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Alveolar Bone Morphology and variations in the Maxillary Central incisor (MCI) in CBCT Scans for Immediate Implant Treatment Planning – A Pilot Study

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ABSTRACT: Implants have been widely used to restore missing teeth. The success of implant placement in this region can be influenced by various factors, including the anatomical considerations specific to this area. In the current study, Cone Beam Computerized Tomography (CBCT) was used to measure alveolar ridge and buccal undercut dimensions at the maxillary central incisors in the local population for immediate implant treatment planning (IIP).

CBCT scans were screened in 150 subjects with full dentition at maxilla. Measurements were taken at the cross sectional views: Buccolingual width at crest and at apex, apico-coronal height, angulation of tooth in socket, thickness of labial bony plate and thickness of palatal bony plate at crest, middle and at apex, location of buccal undercut, buccal undercut depth and the percentage of teeth showing buccal undercuts were measured.

Mean buccolingual width at crest and at apex was 6.23 and 7.39. Mean apico-coronal height was found to be 15.412. Mean thickness of labial bony plate at crest, at middle and at apex is 0.91, 0.67, 1.618. Mean thickness of palatal bony plate at crest, at middle and at apex is 1.21, 3.28 and 6.01. Mean Angulation within the socket is 8.21. Mean buccal undercut location is 4.99. Mean buccal undercut depth is 1.32. The maximum percentage of undercuts was seen in females at 26%. Our study showed statistically significant differences between different age-groups and genders for parameters: Bucco-lingual width at apex., thickness of palatal bony plate at middle, Thickness of palatal bony plate at apex and Angulation within socket. Also, statistically significant differences between males and females in Buccal undercut depth. (p value <0.05).

This study showed that the quality of maxillary bone in the local population around maxillary central incisors was compromised and deficient as compared to other populations and requires careful preoperative treatment planning including augmentation procedures to successfully manage the same.

There is a wide variance in the dimensions of the alveolar bone amongst different ethnicities, population, age and gender groups and hence it is difficult to standardize surgical drilling protocols. Precautions and suitable modifications need to be undertaken when placing implants in this region because of its varied anatomy and a detailed study of the ridge based on the parameters is a prerequisite to avoid potential complications and failures.

Keywords: Dental implant, Immediate placement, CBCT, Maxillary Central Incisors, Esthetics.

INTRODUCTION

Cone-beam computed tomography (CBCT) is a valuable imaging tool that provides three-dimensional information about the oral and maxillofacial region, including the quality and quantity of bone (Lee *et al.*, 2015). CBCT can produce accurate and high-resolution multiple planar reformatted images while exposing patients to relatively low levels of radiation (Zhang *et al.*, 2015). CBCT plays a significant role as an aid in diagnosis, treatment planning, and minimizing complications during various dental procedures, including tooth extraction and dental implantation (Lee et al., 2015). The introduction of implants in dentistry has caused a major paradigm shift in treatment planning. For the successful result of the treatment, preoperative study and planning is very important. This is particularly important in cases of the anterior aesthetic zone (Benavides *et al.*, 2021). In the present study, CBCT images were used to evaluate alveolar ridge dimension and the presence and size of buccal undercut at the maxillary anterior region. This study was aimed to provide more quantitative information to assist immediate implant treatment in the maxillary anterior area.

MATERIAL AND METHODS

A. Study design and setting

This study had a retrospective cross-sectional design and used CBCT imaging to measure alveolar bone thickness, apico-coronal height, angulation of teeth and buccal undercut depth in the aesthetic zone of the maxillary anterior teeth. CBCT scans of 150 adult patients were obtained from Terna dental College and Hospital database, India. All scans were obtained previously for various clinical reasons (e.g. removal of impacted teeth). The present study was conducted between March to April 2023. This study was reviewed and approved by Terna Dental College Research Ethics Committee.

Inclusion criteria:

1) CBCT scans of bilateral permanent maxillary anterior teeth in individuals aged 18–65 years.

2) Cone beam computed tomography (CBCT) of anterior maxillary compartment with presence of central incisor that was advised for any dental reasons (such as implant therapy and restorative care, endodontic treatment, or orthodontic diagnostic and treatment).

Exclusion criteria:

1) Topical conditions that may affect bone quantity and quality at anterior maxilla, e.g., moderate to severe periodontal disease, cyst, neoplasm, prior trauma or surgery.

