Original Article

Assessment of Anterior Maxillary Bone Thickness and Cemento Enamel junction–Crest Distance Using Cone Beam Computed Tomography

Amna Amjad, Sajjad Hussain, Midhat Ahmed, Mahgul Nasr Aheer, Ayesha Shahid, Minhal Amjad

ABSTRACT

Objective: To evaluate and compare thickness of palatal and labial bone, along with the cementoenamel junction (CEJ) – bone crest distance of anterior maxillary teeth using cone-beam computed tomography (CBCT) technique.

Methods: This study is a retrospective cross-sectional study including 140 CBCT scans fulfilling the inclusion criteria. For each pair of anterior maxillary teeth, the thickness of palatal and facial bones was taken at three points along with distance between CEJ and bony crest. To ensure validity and reliability of measurements, single operator performed and recorded the measurements for each included CBCT scan.

Results: The mean age calculated from 140 CBCT scans was 34.84±8.0 years (age range 15-55 years), out of which there were 76 (54.3%) and 63 (45.0%) males and females, respectively. Most of the mean values at each measurement point of palatal and facial bone thickness were similar for both right and left teeth. Significant differences were noted in mean values among gender. For males, most of these values were higher as compared to the females. In terms of age, some values correlated positively with age including palatal thickness of CI and LI, while some correlated negatively with age including labial thickness of CI and LI.

Conclusion: The bone measurements significantly differed among males and females, and varied across age as well. The bone thickness measurements vary across populations therefore it is vital to know the anatomical bone dimensions in anterior maxilla for optimal 3-dimensional placement of the implant.

KEYWORDS: Maxilla, cuspid, incisor, cone - beam computed tomography, dental implants

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INTRODUCTION

In dental practice, implant placement is the most frequently performed procedures for replacement of lost teeth. Success in implant dentistry is highly dependent on proper planning, particularly anterior maxillary region, which is important in esthetics.[1] A detailed understanding the anatomy of alveolar bone, especially the facial and palatal bone plates, is essential for achieving favorable functional and esthetic outcomes.[2] Long-term success of implants is determined not only by osseointegration but also by the harmonious relationship between the implant, surrounding soft tissues, and underlying bone. Soft tissue recession, bone resorption, and poor esthetics may result from inadequate planning and insufficient bone volume. This is especially critical for maxilla, where the facial bone is often thin and highly susceptible to resorption.[3]

Tooth extraction is followed by predictable alveolar bone remodeling, regardless of whether the implant is placed immediately or in a delayed fashion. Studies show that bone resorption, particularly of the facial plate, occurs mostly within the first 3–6 months post-extraction.[4] The width of facial bone before extraction is a key determinant of the extent of resorption. Literature proposed that a facial bone width of at least 2 mm is critical for preserving vertical ridge height and minimizing soft tissue changes post-implant.[5]

The width of facial and palatal bone also influences the regenerative potential and the likelihood of achieving optimal esthetic outcomes. Thin facial bone is associated with higher risks of mucosal depression, appearance of implant threads, and compromised esthetics. Therefore, assessing the dimensions of alveolar bone is crucial during planning, especially in esthetically sensitive zones.[6-7]

Furthermore, the morphology of the anterior maxilla often varies among individuals, and it is influenced by several biological factors, including genetic predisposition, periodontal health, and history of trauma or disease. These factors may lead to asymmetries or inconsistencies in bone thickness, which can significantly influence the clinical approach. A comprehensive radiographic evaluation before implant surgery is, therefore, indispensable.

Cone-beam computed tomography (CBCT) has emerged as reference standard for three-dimensional imaging in implant dentistry. It offers high resolution, multiplanar views, and relatively low radiation exposure.[8] CBCT allows accurate measurement of bone width at coronal, middle, and apical levels on both the labial and palatal sides, as well as the distance between CEJ to bony-crest. These parameters are vital for deciding on immediate implant placement, guided surgery, and the need for bone augmentation.[9] Numerous studies have examined these bone parameters across different populations, reporting considerable variations by ethnicity, gender, and age. For instance, some studies found that males tend to have thicker facial bone than females, while others reported no significant gender-based differences.[10-11] However, much of the existing literature originates from developed countries, with limited data available from developing regions such as South Asia.

