A Comprehensive Study on Dentogingival Dimensions in the Maxillary Anterior Region with CBCT Imaging

Lam Nguyen Le[1,*], Loc Truong Tan[2] , Anh The Thien Dang[2] , Duc Tuan Tran[2] and Trinh Thi Ngoc Nguyen[2]

[1]*Department of Pediatrics and Orthodontics, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam*
[2]*Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam*

Abstract:

Introduction: Cone beam computed tomography (CBCT) is increasingly recognized as a non-invasive diagnostic tool for evaluating the morphological features of dentogingival tissues, especially in the anterior maxilla. In Vietnam, this technology has only recently been implemented, which aims to explore its application in assessing dentogingival morphology using CBCT. The findings from this research are expected to contribute to the growing body of knowledge on the use of CBCT in dental diagnostics and improve clinical outcomes in the country. Our study aims to identify differences in gingival thickness and bone thickness in the maxillary anterior region while also analyzing the correlation between them using CBCT imaging.

Materials and Methods: The study involved 360 anterior maxillary teeth, which were selected from the data of 60 patients treated at the Faculty of Odonto-Stomatology, Can Tho University of Medicine and Pharmacy Hospital. To assess bone thickness (BT) and gingival thickness (GT), reference lines were drawn: one central to the long axis of the tooth and a second line perpendicular to the tooth apex. Measurements, including labial bone thickness (LBT), palatal bone thickness (PBT), labial gingival thickness (LGT), and palatal gingival thickness (PGT), were taken at three distinct locations parallel to the second reference line at 2 mm, 4 mm, and 6 mm above the cementoenamel junction (CEJ). The study employed a cross-sectional descriptive design. Statistical analyses were conducted using One-way Analysis of Variance (ANOVA) and Pearson's correlation coefficient to evaluate the relationship between variables.

Results: Most of the correlations between GT and BT in the anterior maxillary teeth are not statistically significant. Statistically significant correlations were observed for the lateral incisor, which mostly shows a negative correlation, specifically between LGT2 and LBT2; between PGT2 and LBT2, PBT2, LBT4, LBT6; and between PGT6 and PBT2. The only positive correlation with statistical significance was between LGT2 and LBT6 ($p = 0.268$). For the canine, all of the statistically significant correlations were found to be negative ($p < 0.05$). Notably, the correlation between PGT2 and LBT2 for the lateral incisor, as well as the correlation between PGT2 and PBT2 for the canine, were statistically significant at the 0.01 level.

Conclusion: Within the scope of this study, we can conclude that the GT and BT on the palatal side are greater than on the labial side, and no clear differences were observed between males and females. On the other hand, most of the correlations between GT and BT in the anterior maxillary teeth were not statistically significant.

Keywords: Dentogingival dimensions, Labial gingival thickness, Palatal gingival thickness, Labial bone thickness, Palatal bone thickness, Cone Beam Computed Tomography.

*Address correspondence to this author at the Department of Pediatrics and Orthodontics, Faculty Odonto-Stomatology, Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam; E-mail: lenguyenlam@ctump.edu.vn

1. INTRODUCTION

Understanding periodontal biotypes is essential for clinicians, as gingival thickness, width, and alveolar bone morphology influence the periodontium's response to stress and treatments [1]. Gingival biotype (GB) impacts both short- and long-term aesthetic outcomes, particularly in the anterior maxilla, affecting crown length, texture, and color [2]. A direct correlation has been observed between GB and the susceptibility to gingival recession following surgical and restorative procedures. Thus, accurately assessing the thickness of periodontal tissues is of paramount importance. [1]

The width of the labial bone is crucial in determining its resorption pattern, which impacts immediate implant placement outcomes, particularly in aesthetic zones. The width of the buccal bone also serves as a predictive factor for hard tissue changes following immediate implant placement. The anatomical shape of the labial bone above maxillary and mandibular teeth leads to varying bone thicknesses at different distances from the bone crest (BC), with bone thinness being a key predictor of recession [3]. A correlation between gingival thickness (GT) and bone thickness (BT) has been noted, especially for maxillary incisors, though no such relationship exists for mandibular incisors [4].

Patients with a thin GB are at greater risk of experiencing gingival recession and alveolar bone retraction after implantation, which increases the likelihood of aesthetic concerns. However, there is limited information on the relationship between bone thickness (LBT) and labial gingival thickness (LGT), mainly due to the lack of standardized measurement techniques for both hard and soft tissues. This knowledge gap can lead to inadequate surgical planning, complications, and less predictable postsurgical outcomes [5, 6].

Accurate assessment of the dentogingival complex is essential for diagnosis and presurgical planning [5]. Patients with a thin gingival biotype (GB) are more prone to gingival recession and alveolar bone retraction after implantation, increasing aesthetic concerns. However, there is limited understanding of the relationship between labial bone thickness (LBT) and labial gingival thickness (LGT) due to the lack of standardized measurement techniques. This knowledge gap can result in inadequate surgical planning, complications, and less predictable outcomes.

The cementoenamel junction (CEJ) marks the boundary between the anatomical crown, covered by enamel, and the anatomical root, covered by cementum. The CEJ is a critical reference in clinical dentistry for diagnosing periodontal conditions and guiding treatments like scaling, root planing, and surgeries [7]. Many studies measure root length from the CEJ to the root apex, while crown length is measured from the incisal edge to the CEJ [8-11].

Measuring periodontal soft tissue dimensions is crucial for clinical decision-making and aesthetic outcomes, but the reliability of various measurement techniques is still uncertain [7]. Measurement techniques for GT include both invasive approaches, such as direct puncture (which requires local anesthesia), and non-invasive methods, such as ultrasonic measurement. Although traditional radiographs (two-dimensional) are commonly used, they do not provide sufficient information to evaluate gingival and alveolar bone thickness. Anatomical measurements are often grouped to provide average values, which may not always reflect the unique characteristics of individual patients. For accurate clinical decision-making, each tooth site must be assessed individually to improve the precision and predictability of surgical procedures [2].

Elgaddari and Albandar conducted a study to assess the thickness of the palatal bone at the maxillary canines and incisors at three different locations. The results indicated that maxillary canines had significantly greater PBT compared to maxillary incisors. The study by Rodrigues *et al.*, about the relationship between GT and other periodontal phenotypical features, found that GT progressively increased towards the apical direction. Maxillary central incisors and male individuals typically exhibited thicker GT, while females tended to have thinner GT. The study also revealed that narrower tooth crowns and roots in the bucco-lingual dimension were associated with thicker gingiva. Teeth with a thin GB had larger CEJ-BC distances and greater buccolingual tooth width dimensions [12].

Notably, cone beam computed tomography (CBCT) is gaining attention as a noninvasive diagnostic tool for assessing the morphological features of both soft and hard tissues [12]. The introduction of CBCT allows for three-dimensional (3D) evaluation through high-resolution image reconstruction. The images are acquired with a single rotation, offering benefits such as lower cost, reduced radiation dose, and easier operation compared to conventional multislice CT [13]. Its high-quality 3D imaging capabilities, along with its ability to provide both linear and

volumetric data, have made it an essential tool for diagnosis and planning. CBCT is considered a relatively reliable method for measuring GT and BT in both anterior and posterior regions when compared with direct probing. The ability to precisely measure the dentogingival unit for individual teeth and sites using 3D imaging can significantly enhance treatment outcomes [5].