2) Systemic/endocrine diseases that influence bone metabolism, e.g., osteoporosis, hyperparathyroidism, Paget's disease, and renal osteodystrophy, maxillary fractures, tumours, bone disease, tooth loss, evidence of periodontal bone loss or growth alterations, previous surgeries, developmental anomalies and root resorption.

3) Abnormality that would alter the bone thickness like Maxillary anterior teeth that are impacted, overlapped, extracted, lacked clear bony boundaries, or have not erupted images with distortions or poor-quality images.

4) Images in which one or more maxillary anterior teeth were missing.

B. CBCT imaging acquisition

CBCT images were evaluated in this study using NNT Viewer 6.0 software (NewTom, Verona, Italy). Images had high-resolution and had been taken by New Tom CBCT scanner with 11 × 8cm field of view. Measurements were made using the digital ruler of the software with 0.1mm accuracy.

C. Radiographic assessment of Variables/ Parameters

At each maxillary central incisor,

1. Bucco-lingual width: was measured as the distance from the inner labial cortical plate to the inner palatal cortical plate at the crest of bone and immediately below the apex of the root (Fig. 1).

2. Apico-coronal height: was measured as a distance from crest of bone to the floor of the nasal cavity (Fig. 2).

3. Angulation of the tooth: The crown axis of the maxillary central incisor was drawn by joining the point incisor superius (Is) to the middle point of cement enamel junction; and the root axis was traced by extrapolating between crown and root axis. The collum angle was thus obtained (Fig. 3).

4. Thickness of labial bony plate: Distance from outer border of labial cortical plate to labial tooth surface was measured at 3 points (Fig. 4).

• At crest of bone; • Middle of root ; • At apex of root

5. Thickness of palatal bony plate: Distance from outer border of palatal cortical plate to palatal tooth surface was measured at 3 points (Fig. 4).

• At crest of bone; • Middle of root ; • At apex of root

6. Buccal undercut depth: A line tangent to buccal cortical plate and parallel to the long axis of alveolar ridge was drawn. The distance from the deepest point of the buccal undercut to the aforementioned line was defined as the buccal undercut depth (Fig. 5).

7. Percentage of teeth with buccal undercut: The formula to calculate the percentage of teeth with buccal undercut was: (the number of teeth with buccal undercut)/ (total number of teeth evaluated) × 100.

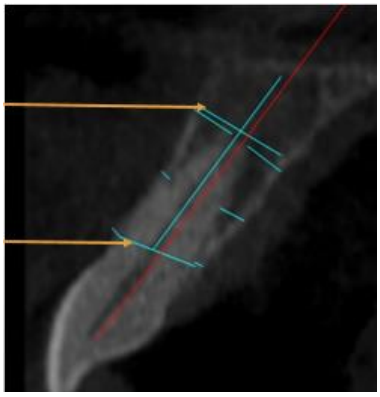

Fig. 1. Showing Bucco-lingual width at apex and at crest.

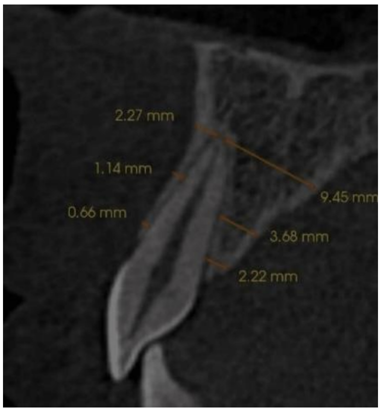

Fig. 2. Showing apico-coronal height.

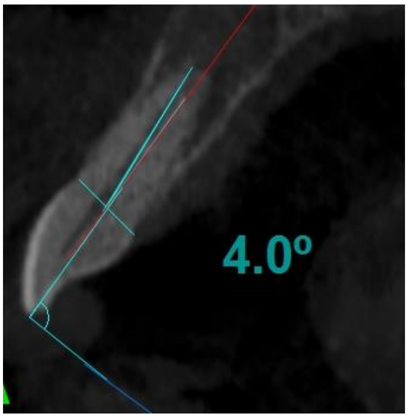

Fig. 3. showing angulation of the tooth.

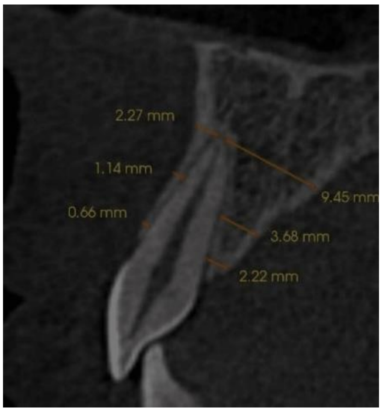

Fig. 4. showing thickness of labial bony plate and palatal bony plate at crest, middle of root and at apex.