Understanding variations in labial and palatal bone thickness, as well as CEJ-to-crest distances at mid-facial, mesial, and distal sites, can help practitioners plan implants more precisely and avoid complications. Moreover, such data can serve as a foundational reference for developing population specific protocols, enhancing educational curricula in dental institutions, and improving patient counseling regarding surgical risks and esthetic expectations. This retrospective study aimed to evaluate facial and palatal bone thickness around maxillary CI, LI, and canines using CBCT scans. Additionally, it measured the vertical distance between CEJ and crest at three locations (mid-facial, mesial, and distal) to assess bone levels. Comparisons were also made based on gender, age, and side to identify any anatomical variations within the Pakistani population. The findings are expected to contribute valuable local data for implant treatment planning and surgical decision-making.

METHODOLOGY

A retrospective cross-sectional study was carried out at Department of Prosthodontics of Rawal Institute of Health Sciences, reviewing the records of dental patients who underwent CBCT scans from Jan 2023 to Dec 2024. Ethical approval for this study was attained from the Ethics Committee of Rawal Institute of Health Sciences (Approval no: RIHS/IRB/D/24/004). The CBCT scans of patients with normal dentition or minor dental problems, taken for various clinical reasons including extractions, impacted teeth, orthodontic assessments or implant planning were screened for inclusion in the study. Properly exposed CBCT volumes with good contrast images, patient age more than 20 years, presence of six anterior maxillary teeth were included in the study. History of dental pathologies, oral lesions, gingival disease, evidence of periodontal bone loss, crowed teeth hindering the bone measurements or patients who underwent orthodontic treatment were excluded from the study. A total of 140 CBCT scans were included, all performed and reported by qualified operators using the CS9300 system (Carestream Health Inc., Paris, France).

The measurements were taken using SIMPLANT Pro 17 software (Materialise Dental, Leuven, Belgium). The thickness of palatal and facial bone plates was measured in facio-palatal direction at right angle to the elongated axis of the root, as directed in previous studies. For each tooth, the width of facial wall and palatal wall was measured three points including the coronal third which is the thickest part of the bone within approximately 3 mm from the crest, middle third and the apical third of the root. Using the same three points, the palatal wall thickness was measured as well. In addition, the distance from CEJ to alveolar crest was measured at mesial, distal, and mid-facial sites. Each set of measurement was taken for three pairs of teeth including right and left CI, LI and canines.

In order to ensure validity of measurements, single operator took all the measurements from the scans. The data was managed and organized by using the IBM SPSS software (version 29.0). Normality of data was assessed using histograms and Q–Q plots. means and standard deviations were reported for all bone measurements. In order to compare the mean measurements between right and left pair of teeth, we used paired-samples T-test, while to compare the mean measurements between gender we used independent-samples T-test. Age was correlated with mean measurements using the Pearson's correlation test. The p-value =0.05 was considered significant.

RESULTS

140 subjects were included in the study, CBT volumes were measured for each enrolled participant. The mean age was 34.84±8.0 years (minimum age 15 years and maximum age 55 years). The study population comprised of 76 (54.3%) males and 63 (45.0%) females. Table 1 provides mean, minimum and maximum values of each tooth for various point measurements.

The point measurements were compared for each right and left tooth respectively using the paired samples T-test as shown in table 2. Most of the measurements were alike for both right and left teeth where the p-values were not significant, while on the contrary some mean point measurements were not alike for right and left teeth shown by significant differences in the means. This might be due to slight variations in taking the measurements.