The purpose of this study was to determine the measurements of the dentogingival dimensions in the maxillary anterior region using CBCT imaging and compare the BT and the GT at specific landmarks relative to the CEJ.

2. MATERIALS AND METHODS

2.1. Subjects and Eligibility Criteria

The study involved a total of 360 anterior maxillary teeth, which were selected from the data of 60 patients at the Faculty of Odonto-Stomatology, Can Tho University of Medicine and Pharmacy Hospital.

These patients were selected based on the sample size calculation formula for estimating a mean, with the average GT at 4 mm below the CEJ being 0.86 mm and a standard deviation of 0.17 mm, as reported by Wang *et al*. [2] Specifically, the formula (1) used is as follows:

$$n = Z_{1-\alpha/2}^2 \frac{s^2}{(\bar{x}.\varepsilon)^2} = 1.96^2 \frac{0.17^2}{(0.86 \times 0.05)^2} \approx 60 \quad (1)$$

(n = sample size; α = significance level; s = standard deviation; ε = relative error between the sample parameter and the population parameter; $\bar{x}$: mean; ε: relative error between the sample parameter and the population parameter).

All participants voluntarily agreed to take part in the study after being informed about the purpose and procedures involved. The selection process adhered to the ethical guidelines and received approval from the Ethics Committee for Biomedical Research, as outlined in Decision No. 23.005/PCT-HĐĐĐ. This cross-sectional descriptive study was conducted in accordance with established research protocols.

The study conducted a retrospective analysis of CBCT images from patients who had been examined and treated at Can Tho University of Medicine and Pharmacy Hospital. Patients were indicated for CBCT imaging for general dental conditions. Then, the patients were examined and evaluated based on the inclusion criteria consisting of the presence of fully erupted, not suffering from osteosarcoma, non-orthodontics treatment, and non-crowded maxillary anterior teeth in otherwise healthy patients without any dental defects. The exclusion criteria included root fractures, crown restorations, alveolar bone resorption, and severe artifacts on the CBCT images.

2.2. CBCT Scans

The images were obtained using a Sirona Orthophos SL 3D device (Sirona, Germany), with a voxel base size of 0.08 mm, power lines and voltages of 3.0–16.0 mA and 60–90 kV,

respectively, a scanning time of 14.9 seconds, and the capacity for cylindrical (field of view) measurements of 40-40 mm, 60-60 mm or 80-80 mm. During CBCT scanning, a plastic lip retractor was used to retract the lips and cheeks, allowing for better visualization of the periodontal soft tissues (Fig. **1**). Datasets resulting from the scans were saved in Digital Imaging and Communications in Medicine (DICOM) format. Images were analyzed using specific software (GALILEOS software version 1.8, Sirona, Germany) and reconstructed by using cross-sectional slices in the radial plane, perpendicular to the alveolar ridge at 0.9 mm intervals on Samsung computer screen seri LF27T350 FHEXXV, 1920x1080px, and 75Hz. The cross-section of each tooth in the radio plane was viewed in the center of its mid-facial position and evaluated relative to the surrounding soft and hard tissue. Brightness and contrast were adjusted to facilitate visualization of the soft tissue with 1920x1080.
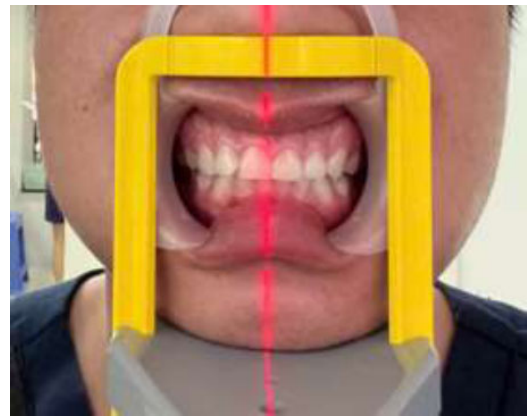

Fig. (1). Lips and cheeks were retracted by using a plastic lip retractor during CBCT scanning.

Measurements, including labial bone thickness, palatal bone thickness, labial gingival thickness, and palatal gingival thickness, were taken at three distinct locations parallel to the second reference line at 2 mm (line D1), 4 mm (line D2), and 6 mm (line D3) above the cementoenamel junction (Fig. **2**).

2.3. Measurement Error

To avoid errors in drawing and measuring operations on film, all procedures were performed by a researcher. This researcher's consistency was tested as follows: after the previously estimated total samples were measured, 20 films were randomly selected to be plotted and measured again with the same method by the same person 24 hours later (test-retest method). The data from the second measurement were compared with the first using Pearson's correlation coefficient.

3. RESULTS

The research involves 60 CBCT images, with 27 images taken from males and 33 from females. All results were expressed as mean ± standard deviation.
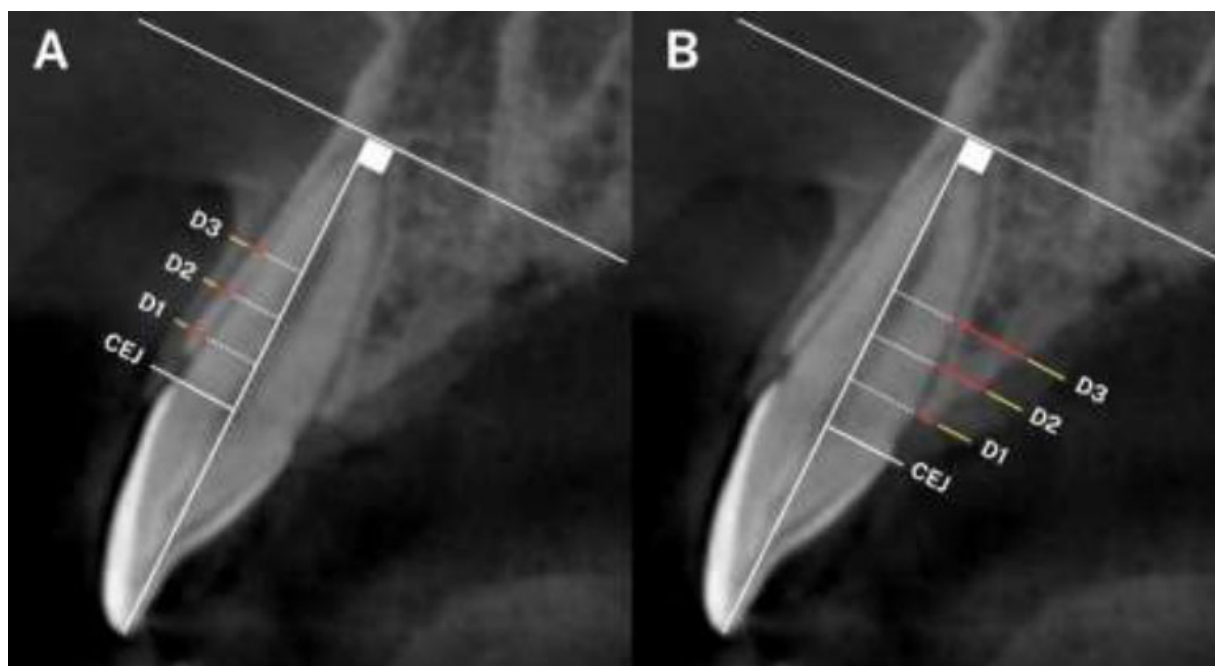
Fig. (2). Measurements of labial and palatal sides of the central incisor at 3 positions, D1: 2mm above the CEJ, D2: 4mm above the CEJ, D3: 6mm above the CEJ; Red-line: bone thickness, yellow-line: gingival thickness. *A: Labial measurements; B: Palatal measurements.*

