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Cone Beam Computerized Tomographic (CBCT) Assessment of Buccal Bone Thickness in Maxillary Aesthetic Region

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ABSTRACT

Buccal bone thickness (BBT) in the maxillary aesthetic region is a key determinant of ridge remodeling and the chances of recession of the mucosa following implantation. **Objectives:** To measure BBT at standardized levels around maxillary central incisors, lateral incisors, and canines on CBCT scans of patients from Peshawar, Pakistan. **Methods:** This cross-sectional study assessed 96 CBCT scans of patients aged 18–60 years obtained from the Department of Oral and Maxillofacial Radiology, Rehman Medical Institute/Rehman College of Dentistry, Peshawar, over six months from 3 February 2025 to 3 August 2025. BBT was measured on sagittal reconstructions at the crestal level (L0) and at 1 mm (L1), 3 mm (L3), and 5 mm (L5) apical to the crest. Descriptive statistics were reported; gender differences were explored using independent-samples tests and age associations using Spearman correlation (α=0.05). **Results:** At L0, BBT was <1 mm in 90.6% of central incisors, 90.7% of lateral incisors, and 84.3% of canines. Males showed greater BBT than females at selected levels (central incisors: L1 and L5; lateral incisors: L5). Age showed statistically significant but weak correlations with BBT at L1 for central incisors and at L5 for lateral incisors and canines. **Conclusions:** In this sample, the buccal plate in the anterior maxilla was predominantly thin (<1 mm), particularly for lateral incisors and at the crest. Preoperative CBCT assessment should guide implant positioning and the anticipated need for augmentation, with consideration of patient sex and age.

INTRODUCTION

The key to the successful placement of the implants in the maxillary aesthetic area is maintaining the buccal plate and peri-implant soft tissues. When immediate implant placement is scheduled, a thin buccal bone wall is related to increased post-extraction remodeling and an increased likelihood of mid-facial recession. Conebeam computed tomography (CBCT) offers three-dimensional imaging, which allows the effective preoperative measurement of buccal bone thickness (BBT) and cementoenamel junctional alveolar crest (CEJAC) distance, which will determine the timing of implant creation, placement, and augmentation requirement. The measurement of the BBT in the maxillary aesthetic part is essential in dental implant placement as well as maintenance of oral aesthetics. CBCT has emerged as a preferred imaging technique, providing precise, three-dimensional representations of maxillofacial structures with reduced radiation exposure compared to traditional computed tomography [1, 2]. This

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high-precision imaging allows clinicians to evaluate buccal bone dimensions that are vital for planning successful dental procedures, particularly in the maxillary aesthetic zone, where bone deficiency can significantly impact aesthetic outcomes and functional success [3, 4]. Previous studies underscore the importance of accurately measuring buccal bone thickness as it can greatly influence treatment strategies, particularly in post-extraction scenarios and in implantology [5, 6]. The ability to ascertain the morphology of buccal bone enhances treatment decision-making by identifying the volume available for implants and anticipating potential complications related to bone thickness [7, 8]. Notably, Fuentes et al. documented the effectiveness of CBCT in assessing buccal bone thickness, finding it essential for evaluating the anatomical considerations of extraction sites before implant placements [9]. Equally, research has noted that there have been thin buccal bone walls which are less softened than 1 mm at different anterior maxillary positions, posing a possible threat of resorption after implantation has been done [10, 11]. A difficulty for clinicians in placing dental implants in the anterior maxilla is the complex anatomical conditions coupled with the very high aesthetic demands of patients [12]. In the replacement of one anterior tooth in a region that does not have deficiencies of tissue, predictable results, such as esthetic results, may frequently be attained, primarily because of the soft-tissue support of the surrounding teeth. However, very few authors have covered the replacement of other surrounding absent teeth in the anterior maxilla with fixed implant restorations, and the cosmetic results cannot be predicted, especially when it comes to the preservation of natural soft tissue profiles [13]. This is the new trend of placing the implants within the aesthetic zone immediately after the removal of the failing tooth and then provisionalizing it immediately [14]. Provisionalization of implants in healed regions of the maxillary aesthetic area, which is temporary, yields the same outcomes as delayed provisionalization [15]. Treatment of the anterior maxilla with implants presents special problems due to the high aesthetic requirements and the morphology of the anatomy in this area. An adequate amount of bone in the bucca is one of the basic factors that dictate the stability of implants, proper placement, and success in the long-term aesthetics. There are significant dimensional changes that take place in the alveolar bone after the removal of the tooth, which commonly results in a loss of width and height of the ridge. The buccal plate thickness is especially important, as it is highly likely to be resorbed and, as such, disagrees with the hard and soft tissue support.