The measurements were compared between gender, most of the mean values were similar for both gender and p-values were not found significant. While significant

Table 1: Minimum, Maximum and mean value of all measurements taken for each tooth in millimeters

Tooth	Measurement points	Minimum	Maximum	Mean	SD
Right CI	Labial coronal 3rd	0.40	1.61	0.81	0.28
	Labial middle 3rd	0.24	1.72	0.81	0.27
	Labial apical 3rd	0.45	2.00	0.95	0.36
	Palatal coronal 3rd	0.85	3.05	1.60	0.51
	Palatal middle 3rd	1.41	5.40	3.03	0.89
	Palatal apical 3rd	1.79	9.50	5.06	1.74
	CEJ to mid-crest	0.57	6.83	2.83	0.92
Right LI	Labial coronal 3rd	0.00	1.44	0.76	0.32
	Labial middle 3rd	0.00	1.70	0.75	0.38
	Labial apical 3rd	0.00	1.70	0.73	0.41
	Palatal coronal 3rd	0.72	2.42	1.56	0.46
	Palatal middle 3rd	1.26	5.73	2.98	0.98
	Palatal apical 3rd	2.00	8.90	4.71	1.59
	CEJ to mid-crest	0.72	5.53	2.22	0.85
Right Canine	Labial coronal 3rd	0.00	1.79	1.08	0.43
	Labial middle 3rd	0.00	1.79	0.96	0.42
	Labial apical 3rd	0.00	2.00	0.88	0.49
	Palatal coronal 3rd	1.23	4.11	2.15	0.61
	Palatal middle 3rd	1.71	4.44	3.07	0.50
	Palatal apical 3rd	2.43	9.10	4.21	1.24
	CEJ to mid-crest	1.08	5.34	2.33	0.96
Left Canine	Labial coronal 3rd	0.00	1.83	0.99	0.32
	Labial middle 3rd	0.00	2.78	0.91	0.41
	Labial apical 3rd	0.00	3.33	1.00	0.49
	Palatal coronal 3rd	1.08	3.13	2.21	0.56
	Palatal middle 3rd	1.30	5.95	3.14	0.65
	Palatal apical 3rd	2.04	8.77	4.31	1.28
	CEJ to mid-crest	0.88	5.26	2.27	0.89
Left CI	Labial coronal 3rd	0.00	1.50	0.86	0.29
	Labial middle 3rd	0.00	1.44	0.84	0.30
	Labial apical 3rd	0.00	1.81	0.99	0.44
	Palatal coronal 3rd	0.89	3.05	1.77	0.49
	Palatal middle 3rd	1.51	6.72	3.27	1.01
	Palatal apical 3rd	2.00	10.43	4.75	1.62
	CEJ to mid-crest	0.69	5.57	2.20	0.94
Left LI	Labial coronal 3rd	0.00	2.61	0.85	0.41
	Labial middle 3rd	0.00	2.78	0.81	0.43
	Labial apical 3rd	0.00	2.61	0.81	0.45
	Palatal coronal 3rd	0.82	3.05	1.59	0.45
	Palatal middle 3rd	1.33	5.56	3.00	0.95
	Palatal apical 3rd	1.84	8.13	4.43	1.34
	CEJ to mid-crest	0.65	4.95	2.13	0.84

