increase in cortical and buccal bone thickness from the anterior to posterior mandible, with a minor exception at the second premolar. This implies a gradual variation in bone shape along the dental arch under functional loading and structural anatomy. The current study's focus was specific to the maxillary anterior, indicating facial bone thickness was greatest at the lateral incisors, central incisors, and smallest at canines. Although this is not an anterior-to-posterior linear progression like that for the mandibular data from Ahmad *et al.,* localized variation related to tooth form and location exists.[20] Similarly, a study by Arbab *et al.,* in local Pakistani population measured alveolar bone thickness in the anterior maxilla and concluded that the lateral incisors measured 1.25mm, central incisors 1.05mm, and canines 0.95mm thick, thereby supporting the conclusions of this research.[21] The canine region's smaller facial bone (0.98±0.04 mm) suggests a higher risk of fenestration or dehiscence issues when receiving orthodontic treatment or having implants placed. However, implants and other restorative procedures may benefit from the greater bone thickness at the lateral incisors (1.29±0.04 mm). The similarity of these results among several Pakistani studies implies that the trends in alveolar bone thickness observed may be typical for the local population. The consistency of these findings with various Pakistani studies indicates that the trends in alveolar bone thickness that were seen may be characteristic for the local population and may be relevant for understanding ethnic variation in craniofacial structure and bone density.

LIMITATIONS OF THE STUDY

This study offers invaluable insight into the thickness of the facial plate of the alveolar bone in the maxillary anterior region; however, there are a few limitations as well. First, the sample size was small, which restricted the generalization of the data to extensive populations. Furthermore, the study did not take into consideration the effects of potential factors like direction and magnitude of occlusal forces, status of the patient's periodontal health, or genetic factors, which could influence bone thickness.

In the future, the studies must target more diverse and broader cohorts of populations to strengthen these findings and data. Additionally, longitudinal research studies evaluating changes in alveolar bone thickness over time would enable a more detailed understanding of bone remodeling dynamics. Evaluating the influence of different factors on facial plate thickness, such as tooth loss, orthodontic treatment, and implant surgeries could also provide clinically appropriate knowledge.

CONCLUSION

In conclusion, a significant variation in the facial bone thickness of local Pakistani dentate patients in the maxillary teeth in aesthetic region is found. A crucial role is demonstrated by thickness of the facial plate bone in this region as it determines the optimum course of treatment, particularly for early implant implantation.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

MS & SK: Data acquisition, data analysis, critical review, approval of the final version to be published.

SSZR & WP: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

SS & SK: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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