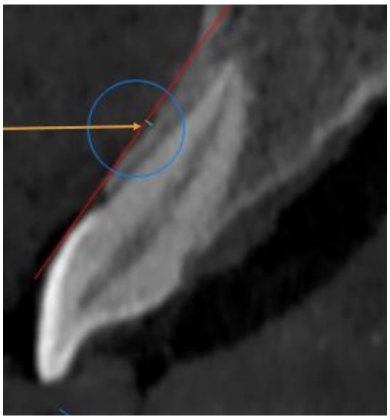

Fig. 5. Showing buccal undercut depth

The data thus obtained was compared between males and females and between different age groups which includes 20-39 years (Group A), 40-59 years (Group B) and 60 years-above (Group C).

RESULTS AND DISCUSSION

A. Statistical analysis

Statistical analysis was performed using Statistical package for social sciences (SPSS) software (IBM Corp) (v.21.0).

Descriptive statistics of the different parameters assessed in the study was performed. Gender-wise and age-group wise analysis was done to assess significant results. Independent samples t-test/Unpaired t-test was performed to assess significant differences between males and females. One-way Analysis of variance (ANOVA) followed by Tukey's post hoc test was performed to assess significant differences between various age groups. A p value of less than 0.05 was considered as statistically significant at 95% confidence intervals in the study.

B. Results

A total of 150 cases were analyzed in the present study within the age of 18 years to 60 years.

The results of this study showed that mean buccolingual width at crest and at apex is 6.2mm, 7mm and 6.3mm, 7.6 mm in females and males respectively. Buccolingual width at crest is 6.3mm, 6.3 mm and 6.1 mm in group A, group B and group C respectively. Buccolingual width at apex is 7.3mm, 7.9mm and 7.2mm in group A, group B and group C respectively. Overall mean buccolingual width at crest and at apex is 6.2mm and 7.4mm respectively.

Mean apico-coronal height is 14.9mm and 15.6mm in females and males respectively. Apico-coronal height is 15.2mm, 15mm and 16.4mm in group A, group B and group C respectively. Overall mean apico-coronal height is 15.4mm.

Mean thickness of labial bony plate at crest, at middle and at apex is 0.9mm, 0.7mm and 1.5mm in females. Mean thickness of labial bony plate at crest, at middle and at apex is 0.9mm, 0.7mm and 1.7 in males. Similarly, it was, 0.9mm, 0.7mm and 1.6mm is group A, 0.9mm, 0.7mm and 1.7mm in group B and 0.9mm, 0.7mm and 1.6mm in group C. Mean thickness of labial bony plate at crest, at middle and at apex is 0.9mm, 0.6mm and 1.6mm.

Mean thickness of palatal bony plate at crest, at middle and at apex is 1.2mm, 2.7mm and 5.6mm in females. Mean thickness of palatal bony plate at crest, at middle and at apex is 1.3mm, 3.6mm and 6.5mm in males. Similarly, it was, 1.1mm, 3.2mm and 5.9mm is group A, 1.3mm, 3.3mm and 6.3mm in group B and 1.3mm, 3.1mm and 5.7mm in group C. Overall mean thickness of palatal bony plate at crest, at middle and at apex is 1.2mm, 3.1mm and 6mm.

Mean angulation within socket is 8.1° and 8.3° in females and males respectively. Angulation within socket is 8.7°, 7.6° and 8.5° in group A, group B and group C respectively. Overall mean angulation within socket is 8.2°.

Mean buccal undercut depth was 1.3mm and 1.2mm in females and males respectively. Buccal undercut depth was 1.3mm, 1.2mm and 1.6mm in group A, group B and group C respectively. Mean buccal undercut depth was 1.3mm.

A mean of 25% of the sampled teeth showed the presence of buccal undercuts.

Table 1: Intergroup comparison of different parameters between Males and Females.