This study does not support a large sample size to define the gap. This study aims to investigate the buccal bone thickness at standardized levels around maxillary central incisors, lateral incisors, and canines on CBCT scans of patients from Peshawar, Pakistan

METHODS

The present cross-sectional study was done during the period from 3 February 2025 to 3 August 2025, and involved the analysis of 96 CBCT scans done at the Department of Oral and Maxillofacial Radiology, Rehman Medical Institute (RMI). The sampling technique of collecting the CBCT images of the patients attending Rehman College of Dentistry RCD was a convenience sampling procedure. The Institutional Review Board of Rehman College of Dentistry approved the ethical issue with the ref no: RCD-04-23-145. All the CBCT scans were performed by a trained technologist in the CBCT unit (CS9300CBCT, Carestream Dental, Atlanta, GA, USA) using the following parameters: 85 k V, 12 mA, a voxel size of 0.1 mm, and a field of view of 17 13 cm. The sample was established at 96, the basis of which was the prevalence rates of a previous study. CBCTs were also acquired on patients who had received dental services, including oral surgery, dental implants, and orthodontics, and were processed using the help of CS 3D software (Carestream Dental, Atlanta, GA, USA). Inclusion criteria were patients between the ages of 18 and 60 years, with intact maxillary central and lateral incisors and canines, no restorations, periodontal disease, or trauma. Scans that had clinical or radiographic signs of periodontal disease were eliminated. Gingival phenotype was not directly assessed on CBCT; therefore, residual confounding by soft-tissue phenotype cannot be completely excluded and is acknowledged in the limitations. Using EZ3D Plus software, sagittal reconstructions were obtained, and five lines were traced perpendicular to the tooth axis at standardized levels from the cementoenamel junction (CEJ) to the apex. The thickness of the buccal bone was calculated at each level. The sagittal section of CBCT was compared at a particular parallel corresponding level in terms of the wall thickness of the buccal bone. Line A1-A2 was located in the very apical tooth, and line E1-E2 was located at the same level as the crests of the bone. Lines B, C, and D were drawn at an equal and parallel distance between A1-A2 and E1-E2 (Figure 1).

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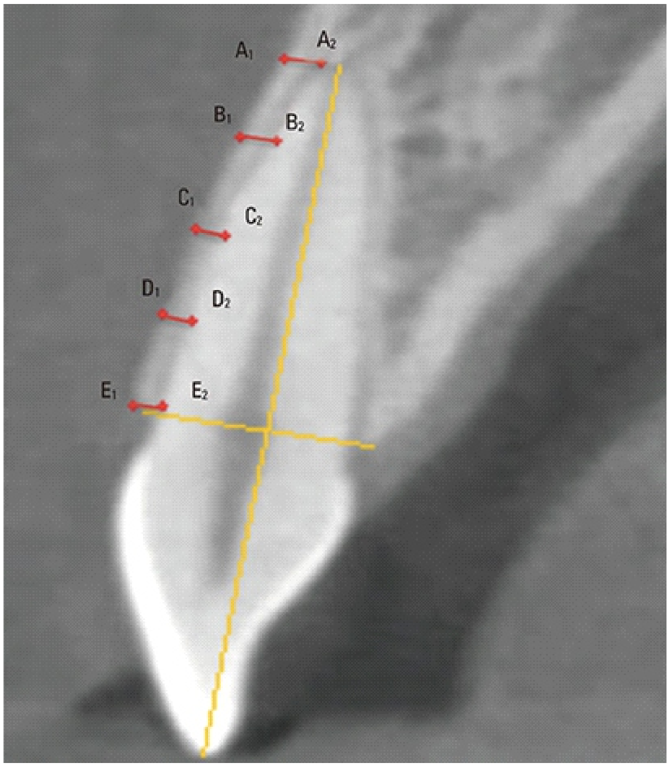

Figure 1: Buccal Bone Wall Thickness on Sagittal Sections of the CBCT Scans Using Standardized Parallel Reference Lines

Means, standard deviations, and frequency distributions were calculated. The independent samples T-test and ANOVA were used to assess differences across gender and age groups, with a significance threshold of $p<0.05$.