On the palatal surface, when considering soft tissue, with a distance of 2 mm from the apex to the CEJ, the lowest corresponding PGT is observed in the maxillary central incisors, while the highest PGT is found in the lateral incisors on both sides. The measurements for each position from the right maxillary canine to the left canine were as follows: 2.07 ± 0.81 mm, 2.48 ± 0.83 mm, 2.39 ± 0.99 mm, 2.08 ± 0.82 mm, 2.46 ± 0.91 mm, 2.40 ± 0.95 mm. When considering gender differences, it follows the same order as mentioned above. At each corresponding position, the PGT in males was larger than those in females, except for the right maxillary central incisors, with 1.95 ± 0.78 mm for males and 2.16 ± 0.84 mm for females.

When considering the PGT at a distance of 4 mm and 6 mm from the apex to the CEJ, the PGT in both males and females showed the highest values at the maxillary canines and gradually thins to the central incisors. At the 4 mm mark, the results for males and females were as follows: on the right side, 3.02 ± 1.25 mm for males and 2.85 ± 1.12 mm for females (p=0.732), and on the left side, 2.74 ± 0.98 mm for males and 2.93 ± 1.09 mm for females (p=0.757). At 6 mm below the CEJ, the following results were obtained: on the right side, *3.18 ± 1.06* mm for males and *3.28 ± 0.91* mm for females (p=0.732), and on the left side, *3.01 ± 1.05* mm for males and *3.12 ± 1.01* mm for females (p=0.757).

In contrast to the results in PGT, when assessing hard tissue at 2 mm below the CEJ, the PBT values for the maxillary central incisors were the highest for both genders, with 1.22 ± 0.52 mm on the right and 1.23 ±

0.48 mm on the left. The data is also evaluated in the same order, at a distance of 4 mm and 6 mm from the apex to the CEJ. In addition, except for the right lateral incisors at 2 mm below the CEJ, which recorded a result of *0.95 ± 0.44* mm for males and *1.04 ± 0.53* mm for females (p=0.732), all other positions showed that the measurements for males were greater than that for females (Table **1**).

When evaluating at the labial side, at 2 mm below the CEJ, the LGT in males is generally smaller than in females for the anterior teeth of the maxilla, except for the right central incisor with 0.91 ± 1.27 for males and 0.89 ± 0.34 for females. Regarding the LBT, the right central incisor (p=0.599), right canine (p=0.299), and left lateral incisor (p=0.204) are thicker in males than in females, while the thickness of the right lateral incisor (p=0.914), left central incisor (p=0.687), and left canine (p=0.328) shows the opposite pattern. However, all differences are not statistically significant. A negative correlation is observed in most regions, except for tooth 12, which shows a positive correlation with a Pearson correlation coefficient of 0.271.

At 4 mm below the CEJ, the LGT in males is thinner than in females in all anterior maxillary teeth. On the other hand, the LBT is thicker in males, except the central incisor on both sides is thinner in males compared to females. The difference in LGT at the left central incisor is statistically significant (p=0.967), while all other differences are not statistically significant. A negative correlation is observed at the canines on both sides, while the remaining regions show a positive correlation.

Table 1. Palatal gingival thickness (PGT) and Palatal bone thickness (PBT) at 2, 4, and 6 mm apical to the CEJ.

Variables	Gender	Tooth					
		11	12	13	21	22	23
		At 2 mm below the CEJ					
PGT2 (mm)	Male	1.95 ± 0.78	2.56 ± 0.93	2.55 ± 1.12	2.10 ± 0.90	2.51 ± 0.86	2.42 ± 1.09
	Female	2.16 ± 0.84	2.42 ± 0.75	2.26 ± 0.87	2.06 ± 0.76	2.42 ± 0.96	2.40 ± 0.85
	Total	2.07 ± 0.81	2.48 ± 0.83	2.39 ± 0.99	2.08 ± 0.82	2.46 ± 0.91	2.40 ± 0.95
	p-value	0.881	0.517	0.270	0.923	0.767	0.779
PBT2 (mm)	Male	1.25 ± 0.52	0.95 ± 0.44	1.00 ± 0.39	1.27 ± 0.50	0.97 ± 0.47	1.13 ± 0.56
	Female	1.19 ± 0.53	1.04 ± 0.53	0.95 ± 0.51	1.20 ± 0.48	0.96 ± 0.46	0.95 ± 0.45
	Total	1.22 ± 0.52	1.00 ± 0.49	0.97 ± 0.46	1.23 ± 0.48	0.96 ± 0.46	1.03 ± 0.51
	p-value	0.374	0.732	0.689	0.574	0.697	0.181
Pearson Correlation		0.150	0.274*	0.031	0.286*	0.046	0.165
		At 4 mm below the CEJ					
PGT4 (mm)	Male	2.50 ± 0.82	2.83 ± 1.05	3.02 ± 1.25	2.22 ± 0.76	2.67 ± 0.88	2.74 ± 0.98
	Female	2.39 ± 0.78	2.75 ± 0.96	2.85 ± 1.12	2.37 ± 0.77	2.87 ± 0.95	2.93 ± 1.09
	Total	2.44 ± 0.79	2.78 ± 1.00	2.93 ± 1.17	2.30 ± 0.76	2.78 ± 0.92	2.84 ± 1.04
	p-value	0.593	0.3	0.732	0.504	0.330	0.757
PBT4 (mm)	Male	2.07 ± 0.94	1.83 ± 0.88	1.92 ± 0.63	2.22 ± 0.80	1.88 ± 0.93	2.06 ± 0.75
	Female	2.00 ± 0.69	1.58 ± 0.74	1.54 ± 0.52	2.07 ± 0.84	1.49 ± 0.60	1.55 ± 0.55
	Total	2.03 ± 0.81	1.69 ± 0.81	1.71 ± 0.60	2.14 ± 0.82	1.67 ± 0.78	1.78 ± 0.69
	p-value	0.719	0.689	0.276	0.443	0.030	0.006
Pearson Correlation		0.124	0.097	-0.073	-0.136	0.007	0.059
		At 6 mm below the CEJ					
PGT6 (mm)	Male	2.36 ± 0.67	2.84 ± 1.00	3.18 ± 1.06	2.18 ± 0.64	2.65 ± 0.86	3.01 ± 1.05
	Female	2.31 ± 0.74	2.59 ± 0.74	3.28 ± 0.91	2.12 ± 0.58	2.80 ± 1.13	3.12 ± 1.01
	Total	2.33 ± 0.71	2.70 ± 0.87	3.23 ± 0.97	2.15 ± 0.60	2.73 ± 1.01	3.07 ± 1.02
	p-value	0.713	0.276	0.300	0.674	0.528	0.756
PBT6 (mm)	Male	3.19 ± 1.57	2.82 ± 1.10	2.96 ± 0.92	3.18 ± 1.15	2.79 ± 1.24	3.18 ± 1.17
	Female	2.93 ± 0.97	2.45 ± 1.22	2.32 ± 0.91	3.01 ± 1.18	2.17 ± 0.93	2.35 ± 0.83
	Total	3.05 ± 1.27	2.62 ± 1.17	2.61 ± 0.96	3.08 ± 1.16	2.45 ± 1.12	2.73 ± 1.07
	p-value	0.526	0.197	0.197	0.603	0.032	0.007
Pearson Correlation		-0.109	0.000	-0.118	-0.028	-0.166	0.013