	Parameter	Groups	Mean	Std. Deviation	Mean difference	P value
Male vs Female	Bucco-lingual width at crest	Male	6.2733	.53910	.04667	.582
		Female	6.2267	.49575		
	Bucco-lingual width at apex	Male	7.7813	1.64963	.66667	.034*
		Female	7.1147	2.13622		
	Apico-coronal Height	Male	15.5933	3.80257	.58400	.291
		Female	15.0093	2.88164		
	Thickness of labial bony plate at Crest	Male	.8893	.24582	-.00667	.876
		Female	.8960	.27726		
	Thickness of labial bony plate at middle	Male	.7053	.26605	.05200	.235
		Female	.6533	.26829		
	Thickness of labial bony plate at Apex	Male	1.6867	.78039	.17333	.155
		Female	1.5133	.70141		
	Thickness of palatal bony plate at Crest	Male	1.2427	.35457	.05333	.391
		Female	1.1893	.40255		
	Thickness of palatal bony plate at middle	Male	3.7040	1.04020	.93600	.000*
		Female	2.7680	1.33914		
	Thickness of palatal bony plate at apex	Male	6.6893	1.44181	.96400	.001*
		Female	5.7253	2.11444		
	Angulation within socket	Male	8.5547	3.07704	.51200	.260
		Female	8.0427	2.42638		
	Buccal undercut depth	Male	.1533	.36218	-.18800	.048*
		Female	.3413	.72988		

*p value <0.05 statistically significant

This comparison showed statistically significant differences between males and females for parameters: Bucco-lingual width at apex., thickness of palatal bony plate at middle, Thickness of palatal bony plate at apex and Buccal undercut depth (p value <0.05).

Table 2: Intergroup comparison of different parameters between various age-groups: 20-39 years vs 40-59 years vs 60 years and above.

	Parameter	Sum of Squares	df	Mean Square	F	P value
20-39 years vs 40-59 years vs 60 years and above	Bucco-lingual width at crest	1.642	2	.821	2.857	.061
	Bucco-lingual width at apex	2.579	2	1.289	.306	.037*
	Apico-coronal Height	21.267	2	10.633	1.562	.213
	Thickness of labial bony plate at Crest	.458	2	.229	2.852	.061
	Thickness of labial bony plate at middle	.076	2	.038	.773	.463
	Thickness of labial bony plate at Apex	.944	2	.472	1.030	.359
	Thickness of palatal bony plate at Crest	.348	2	.174	1.213	.300
	Thickness of palatal bony plate at middle	1.539	2	.769	.524	0.03*
	Thickness of palatal bony plate at apex	16.205	2	8.102	1.993	.014*
	Angulation within socket	64.662	2	32.331	4.281	.016*
	Buccal undercut depth	2.225	2	1.113	2.777	.065

*p value <0.05 statistically significant

This comparison showed statistically significant differences between different age-groups for parameters: Bucco-lingual width at apex., thickness of palatal bony plate at middle, Thickness of palatal bony plate at apex and Angulation within socket (p value <0.05).

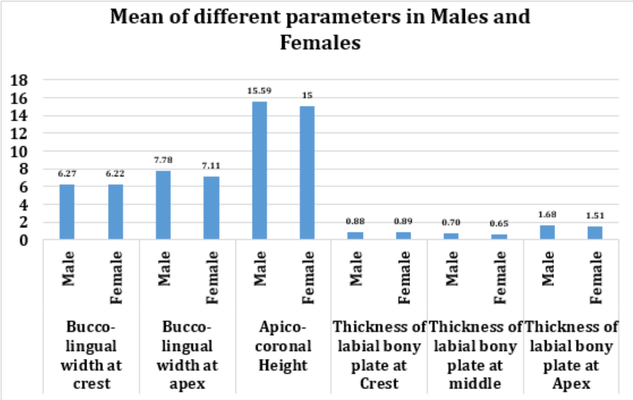

Fig. 6. Represents mean difference between buccolingual width at crest and at apex, apicocoronal height as well as thickness of labial bony plate at crest, middle and at apex in Males and Females.

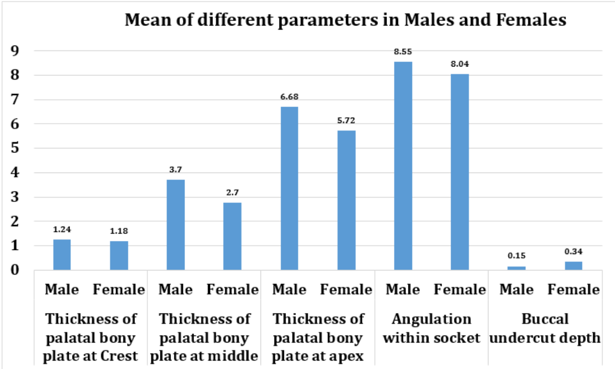

Fig. 7. Represents mean difference between thickness of palatal bony plate at crest, middle, at apex, angulation within socket and buccal undercut depth in Males and Females.