RESULTS

In this cross-sectional study, 96 CBCT scans from patients aged 18–60 years were assessed, with a mean age of 36.8 ± 10.9 years. Participants were distributed across the 18–30 (35.4%), 31–45 (39.6%), and 46–60 (25.0%) year age groups. The sample included 28 males (29.2%) and 68 females (70.8%). CBCT indications comprised orthodontics (31.2%), oral surgery (41.7%), and implant planning (27.1%). All scans were obtained from the Oral and Maxillofacial Radiology Department, Rehman Medical Institute/Rehman College of Dentistry, Peshawar, between 3 February 2025 and 3 August 2025 (Table 1).

Table 1: Demographic Characteristics of the Study Sample (n=96)

Characteristic	Value
Age (Years), Mean ± SD	36.8 ± 10.9
Age Groups, n (%)	18–30: 34 (35.4%); 31–45: 38 (39.6%); 46–60: 24 (25.0%)
Sex, n (%)	Male: 28 (29.2%); Female: 68 (70.8%)
Indication for CBCT, n (%)	Orthodontics: 30 (31.2%); Oral Surgery: 40 (41.7%); Implant Planning: 26 (27.1%)
CBCT Acquisition Period	3 February 2025 - 3 August 2025 (6 Months)

There was a buccal bone layer very thin (L0) at the crestal part in 28.1 per cent. of central incisors, 46.9 percent. of lateral incisors and 33.3 per cent. of canines. In 62.5 percent of central, 43.8 percent of lateral, and 51.0 percent of canines, a thickness of between 0.5mm and 1mm was observed. Only 9.4% of central incisors, 9.3% of lateral incisors, and 15.7% of canines had a heavier bone (1 2 mm). Thin apical buccal bone (0.5 -1 mm) was observed at 1 mm apical to the crest (L1) in 65.6% of central incisors. On 13.6, 11.4, and 14.5 percent of central incisors, lateral incisors, and canines, respectively, a thickness of 1 to 2 mm was noticed. Very thin bone (<0.5 mm) occurred at 3 mm apical to the crest (L3) in 18.7% of central incisors, 35.4% of lateral incisors, and 19.8% of canines. Very thin bone (less than 0.5 mm) was present at 5 mm apical to the crest (L5) in 25.0 percent of central incisors, 53.1 percent of lateral incisors, and 22.9 percent of canines. Thickness of up to 0.5 mm to 1 mm was observed in 61.5 percent of central incisors, 41.7 percent of lateral incisors, and 59.4 percent of canines. The only central incisors, lateral incisors, and canines with a thickness of 1 to 2 mm were 13.5 percent, 5.2 percent, and 17.7 percent, respectively (Table 2).

Table 2: Buccal Bone Thickness Distribution Categories (<0.5 Mm, 0.5–1 Mm, 1–2 Mm) at Each Level (L0, L1, L3, L5) by Tooth Type

Level	<0.5 mm (%) CI	0.5–1 mm (%) CI	1–2 mm (%) CI	<0.5 mm (%) LI	0.5–1 mm (%) LI	1–2 mm (%) LI	<0.5 mm (%) C	0.5–1 mm (%) C	1–2 mm (%) C
L0	28.1	62.5	9.4	46.9	43.8	9.3	33.3	51.0	15.7
L1	20.8	65.6	13.6	31.3	57.3	11.4	23.0	62.5	14.5
L3	18.7	68.8	12.5	35.4	54.2	10.4	19.8	65.7	14.5
L5	25.0	61.5	13.5	53.1	41.7	5.2	22.9	59.4	17.7

The average distance of the CEJ to the alveolar crest was 2.10 ± 0.78 mm in central incisors, 2.18 ± 0.82 mm in lateral incisors, and 2.25 ± 1.10 mm in canines. The last value of the mean BBT at the crest measured 0.68 bbcci, 0.61 bbcci, and 0.72 bbcci with crest in central incisors, lateral incisors, and canines, respectively. The mean thickness at 1 mm apical to the crest was 0.81 ± 0.20 mm (central incisors), 0.73 ± 0.25 mm (lateral incisors), and 0.82 ± 0.27 mm (canines). Mean thicknesses at 5 mm were 0.71 ± 0.21 mm (central incisors), 0.50 ± 0.22 mm (lateral incisors), and 0.66 ± 0.26 mm (canines) (Table 3).