Note: *One-way ANOVA test and Pearson correlation coefficient.
(CEJ: Cementoenamel junction; PGT: palate gingival thickness; PBT: palate bone thickness; LGT: labial gingival thickness; LBT: labial bone thickness; Tooth 11: right maxilla central incisor; Tooth 12: right maxilla lateral incisor; Tooth 13: right maxilla canine; Tooth 21: left maxilla central incisor; Tooth 22: left maxilla lateral incisor; Tooth 23: left maxilla canine).

At 6 mm from the CEJ to the apex, none of the differences are statistically significant, with the LGT being thicker in females than in males. The lowest corresponding LBT is observed in the maxillary lateral incisors, while the highest LBT is found in the canines on both sides. The measurements for each position from the right maxillary canine to the left canine were as follows: *0.62 ± 0.20* mm, *0.52 ± 0.21* mm, *0.67 ± 0.30* mm, *0.70 ± 0.19* mm, *0.60 ± 0.24* mm, *0.76 ± 0.33* mm. When considering gender differences, it follows the same order as mentioned above. The Pearson correlation is similar to that at 4 mm below the CEJ, with most regions showing a positive correlation, except for the canines on both sides (Table **2**).

Table 2. Labial gingival thickness (LGT) and Labial bone thickness (LBT) at 2, 4, and 6 mm apical to the CEJ.

Variables	Gender	Tooth					
		11	12	13	21	22	23
		At 2 mm below the CEJ					
LGT2 (mm)	Male	0.91 ± 1.27	0.65 ± 0.32	0.68 ± 0.32	0.77 ± 0.36	0.74 ± 0.32	0.76 ± 0.30
	Female	0.89 ± 0.34	0.75 ± 0.30	0.74 ± 0.28	0.85 ± 0.35	0.81 ± 0.33	0.83 ± 0.34
	Total	0.9 ± 0.88	0.71 ± 0.31	0.71 ± 0.3	0.81 ± 0.36	0.78 ± 0.32	0.8 ± 0.32
	p-value	0.883	0.193	0.409	0.228	0.638	0.381
LBT2 (mm)	Male	0.66 ± 0.23	0.67 ± 0.28	0.71 ± 0.30	0.72 ± 0.29	0.68 ± 0.22	0.65 ± 0.28
	Female	0.61 ± 0.34	0.68 ± 0.36	0.62 ± 0.35	0.73 ± 0.34	0.59 ± 0.25	0.56 ± 0.31
	Total	0.64 ± 0.03	0.68 ± 0.32	0.67 ± 0.33	0.72 ± 0.32	0.63 ± 0.24	0.60 ± 0.30
	p-value	0.599	0.914	0.299	0.687	0.204	0.328
Pearson Correlation		-0.160	0.271*	-0.414**	-0.573**	-0.281*	-0.485**

(Table 2) contd.....

Variables	Gender	Tooth					
		At 2 mm below the CEJ					
		11	**12**	**13**	**21**	**22**	**23**
		At 4 mm below the CEJ					
LGT4 (mm)	Male	0.57 ± 0.22	0.56 ± 0.22	0.54 ± 0.25	0.57 ± 0.22	0.59 ± 0.23	0.56 ± 0.22
	Female	0.60 ± 0.16	0.65 ± 0.22	0.58 ± 0.15	0.71 ± 0.19	0.66 ± 0.24	0.64 ± 0.24
	Total	0.59 ± 0.19	0.61 ± 0.23	0.56 ± 0.20	0.65 ± 0.21	0.63 ± 0.23	0.60 ± 0.23
	p-value	0.602	0.142	0.519	0.030	0.203	0.287
LBT4 (mm)	Male	0.71 ± 0.27	0.71 ± 0.31	0.87 ± 0.36	0.76 ± 0.25	0.78 ± 0.31	0.95 ± 0.35
	Female	0.75 ± 0.23	0.68 ± 0.28	0.75 ± 0.32	0.80 ± 0.20	0.74 ± 0.29	0.84 ± 0.31
	Total	0.73 ± 0.25	0.69 ± 0.29	0.81 ± 0.34	0.78 ± 0.23	0.76 ± 0.29	0.89 ± 0.33
	p-value	0.847	0.615	0.170	0.967	0.596	0.287
Pearson Correlation		0.164	0.059	-0.009	0.126	0.096	-0.096
		At 6 mm below the CEJ					
LGT6 (mm)	Male	0.56 ± 0.25	0.56 ± 0.24	0.55 ± 0.19	0.61 ± 0.26	0.61 ± 0.28	0.63 ± 0.29
	Female	0.57 ± 0.18	0.69 ± 0.29	0.65 ± 0.26	0.68 ± 0.20	0.69 ± 0.28	0.67 ± 0.26
	Total	0.57 ± 0.21	0.63 ± 0.27	0.60 ± 0.24	0.64 ± 0.23	0.66 ± 0.28	0.65 ± 0.28
	p-value	0.877	0.091	0.116	0.563	0.274	0.496
LBT6 (mm)	Male	0.61 ± 0.20	0.53 ± 0.21	0.70 ± 0.29	0.70 ± 0.23	0.58 ± 0.20	0.82 ± 0.32
	Female	0.62 ± 0.20	0.51 ± 0.22	0.64 ± 0.31	0.70 ± 0.17	0.62 ± 0.27	0.71 ± 0.33
	Total	0.62 ± 0.20	0.52 ± 0.21	0.67 ± 0.30	0.70 ± 0.19	0.60 ± 0.24	0.76 ± 0.33
	p-value	0.954	0.436	0.431	0.625	0.769	0.118
Pearson Correlation		0.167	0.021	-0.123	0.264*	0.118	-0.025

Note: *One-way ANOVA test and Pearson correlation coefficient.

(CEJ: Cementoenamel junction; PGT: palate gingival thickness; PBT: palate bone thickness; LGT: labial gingival thickness; LBT: labial bone thickness; Tooth 11: right maxilla central incisor; Tooth 12: right maxilla lateral incisor; Tooth 13: right maxilla canine; Tooth 21: left maxilla central incisor; Tooth 22: left maxilla lateral incisor; Tooth 23: left maxilla canine).

The results show that the mean crown length (CL), root length (RL), mesiodistal width, labio-lingual width, and BC-CEJ distance of the anterior maxillary teeth are 9.31 ± 1.28 mm, 12.75 ± 2.27 mm, 6.84 ± 0.82 mm, 7.21 ± 2.67 mm, and 1.83 ± 0.62 mm, respectively. All differences are statistically significant, particularly the crown length, root length, and mesiodistal width ($p < 0.001$) (Table **3**).