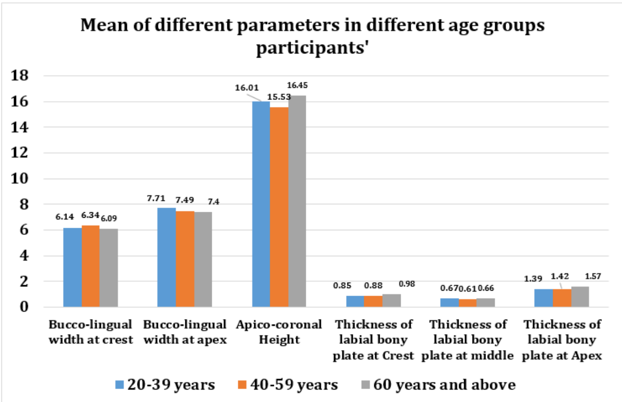

Fig. 8. represents mean difference between buccolingual width at crest and at apex, apicocoronal height, thickness of labial bony plate at crest, middle and at apex in three age groups. i.e, between 20-39 years, 40-59 years and 60 years and above.

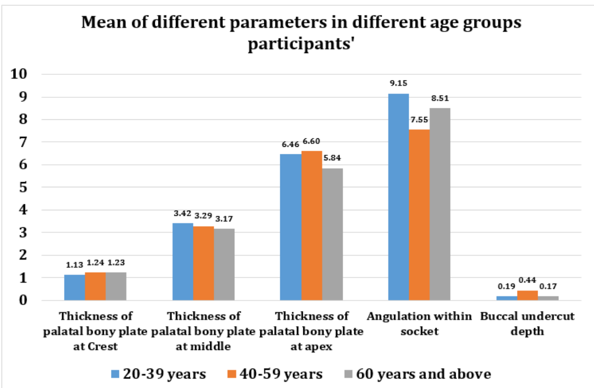

Fig. 9. Represents mean difference between thickness of palatal bony plate at crest, middle, at apex, angulation within socket and buccal undercut depth in in three age groups. i.e, between 20-39 years, 40-59 years and 60 years and above.

DISCUSSION

Dental implant placement following extraction is now a common dental procedure. Satisfactory results and long-term stability with implant treatment depend on the presence of an alveolar bone of sufficient height and thickness (Sheerah *et al.,* 2019). Furthermore, the maxillary anterior region is of particular importance because it plays a significant role in a person's smile and overall facial aesthetics. Any deformities in this region can be highly noticeable to patients and may have a significant impact on their self-confidence and satisfaction with their appearance (Zhang *et al.,* 2015). In the present study, the mean alveolar bone dimensions in the maxillary central incisor was measured with cone beam computed tomography. The accuracy and reliability for linear and angular measurements of cone beam computed tomography images is reported to be high. Thus, it is being employed for a lot of purposes such as implant site assessment, temporomandibular joint examination, visualisation of periodontal osseous situation and identification of periodontal ligament spaces (Venkatesh *et al.*, 2017).

The thickness of the facial bone wall is an important consideration, when planning for implant implant placement in the maxillary anterior region. It is generally recommended that the facial bone wall should be at least 1.5-2 mm thick to provide adequate support for the soft tissues and prevent complications (Cha *et al.,* 2016). The result of our study showed that the thickness of labial bony plate at the crest, middle and at apex is 0.9 mm, 0.7mm and 1.6mm which is highly deficient. The present analysis indicates that our maxillary central incisors have the least bone thickness. These results are consistent with those of previous clinical studies (Ghassemian *et al.,* 2012; Han *et al.,* 2011). The thickness of labial and palatal bony plate is more in males than females, these results correlate with other studies (Wang *et al.,* 2022). The thickness of the palatal bony wall was significantly larger than the labial bony wall. Palatal thickness at the crest was thin. The results of the study by Zhou *et al*. (2014) indicated that the contour of the labial bone was most curved at the central incisor and the effect of maxillary protrusion on the labial bone profile at the central incisor revealed that the curvature angle was the smallest in subjects with retruded maxillae. In other words, clinicians must angulate the apex of implant more palatally at the upper central incisor, especially for patients with retruded maxillae. Nevertheless, we suggest the implant should not be angulated too palatally at the apical area, considering the possibility of overcompensation towards the labial wall at the coronal region to cause fenestration or even the loss of coronal crestal bone (Zhou *et al.,* 2014). In the present study, the apical third of the facial bone appeared to have the most favorable thickness. These results are of particular significance because they demonstrate that even a slightly deeper placement of an immediate implant might allow for increased stability and thus the desired emergence profile.