CI=central incisor, LI=lateral incisor

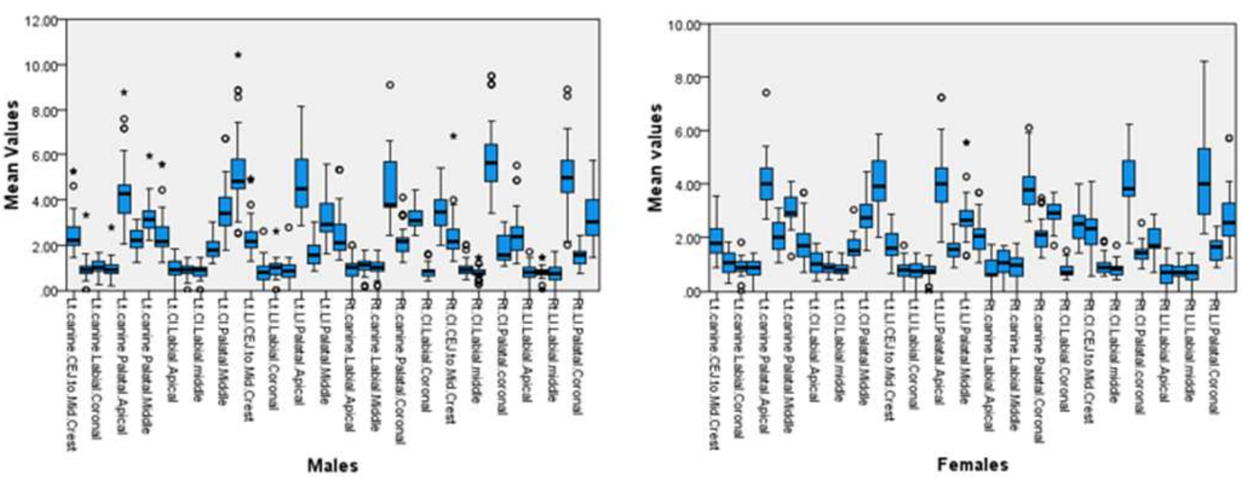
differences were found for right CI palatal coronal 3rd (p<0.001), palatal middle 3rd (p<0.001), palatal apical 3rd (p<0.001); left CI palatal coronal 3rd (p<0.001), palatal middle 3rd (p<0.001), palatal apical 3rd (p<0.001), CEJ to mid-crest (p<0.001); left LI labial coronal 3rd (p=0.003), palatal middle 3rd (p=0.033), palatal apical 3rd (p=0.008), CEJ to mid-crest (p<0.001); right LI palatal apical 3rd (p=0.015), CEJ-to mid-crest (p<0.001); right canine palatal middle (p=0.004), palatal apical (p=0.013), CEF to mid-crest (p0.010); and left canine CEJ to mid-crest (p=0.001). All the mean values were higher among males as compared to the females as shown in figure 1.

The study population age was correlated with the point measurements for each tooth and some significant relationships were observed. There was a negative correlation found between age and right CI labial coronal 3rd (r=-0.216, p=0.010), left CI labial apical 3rd (r=-0.183, p=0.030), left LI labial coronal 3rd (r=-0.238, p=0.005), right LI labial middle 3rd (r=-0.239, p=0.004), left LI labial middle 3rd (r=-0.187, p=0.027), left LI labial apical 3rd (r=-0.193, p=0.022) which means lower values were noted with increasing age. While on the other hand, a positive correlation was found between age and left CI palatal apical 3rd (r=0.0272, p=0.001),

Table 2: Point dimensions for right and left teeth (mm)

Tooth	Measurement point	Overall	Right side	Left side	p
CI	Labial coronal 3rd	0.84±0.24	0.815±0.28	0.86±0.29	0.045
	Labial middle 3rd	0.83±0.25	0.81±0.27	0.84±0.30	0.147
	Labial apical 3rd	0.97±0.33	0.95±0.36	0.99±0.44	0.250
	Palatal coronal 3rd	1.68±0.42	1.60±0.51	1.77±0.49	<0.001
	Palatal middle 3rd	3.15±0.85	3.03±0.89	3.27±1.01	0.001
	Palatal apical 3rd	4.91±1.58	5.06±1.74	4.75±1.6	0.002
	CEJ to mid-crest	2.29±0.76	2.38±0.92	2.20±0.94	0.046
LI	Labial coronal 3rd	0.80±0.33	0.76±0.32	0.85±0.41	0.001
	Labial middle 3rd	0.78±0.38	0.75±0.38	0.81±0.43	0.021
	Labial apical 3rd	0.77±0.39	0.73±0.41	0.81±0.45	0.022
	Palatal coronal 3rd	1.57±0.37	1.56±0.46	1.59±0.45	0.524
	Palatal middle 3rd	0.78±0.38	2.98±0.98	3.00±0.95	0.788
	Palatal apical 3rd	4.57±1.33	4.71±1.59	4.43±1.34	0.009
	CEJ to mid-crest	2.17±0.80	2.22±0.85	2.13±0.84	0.059
Canine	Labial coronal 3rd	1.03±0.33	1.08±0.43	0.99±0.32	0.005
	Labial middle 3rd	0.93±0.37	0.96±0.42	0.91±0.41	0.096
	Labial apical 3rd	0.94±0.43	0.88±0.49	1.00±0.49	0.003
	Palatal coronal 3rd	2.18±0.54	2.15±0.61	2.21±0.56	0.138
	Palatal middle 3rd	3.11±0.46	3.07±0.50	3.14±0.65	0.242
	Palatal apical 3rd	4.26±1.14	4.21±1.24	4.31±1.28	0.289
	CEJ to mid-crest	2.30±0.86	2.33±0.96	2.27±0.86	0.215