Most of the correlations between GT and BT in the anterior maxillary teeth are not statistically significant. Statistically significant correlations were observed for the lateral incisor, which mostly shows a negative correlation, specifically between LGT2 and LBT2; between PGT2 and LBT2, PBT2, LBT4, LBT6; and between PGT6 and PBT2. The only positive correlation with statistical significance was between LGT2 and LBT6. For the canine, all of the statistically significant correlations were found to be negative. Notably, the correlation between PGT2 and LBT2 for the lateral incisor, as well as the correlation between PGT2 and PBT2 for the canine, were statistically significant at the 0.01 level (Table **4**).

Table 3. Mean mesiodistal width, labiolingual width, crown length, root length and distance BC-CEJ of tooth.

Variables	Tooth	Mean (mm)	Std. Deviation (mm)	Minimum (mm)	Maximum (mm)	p-value
Crown length (CL)	11	10.14	1.12	6.44	12.47	<0.001
	12	8.95	1.42	0.00	11.12	
	13	8.91	1.12	6.59	11.37	
	21	10.18	1.02	7.82	12.48	
	22	8.95	0.89	6.80	11.75	
	23	8.75	1.19	6.27	11.96	
	Total	9.31	1.28	0.00	12.48	
Root Length (RL)	11	12.28	1.49	8.36	15.93	<0.001
	12	12.19	1.73	8.68	16.00	
	13	13.87	2.59	9.46	21.50	
	21	12.27	1.47	8.66	15.62	
	22	11.94	2.27	1.23	16.99	
	23	13.95	2.82	5.50	18.73	
	Total	12.75	2.27	1.23	21.50	

(Table 3) contd.....

Variables	Tooth	Mean (mm)	Std. Deviation (mm)	Minimum (mm)	Maximum (mm)	p-value
Mesio-Distal (MD)	11	6.70	0.47	5.77	7.69	<0.001
	12	6.25	0.50	4.76	7.41	
	13	7.63	0.73	6.04	9.41	
	21	6.80	0.62	4.86	8.56	
	22	6.18	0.57	5.02	7.38	
	23	7.50	0.73	5.63	9.59	
	Total	6.84	0.82	4.76	9.59	
Labio-Lingual (LL)	11	7.92	0.68	5.62	9.41	0.017
	12	7.25	6.21	3.51	53.98	
	13	6.93	0.92	5.03	8.79	
	21	7.73	0.73	5.55	8.75	
	22	6.35	0.84	3.43	8.14	
	23	7.10	0.88	5.10	8.92	
	Total	7.21	2.67	3.43	53.98	
Cementoenamel junction-Bone crest (CEJ-BC)	11	1.87	0.85	0.83	6.76	0.016
	12	1.73	0.52	0.69	2.75	
	13	1.81	0.52	0.98	2.99	
	21	1.63	0.41	0.57	2.41	
	22	1.95	0.59	0.70	4.19	
	23	1.98	0.65	0.98	4.38	
	Total	1.83	0.62	0.57	6.76	

Note: *One-way ANOVA test.
(Tooth 11: right maxilla central incisor; Tooth 12: right maxilla lateral incisor; Tooth 13: right maxilla canine; Tooth 21: left maxilla central incisor; Tooth 22: left maxilla lateral incisor; Tooth 23: left maxilla canine).

Table 4. Correlation between values.

-	Tooth	LBT2	PBT2	LBT4	PBT4	LBT6	PBT6
LGT2	Central Incisor	0.150	-0.232	0.105	-0.012	0.077	0.180
	Lateral Incisor	-0.271*	-0.021	0.248	-0.107	0.268*	-0.180
	Canine	0.031	-0.126	0.005	0.084	0.177	0.099
PGT2	Central Incisor	-0.092	-0.160	-0.030	0.007	0.044	-0.111
	Lateral Incisor	-0.355**	-0.271*	-0.318*	0.063	-0.261*	0.053
	Canine	-0.287*	-0.414**	-0.070	0.064	-0.037	0.174
LGT4	Central Incisor	-0.002	-0.195	0.124	-0.213	0.176	-0.104
	Lateral Incisor	0.142	0.033	0.0097	-0.048	0.158	-0.104
	Canine	0.091	-0.270*	-0.073	-0.050	0.168	0.081
PGT4	Central Incisor	-0.094	0.026	0.079	0.164	0.014	0.033
	Lateral Incisor	-0.140	-0.111	-0.110	0.059	-0.149	0.015
	Canine	-0.203	-0.020	-0.166	-0.009	-0.235	0.207
LGT6	Central Incisor	0.083	-0.127	-0.004	-0.005	-0.109	0.077
	Lateral Incisor	0.015	-0.142	-0.032	0.040	0.000	-0.002
	Canine	0.108	-0.275*	-0.087	-0.169	-0.118	0.086
PGT6	Central Incisor	-0.181	-0.071	-0.083	0.216	-0.044	0.167
	Lateral Incisor	-0.199	-0.309*	-0.215	-0.139	-0.073	0.021
	Canine	-0.043	0.082	0.072	0.021	0.041	-0.123

Note: * Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
(LBT2: labial bone thickness at 2mm below the cementoenamel junction; PBT2: palatal bone thickness at 2mm below the cementoenamel junction; LGT2: labial gingival thickness at 2mm below the cementoenamel junction; PGT2: palatal gingival thickness at 2mm below the cementoenamel junction; LBT4: labial bone thickness at 4mm below the cementoenamel junction; PBT4: palatal bone thickness at 4mm below the cementoenamel junction;LGT4: labial gingival thickness at 4mm below the cementoenamel junction; PGT4: palatal gingival thickness at 4mm below the cementoenamel junction; LBT6: labial bone thickness at 6mm below the cementoenamel junction; PBT6: palatal bone thickness at 6mm below the cementoenamel junction; LGT6: labial gingival thickness at 6mm below the cementoenamel junction; PGT6: palatal gingival thickness at 6mm below the cementoenamel junction).

The PGT > 2 mm at the 2 mm, 4 mm, and 6 mm levels below the CEJ accounted for the largest proportion compared to the other thickness groups, with frequencies of 50%, 72.5%, and 65%, respectively. Followed by the thickness range of 1-2 mm, while the least common is < 1 mm. In contrast, for the LGT, the proportion of thickness