In comparison with other studies, this study showed that the quality of labial as well as palatal bony plate in maxillary central incisors is compromised and deficient as compared to other study populations. A study was conducted in nepalese population which showed that the quality of bone in maxillary central incisor region is highly compromised (Shrestha *et al.,* 2019).

Mean apico-coronal height in our study is 15.4mm. Current study showed that alveolar bone height is more in males. These results are consistent with previous study by Ahmed. However, there alveolar height was approximately 18 mm in their Egyptian population (Ahmed *et al.,* 2019). Crest height in aesthetically relevant anterior maxillary regions can drive the selection of an appropriate treatment approach, especially when immediate implant placement is required. Accordingly, in cases with limited or reduced alveolar bone crest height, short implants are a preferable treatment option (Karthikeyan *et al.,* 2012). Insufficient crest height may also influence the interproximal papilla level, which may compromise aesthetic outcomes.

Angulation of implant also known as collum angle. The results of this study showed that the mean collum angle in Indian population is 8.21° and is more in males than in females, however these result is statistically non-significant. This result is in contradiction with other research which found more angulation in females (Wang *et al.,* 2022). However, using an angled implant can cause stress to concentrate in the cortical bone zone contralateral to the abutment turning point. In other words, if an angled implant is used in the maxillary anterior zone, stresses will concentrate on the facial cortical bone zone; i.e., the alveolar ridge under the free gingival margin. When stress is concentrated on the alveolar ridge of the facial profile in the maxillary anterior zone, the covering gingival tissue in this zone experiences considerable tension. If an undue external force (such as damage caused by excessive force during gingival retraction) or eccentric occlusal overload is imposed in addition to this tension, gingival recession may occur with adverse cosmetic effects. Additionally, the alveolar ridge of the facial profile in the maxillary anterior zone is usually thin, and when implant supported prostheses begin to experience occlusal forces, the phenomenon of microvertical bone loss is highly likely to occur.

A buccal undercut increases the risk of alveolar cortical plate perforation and surgical complication, or indicates the need for additional grafting procedures (Chan *et al.,* 2011). Our study found the percentage of buccal undercut depths to be less than 25%. This finding contrast with the study done by wenijen et al, which found the percentage of buccal undercut depths to be as high as 41%. In our study, which is again in contrast with the study by wenijen et al which found males having more buccal undercut (Zhang *et al.,* 2015).

From a clinical perspective, Within the first 4-8 weeks following a tooth extraction, there is a well-documented and significant resorption of the alveolar bone ridge. leading to significant ridge alteration (Buser *et al.,* 2009) Thus, to achieve a successful aesthetic outcome, a bone augmentation procedure with a flap approach is indicated in immediate or early implant placement cases. Generally, bone augmentation is needed to achieve adequate ridge width or height that was lost due to factors including extraction, trauma, periodontal disease, sinus pneumatization, or extended use of removable dentures (Deshpande *et al.*, 2014). Some studies have, however, suggested bone augmentation even in the absence of bone fenestration or dehiscence for better aesthetic results (Cha *et al.*, 2016).

LIMITATIONS

The limitations of the study are population heterogeneity and underestimation of actual measurements and small range of errors due to CBCT. Selecting the reference point seems important for evaluating the labial and palatal bony wall thickness.

CONCLUSIONS

This study showed that the quality of maxillary bone in the local study population around maxillary central incisors was compromised and deficient as compared to other populations and requires careful preoperative treatment planning to successfully manage the same. Implants that are commercially available appear to be oversized and not always dimensionally suitable for the deficient bone around the maxillary central incisors in our local population. This study emphasizes the importance of measuring a host of parameters in the CBCT scan for predictable treatment planning in the esthetic zone. This research gives an insight about the measurements, quantity and quality of bone around the maxillary central incisor in our study population. More research is needed to print customized implant sizes, personalized specific membranes and bone scaffolds for bone augmentation for application in immediate implant placement in aesthetic areas in our local study population.

FUTURE SCOPE

Future studies can compare the impact of these parameters on the success of immediate implant placement in a well-designed randomized controlled trial.

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Conflict of interest. None.

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