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Table 3: Mean BBT (mm) and CEJ-AC Distance (mm) by Tooth Type and Level

Tooth	Crest (L0)	1 mm (L1)	3 mm (L3)	5 mm (L5)	CEJ-AC
Central Incisor	0.68 ± 0.23	0.81 ± 0.20	0.75 ± 0.22	0.71 ± 0.21	2.10 ± 0.78
Lateral Incisor	0.61 ± 0.24	0.73 ± 0.25	0.65 ± 0.29	0.50 ± 0.22	2.18 ± 0.82
Canine	0.72 ± 0.26	0.82 ± 0.27	0.79 ± 0.28	0.66 ± 0.26	2.25 ± 1.10

Descriptive statistics for buccal bone thickness and CEJ–AC distance

Sex differences were initially explored using independent-samples tests within each tooth type and measurement level. To assess whether age confounded observed sex differences, we additionally fitted an age-adjusted multivariable model with buccal bone thickness as the outcome, sex as the main predictor, and age as a covariate, accounting for within-subject clustering of repeated measurements. 1. BBT = BBT measured on sagittal CBCT reconstructions. 2. L1 = 1 mm apical to the alveolar crest; L5 = 5 mm apical to the alveolar crest. 3. Sex differences were tested using independent-samples comparisons; only statistically significant results are shown. 4. Age associations were assessed using Spearman's rank correlation (rs). 5. Statistical significance was set at alpha = 0.05 (two-sided). Although age showed statistically significant correlations with BBT at selected levels, the effect sizes were weak and had limited clinical predictive value. Clinical interpretation should prioritize absolute CBCT-measured thickness and whether sites approach commonly cited stability thresholds (≈1.5–2.0 mm), noting that most sites in this cohort remained <1 mm (Table 4).

Table 4: Statistically Significant Associations of Sex and Age with BBT in the Anterior Maxilla (n=96)

Predictor	Tooth Type	Measurement Level	Direction of Association	Effect Estimate/Test Statistic
Sex (Male vs Female)	Central incisor	L1	Males Had Greater BBT Than Females	p=0.006
Sex (Male vs Female)	Central incisor	L5	Males Had Greater BBT Than Females	p=0.031
Sex (Male vs Female)	Lateral incisor	L5	Males Had Greater BBT Than Females	p<0.001
Age (Years)	Central incisor	L1	Increasing Age Was Associated with Thinner BBT	rs = 0.298, p<0.001
Age (Years)	Lateral incisor	L5	Increasing Age Was Associated with Thicker BBT	rs = 0.195, p=0.021
Age (Years)	Canine	L5	Increasing Age Was Associated with Thicker BBT	rs = 0.208, p=0.016

DISCUSSION

This CBCT-based assessment shows that the buccal plate in the anterior maxilla is predominantly thin in this Peshawar cohort, especially at the crestal level. Most sites were <1 mm at L0 across all three tooth types, with lateral incisors demonstrating the least favourable distribution and the lowest mean thickness at deeper levels. This finding is clinically important because the anterior maxilla has high aesthetic demands and limited tolerance for post-extraction and post-implant hard- and soft-tissue changes. Even small losses of facial bone support can translate into mid-facial mucosal recession and compromised aesthetic outcomes in the long term [1, 2]. Current results align with the broader morphometric literature showing that the facial/buccal bone wall in the maxillary aesthetic region is frequently thin when evaluated on CBCT. Systematic reviews and meta-analyses of CBCT studies report a high prevalence of thin facial plates in the anterior maxilla, with substantial inter-individual variability but a consistent pattern of limited buccal thickness at many anterior sites [15, 16]. Multiple CBCT investigations similarly highlight that thin buccal walls are common around maxillary anterior teeth and should be anticipated during implant planning [17-20]. Recent CBCT work focusing on maxillary central incisors also supports that the buccal wall is often slender and morphologically variable, reinforcing the need for site-specific assessment rather than assumptions based on tooth type alone [21]. From a treatment-planning perspective, thin buccal bone is relevant because it is more susceptible to resorption and dehiscence after extraction and during implant therapy. Evidence from experimental and clinical work suggests that a thicker peri-implant buccal wall is associated with more favourable hard- and soft-tissue stability. Experimental evidence has revisited the concept of a "critical" buccal wall thickness, with values around 1.5 mm frequently discussed as a clinically meaningful threshold for reducing remodeling-related risk compared with thinner walls [12]. Clinical trials in the aesthetic zone show that even with immediate implant placement and provisionalization, hard- and soft-tissue alterations occur and may require adjunctive approaches to mitigate aesthetic compromise [9, 10]. Where baseline buccal thickness is limited, augmentation strategies (e.g., guided bone regeneration and/or grafting approaches) may be needed to support appropriate three-dimensional implant positioning and soft-tissue contour stability [6, 7]. These considerations are consistent with classic aesthetic-zone principles that prioritize prosthetically driven implant placement and preservation of facial support [1, 2]. Sex-based differences in this dataset were statistically significant at selected sites/levels (central incisor L1 and L5; lateral incisor L5), with males showing higher BBT. However, the clinical implications of these differences should be interpreted cautiously. The absolute thickness values remained low overall, and the distribution analysis indicates