Figure 1: Comparison of mean point measurements of each tooth among males and females



right LI palatal middle 3rd (r=0.293, p<0.001), left LI palatal middle (r=0.193, p=0.022), right LI palatal apical 3rd (r=0.303, p<0.001), left LI palatal apical (r=0.213, p=0.011), right LI CEJ to mid-crest (r=0.236, p=0.005), right canine palatal middle 3rd (r=0.267, p=0.001), left canine palatal middle 3rd (r=0.293, p<0.001), right canine palatal apical 3rd (r=0.319, p<0.001), left canine palatal apical 3rd (r=0.220, p=0.009), right canine CEJ to mid-crest (r=0.266, p=0.001) and left canine CEJ to mid-crest (r=0.209, p=0.013) which means these measurements increased with increase in age.

DISCUSSION

We examined 140 CBCT scans retrospectively to examine mean bone width of anterior maxillary teeth at various positions. In current study, the mean thickness of labial coronal 3rd was reported to be 0.84 mm for CI, 0.80 mm for LI and 1.03 mm for canines. In current study, the mean thickness of palatal coronal 3rd was reported to be1.68 mm, 1.57 mm and 2.18 mm respectively for CI, LI and canines. The current study reported 2.29 mm, 2.17 mm and 2.30 mm mean distance between CEJ to mid bony-crest for CI, LI and canines, respectively.

In a retrospective study including 156, 149 and 152 CI, LI and canines, respectively Rojo-Sanchis J et al,[12] reported relationship between CEJ to mid bony-crest distance, facial and alveolar bone at anterior maxillary teeth. The authors reported that the facial bone thickness was significantly higher for all the teeth as compared to other measurements, while an inverse relationship was noted between CEJ to mid-bony crest distance and bone thickness measured at all points. The mean width reported for CI, LI and canines are reported to be similar as in present study i.e., 0.79 mm, 0.7 mm and 0.89 mm respectively. In a systematic review reported by Rojo-Sanchis J et al,[13] in 2022, included 17,321 teeth to analyse pooled mean facial alveolar bone thickness of =1 mm in maxillary incisors and canines. Thinner facial bone was associated with age, females and Asian population. The CEJ-bone crest distance averaged 2–2.5 mm, with greater distances observed in males. The findings stated were quite similar to those reported in current study where males are found to have higher bone thickness and younger age group.

Soumya P et al,[14] conducted a research study in Nigeria to report bone thickness at five predefined points and CEJ-crest distances in their local populations. The author found that facial bone over healthy maxillary anterior teeth was very thin (<2 mm at all levels), with 0.5–1 mm at the crest and 1–2 mm at the apex, labio-palatal width at the apex averaged around 7 mm. It was concluded that frequent fenestrations and dehiscence highlight the need for thorough bone evaluation before implant placement. Dominial M et al,[15] conducted CBCT scans of hundred young adults to evaluate the bone deficiencies on the basis of bone thickness and distance measurements. The authors reported that in 91% of the healthy young adults there was at least one bone defect observed, where think alveolar bone was most prevalent. The mean thickness values reported by the author are somewhat lower than the mean values reported in current study, that can be due to variations in study population characteristics. The authors concluded that high prevalence of bone problems highlight the value of understanding the structure of anterior maxillary and other facial bones in order to properly plan for dental implants and procedures.