< 1 mm is almost predominant at LGT2, LGT4, and LGT6. The number of individuals with LGT > 2 mm is found only at PGT2, with a very low percentage of 0.8% (Chart **1**). When evaluating the lateral incisors and canines, it follows the same order as mentioned above (Charts **2**, **3**).
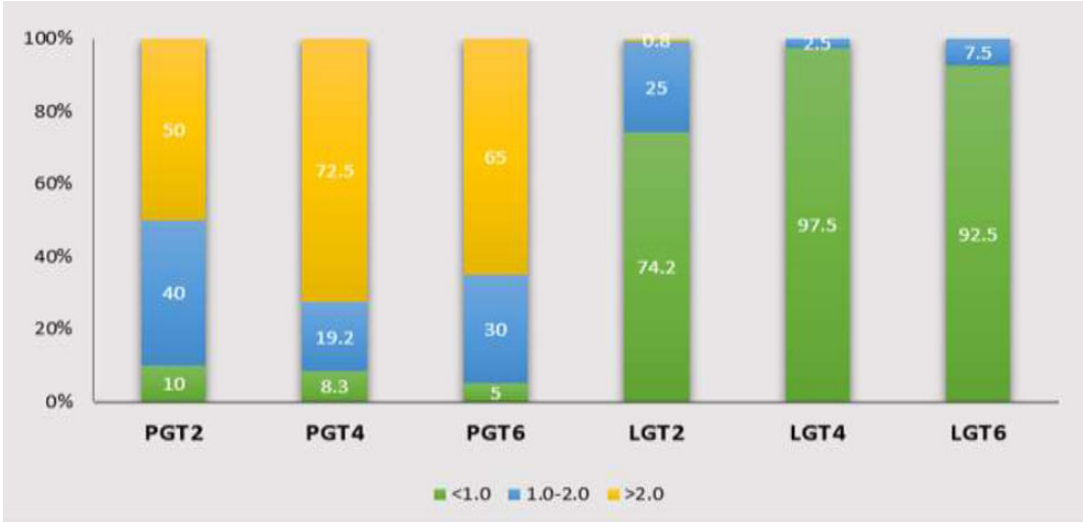
Chart 1. Distribution frequency of Gingival thickness at different sites in the Central incisor region. *LGT2: labial gingival thickness at 2mm below the cementoenamel junction; PGT2: palatal gingival thickness at 2mm below the cementoenamel junction; LGT4: labial gingival thickness at 4mm below the cementoenamel junction; PGT4: palatal gingival thickness at 4mm below the cementoenamel junction; LGT6: labial gingival thickness at 6mm below the cementoenamel junction; PGT6: palatal gingival thickness at 6mm below the cementoenamel junction.*
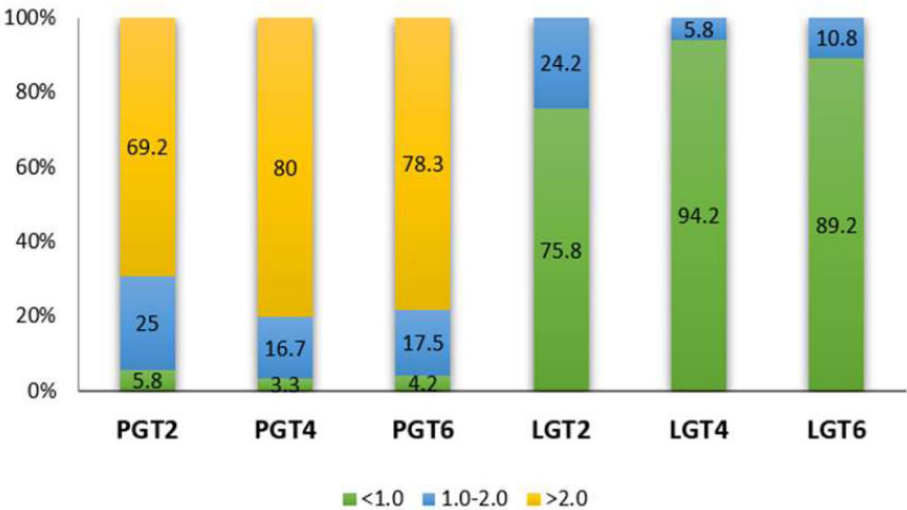
Chart 2. Distribution frequency of Gingival thickness at different sites in the Lateral incisor region. *LGT2: labial gingival thickness at 2mm below the cementoenamel junction; PGT2: palatal gingival thickness at 2mm below the cementoenamel junction; LGT4: labial gingival thickness at 4mm below the cementoenamel junction; PGT4: palatal gingival thickness at 4mm below the cementoenamel junction; LGT6: labial gingival thickness at 6mm below the cementoenamel junction; PGT6: palatal gingival thickness at 6mm below the* cementoenamel junction.

Chart 3. Distribution frequency of Gingival thickness at different sites in the Canine region. *LGT2: labial gingival thickness at 2mm below the cementoenamel junction; PGT2: palatal gingival thickness at 2mm below the cementoenamel junction; LGT4: labial gingival thickness at 4mm below the cementoenamel junction; PGT4: palatal gingival thickness at 4mm below the cementoenamel junction; LGT6: labial gingival thickness at 6mm below the cementoenamel junction; PGT6: palatal gingival thickness at 6mm below the cementoenamel junction.*

At the position of the maxillary central incisors, the bone thickness at the palatal surface, when measured at 2 mm below the CEJ, showed that the PBT2 distribution was evenly spread across the thickness groups. However, at 4 mm below the CEJ, the ratio of PBT4 > 2 accounted for half of the thickness groups. At 6 mm below the CEJ, the ratio of PBT6 > 2 increased significantly, reaching 84.2%.

The proportion of PBT < 0.5 is virtually absent when evaluated at 4 mm and 6 mm below the CEJ. At the labial sides, the bone thickness reached its level of 1.0 - 1.5 mm. The highest ratio was observed in the 0.5 - 1.0 mm group at all measurement points, yielding the following results: 51.7% for 2 mm, 74.2% for 4 mm, and 70% for 6 mm below the CEJ (Chart **4**).
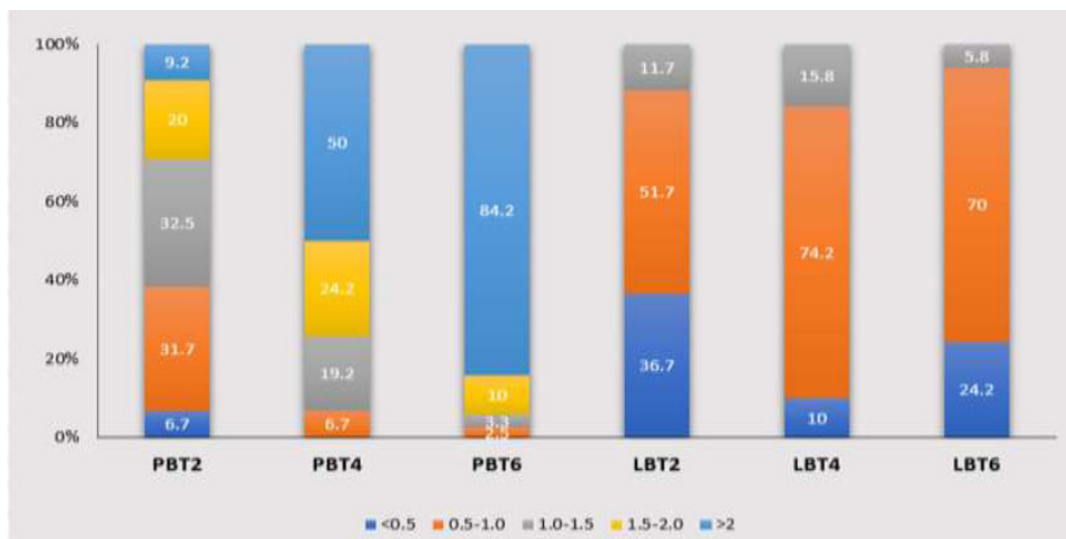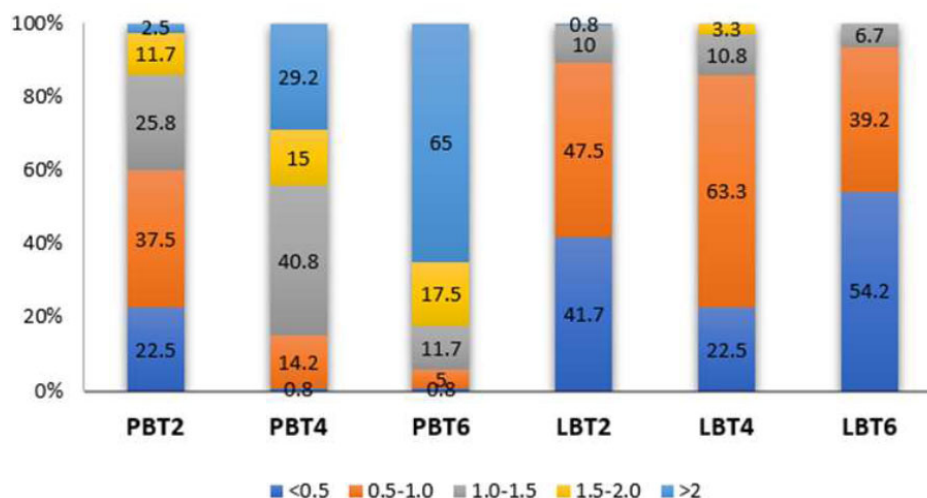