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that most sites still fell below <1 mm, even where sex differences were present. Therefore, sex may contribute to anatomical variability but should not replace direct CBCT-based evaluation of the recipient site. Age showed statistically significant but weak correlations with BBT at specific measurement points. These effect sizes have limited clinical predictive value on their own. Interpreting the associations against anatomical thresholds is more informative than focusing on p-values. At the levels where age correlations were detected, most sites remained within thin-bone categories, meaning that small age-associated shifts are unlikely to move many patients into thicker, lower-risk ranges. Accordingly, treatment decisions in the aesthetic zone should prioritize the measured site-specific thickness and whether it approaches commonly cited stability thresholds (≈1.5–2.0 mm), rather than relying on age alone [15, 16]. Soft-tissue phenotype may also influence aesthetic risk and peri-implant remodeling, but it was not directly measured in this study. Prior work indicates relationships between gingival thickness, underlying bone morphology, and early peri-implant bone changes, suggesting that combined hard–soft tissue assessment is ideal when feasible [8, 14]. The use of convenience sampling from a single centre may also limit the generalizability of the findings. Nonetheless, the study's strengths include standardized CBCT acquisition parameters, defined inclusion/exclusion criteria to reduce confounding from pathology/restorations, and tooth- and level-specific measurements that reflect clinically relevant implant planning landmarks. CBCT remains a suitable modality for three-dimensional assessment in this setting, and diagnostic performance can be influenced by voxel size and reconstruction parameters, which were standardized in our protocol [13]. Overall, the present findings support routine preoperative CBCT assessment in the maxillary aesthetic region to guide implant positioning and to anticipate whether buccal augmentation may be required, particularly in lateral incisor sites and at crestal levels where thin plates are most prevalent [12, 16].

The findings of this study are confined by the single retrospective design that is limited to a single center and cannot support the outcomes to occur after treatment, nor can they be generalized to other populations. One of the weaknesses of the study is the lack of soft-tissue data, which is an essential aspect of the aesthetic results. Being solely a radiographic study, the outcomes are also not corroborated by real-life surgical results or by long-term patient outcomes. Further research ought to determine the direct clinical evidence by following the effect of thin buccal plates on the aesthetics of the implant in the long run. The studies need to foster both 3D bone evaluation and the gingivae phenotype to develop their full risk profile. Further, to enhance the generalizability, the same studies need to be done in multi-center populations that are diverse. Lastly, a comparative analysis is required in order to assess the best bone augmentation methods to use in these high-risk and thin-wall locations.

CONCLUSIONS

The study confirms that in our patients, most anterior maxillary sites have buccal bone thicknesses less than the ideal 2 mm for implant procedures. These findings advocate for routine CBCT assessment and individualized treatment planning in implant dentistry.

Authors' Contribution

Conceptualization: SR, HMA
Methodology: MHA, HMA
Formal analysis: FM
Writing and Drafting: SR, MHA, NN, SS
Review and Editing: SR, MHA, NN, FM, HMA, SS

All authors approved the final manuscript and take responsibility for the integrity of the work.

Conflicts of Interest

All the authors declare no conflict of interest.

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