A study by Lee JE et al,[16] from Korea included twenty participants who underwent CBCT scans to evaluate the structure of anterior maxilla. The authors reported that most Korean participants had labial bony wall width <2 mm at 3 and 5 mm apical to the CEJ in CI and LI, while palatal thickness was generally >2 mm. Males had significantly thicker labial bone than females at these levels. These findings highlight the importance of CBCT-based preoperative assessment for safe extraction or implant placement in anterior regions. Saglikli A et al,[17] retrospectively evaluated hundred and four randomly chosen CBCT scans to examine the width of anterior teeth. The mean widths were reported to be 1.13 mm for CI, 1.22 mm canines and 1.04 mm for LI, with age and bone width negatively related, also lesser width was noticed amongst females. These findings are quite similar to what was reported in current study in terms of relationships, while the mean thickness is slightly lower in our study. A study from Saudia Arabia, conducted by Sheerah H et al,[18] evaluated the bone profile of anterior maxillary teeth using four hundred and ninety CBCT scans of adults, out of which 186 were included in analysis. The authors reported mean thickness values that are quite similar to what were reported in current study. The facial bone thickness varied significantly among anterior teeth, with males showing greater thickness and bone height than females. Facial plate height increased with age, emphasizing the importance of considering age and gender in anterior maxillary treatment planning.

The findings from the present study support the notion that comprehensive evaluation of alveolar bone characteristics is critical in treatment planning for implants in the esthetic zone. One of the significant clinical implications of this study is the identification of areas with inadequate bone volume, which may necessitate ridge augmentation or use of shorter and narrower implants. Additionally, the differences observed in bone parameters by gender and age emphasize the need for individualized treatment protocols. Younger patients, due to having thicker facial bone, may have a higher success rate for immediate implant placement, whereas older individuals may benefit from bone grafting procedures.[19] Moreover, gender-based differences highlight the need for greater caution in planning implants for females, especially when esthetics is a priority.

In terms of surgical protocols, understanding bone thickness at various levels (coronal, middle, and apical) helps determine flap designs, implant angulation, and the choice of implant system.[20] For example, in sites with less than 1 mm of facial bone, a flapless approach might increase the risk of bone loss, thus favoring open flap surgery with simultaneous grafting. Furthermore, the correlation between CEJ-to-crest distance and facial bone thickness suggests that bone remodeling after tooth extraction may follow predictable patterns, aiding clinicians in anticipating and mitigating resorptive changes.

Comparative data from this study also help in forming region-specific guidelines for implantology in the South Asian context. Given the lack of large-scale data from Pakistan and neighboring countries, the current findings provide a foundation for future prospective studies that could incorporate a wider demographic representation and explore additional parameters such as bone density, vascularization, and soft tissue biotype.

Finally, the reliance on CBCT as the diagnostic tool highlights its irreplaceable role in preoperative assessment. With 3D visualization and precise measurements, CBCT ensures that no critical anatomical variations are overlooked. However, its accessibility and cost may limit its use in routine dental practices across developing countries. Thus, these findings also call for policy-level considerations on improving access to advanced imaging technologies in dental healthcare. Our study highlights the frequent need for soft and hard tissue augmentation to ensure optimal implant aesthetics and long-term outcomes in the aesthetic zone.

CONCLUSION

The bone measurements significantly differed among males and females, and varied across age as well. The bone thickness measurements vary across populations therefore it is vital to know the anatomical bone dimensions in anterior maxilla for optimal 3-dimensional placement of the implant. This can help the clinicians place implants in more appropriate and esthetic positions, enhancing their longevity as well.

LIMITATIONS

The limitations include retrospective design, limited sample size that was based on availability of CBCT scans in the institute, and limited time and resources. It is recommended that large prospective studies including study sample from diverse population can provide better estimated of anterior maxilla morphology in our local population.

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