Chart 4. Distribution frequency of Bone thickness at different sites in the Central incisor region. *LBT2: labial bone thickness at 2mm below the cementoenamel junction; PBT2: palatal bone thickness at 2mm below the cementoenamel junction; LBT4: labial bone thickness at 4mm below the cementoenamel junction; PBT4: palatal bone thickness at 4mm below the cementoenamel junction; LBT6: labial bone thickness at 6mm below the cementoenamel junction; PBT6: palatal bone thickness at 6mm below the cementoenamel junction.*

When evaluating PBT in the lateral incisor region, the highest proportions found in PBT2, PBT4, and PBT6 were 0.5-1.0 mm, 1.0-1.5 mm, and > 2 mm, respectively. On the labial sides, the majority of individuals exhibit LBT2 and LBT4 with thicknesses ranging from 0.5 to 1.0 mm. In addition, LBT6 is predominantly greater than 2 mm in thickness (Chart 5).

At the maxillary canine, the PBT increases as it progresses from the CEJ towards the apex. The 0.5-1 mm thickness group accounts for the highest proportion at PBT2 with 39.7%. The 1.5-2 mm thickness group constitutes 37.1%, showing the highest frequency at PBT4. At 6 mm below the CEJ, there is a significant increase in PBT, with 70.7% of the group exhibiting a thickness > 2 mm. On the labial sides, the 0.5-1 mm thickness group predominates at both the 4 mm and 6 mm distances, except for the < 0.5 mm thickness group at LBT2, which accounts for 47.8% (Chart 6).

Chart 5. Distribution frequency of Bone thickness at different sites in the Lateral incisor region. *LBT2: labial bone thickness at 2mm below the cementoenamel junction; PBT2: palatal bone thickness at 2mm below the cementoenamel junction; LBT4: labial bone thickness at 4mm below the cementoenamel junction; PBT4: palatal bone thickness at 4mm below the cementoenamel junction; LBT6: labial bone thickness at 6mm below the cementoenamel junction; PBT6: palatal bone thickness at 6mm below the cementoenamel junction*
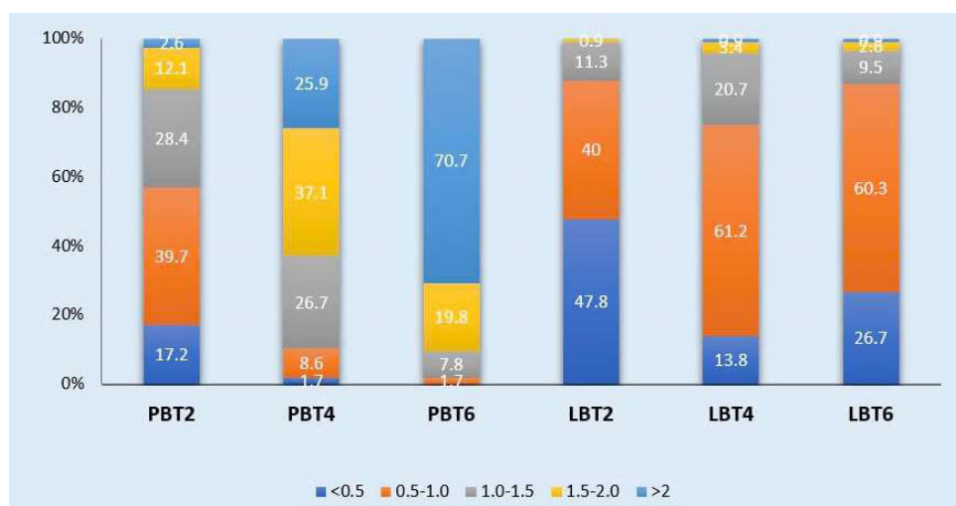

Chart 6. Distribution frequency of Bone thickness at different sites in the Canine region. *LBT2: labial bone thickness at 2mm below the cementoenamel junction; PBT2: palatal bone thickness at 2mm below the cementoenamel junction; LBT4: labial bone thickness at 4mm below the cementoenamel junction; PBT4: palatal bone thickness at 4mm below the cementoenamel junction; LBT6: labial bone thickness at 6mm below the cementoenamel junction; PBT6: palatal bone thickness at 6mm below the cementoenamel junction.*

4. DISCUSSION

In this study, we employed a method to calculate the parameters using CBCT imaging to visualize, measure, and analyze the relationship between various periodontal and alveolar bone structures. When planning for immediate implant placement, clinicians must assess CBCT images for alveolar socket bone thickness, bone height, the bodily position of the tooth and root, inclination, and the expected buccal gap. The root position and remaining alveolar socket bone will influence the planned location for the initial osteotomy and the 3D positioning of the implant. Additionally, the evaluation of these parameters is also crucial when planning for periodontal treatment, orthodontics, prosthodontics, and dental surgery [14-16].

An appropriate tool is necessary for accurate and convenient assessment. Both hard and soft tissues can be visualized and measured using CBCT. Several authors have observed that CBCT provides highly reliable and accurate measurements of both soft and hard tissues. They note that CBCT imaging can serve as a more objective method for determining the thickness of both hard and soft tissues compared to direct measurements [17-19]. CBCT offers more precise imaging of the teeth, gingiva, and other periodontal structures compared to ultrasound devices and probing techniques. Moreover, the size of a specific tooth can be measured multiple times using the same image obtained by CBCT, a capability not possible with other techniques [19].

Compared to implants with thick GB, those with thin GB have a significantly greater prevalence of peri-implantitis, peri-implant mucositis, and soreness/discomfort during oral hygiene [20]. In addition, GB evaluation should be seriously considered in orthodontic treatment since thin GB has been regarded as a useful predictor for the development of bony dehiscence and gingival recession during orthodontic treatment of labial movement of mandibular incisors [21]. Our study showed that, at the position of the maxillary central incisors, the PBT2 distribution was evenly spread across the thickness groups. However, the ratio of PBT4 > 2 accounted for half of the thickness groups, and the ratio of PBT6 > 2 increased significantly. The proportion of PBT < 0.5 is virtually absent when evaluated at 4 mm and 6 mm below the CEJ. On the labial sides, the highest ratio was observed in the 0.5 - 1.0 mm group at all measurement points. Overall, the average bone thickness of the palatal surface was greater than that of the buccal surface.

Howard Gluckman *et al.* [15] concluded that most maxillary anterior teeth have thin facial bone walls, which may compromise the benefits of immediate implant placement if the management of these tissues is not adequately planned. The study by Gotam Das *et al.* [22] demonstrated that the radiographic measurements on CBCT were 1.34 ± 0.17 mm for the right central incisor and 1.28 ± 0.21 mm for the left central incisor. The g in this study was somewhat higher compared to the findings in our research.

Most of the correlations between GT and BT in the anterior maxillary teeth are not statistically significant. Statistically significant correlations were observed for the lateral incisor, which predominantly exhibited a negative correlation, specifically between LGT2 and LBT2; between PGT2 and LBT2, PBT2, LBT4, and LBT6; and between PGT6 and PBT2. The only positive correlation with statistical significance was found between LGT2 and LBT6. For the canine, all statistically significant correlations were negative. Notably, the correlation between PGT2 and LBT2 for the lateral incisor, as well as the correlation between PGT2 and PBT2 for the canine, were statistically significant at the 0.01 level. However, in the study by Linhong Wang *et al.* [2], a correlation between GT and BT in the anterior maxillary region was evaluated. A significant negative correlation was found between BT and GT at the 2 mm apex relative to the CEJ in all maxillary incisors, while a weak negative correlation was observed at the 4 mm apex relative to the CEJ for the canine. No significant correlations were found at other positions. This finding is also consistent with the results of Cao [23] and Stein [24].

CONCLUSION

Within the scope of this study, we can conclude that the gingival and bone thickness on the palatal side is greater than on the labial side, it provides valuable insights for implantology, particularly in planning procedures for aesthetic outcomes and minimizing complications. Additionally, the finding is that gender does not play a critical role in influencing these measurements of the maxillary anterior teeth. Understanding these parameters and their *adjacent structures* is crucial for diagnosis and treatment planning. Besides, sample size limitations are a constraint in our study.

AUTHORS' CONTRIBUTIONS

The authors confirm their contribution to the paper as follows: L.L.L.: Study conception and design; L.T.T.: Data collection; D.T.T.: Methodology: A.T.T.D., T.T.N.N.: Draft manuscript. All authors reviewed the results and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study received approval from the Ethics Committee for Biomedical Research, as outlined in Decision No. 23.005/PCT-HĐĐĐ.

HUMAN AND ANIMAL RIGHTS

All procedures involving human participants were performed in accordance with the ethical standards of the institutional and/or research committees and the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

Written informed consent was obtained prior to the study.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

The data sets analyzed during the current study are available from the corresponding author [L.N.L.] upon reasonable request.

REFERENCES

[1] Abd-Allah A, Edrees M, Hassan K. Analysis of the gingival biotype based on the measurement of hard and soft dental tissue dimensions. Al-Azhar Assiut Dental Journal 2019; 2(1): 1-9.
http://dx.doi.org/10.21608/aadj.2019.60174

[2] Wang L, Ruan Y, Chen J, Luo Y, Yang F. Assessment of the relationship between labial gingival thickness and the underlying bone thickness in maxillary anterior teeth by two digital techniques. Sci Rep 2022; 12(1): 709.
http://dx.doi.org/10.1038/s41598-021-04721-7 PMID: 35027640

[3] Morad G, Behnia H, Motamedian SR, et al. Thickness of labial alveolar bone overlying healthy maxillary and mandibular anterior teeth. J Craniofac Surg 2014; 25(6): 1985-91.
http://dx.doi.org/10.1097/SCS.0000000000001022 PMID: 25377957

[4] Rossell J, Puigdollers A, Girabent-Farrés M. A simple method for measuring thickness of gingiva and labial bone of mandibular incisors. Quintessence Int 2015; 46(3): 265-71.
http://dx.doi.org/10.3290/j.qi.a32919 PMID: 25328921

[5] Gluckman H, Pontes CC, Toit DJ, Coachman C, Salama M. Dimensions of the dentogingival tissue in the anterior maxilla. A CBCT descriptive cross-sectional study. Int J Esthet Dent 2021; 16(4): 580-92.
PMID: 34694081

[6] Martin AM, Lipani E, Martinez BL, Lorenzo AA, Aiuto R, Garcovich D. Reliability of tooth width measurements delivered by the clin-check pro 6.0 software on digital casts: A cross-sectional study. Int J Environ Res Public Health 2022; 19(6): 3581.
http://dx.doi.org/10.3390/ijerph19063581 PMID: 35329271

[7] Arambawatta K, Abeysundara A, Ihalagedera D, et al. Morphological analysis of cementoenamel junction in premolars of Sri Lankans. Anat Sci Int 2021; 96(4): 509-16.
http://dx.doi.org/10.1007/s12565-021-00615-w PMID: 33821420

[8] Rizzatto S, Menezes L, Rabin P, Petersen R, Dalla Lana Mattiello F, Lima LE. Crown and root lengths of impacted maxillary central incisors and contralateral teeth evaluated with cone beam computed tomography. Pesqui Bras Odontopediatria Clin Integr 2017; 17: e3613.
http://dx.doi.org/10.4034/PBOCI.2017.171.58

[9] Shi X, Xie X, Quan J, et al. Evaluation of root and alveolar bone development of unilateral osseous impacted immature maxillary central incisors after the closed-eruption technique. Am J Orthod Dentofacial Orthop 2015; 148(4): 587-98.
http://dx.doi.org/10.1016/j.ajodo.2015.04.035 PMID: 26432314

[10] Sun H, Wang Y, Sun C, et al. Root morphology and development of labial inversely impacted maxillary central incisors in the mixed dentition: A retrospective cone-beam computed tomography study. Am J Orthod Dentofacial Orthop 2014; 146(6): 709-16.
http://dx.doi.org/10.1016/j.ajodo.2014.07.026 PMID: 25432251

[11] Lyu J, Lin Y, Lin H, Zhu P, Xu Y. New clues for early management of maxillary impacted central incisors based on 3-dimensional reconstructed models. Am J Orthod Dentofacial Orthop 2018; 154(3): 390-6.
http://dx.doi.org/10.1016/j.ajodo.2017.11.034 PMID: 30173842

[12] Rodrigues DM, Avila-Ortiz G, Barboza EP, Chambrone L, Fonseca M, Couso-Queiruga E. Relationship between gingival thickness and other periodontal phenotypical features: A cross-sectional study. Int J Periodontics Restorative Dent 2024; 0(0): 1-23.
http://dx.doi.org/10.11607/prd.7265 PMID: 39058941

[13] Le LN, Do TT, Truong LT, et al. Cone beam CT assessment of mandibular foramen and mental foramen positions as essential anatomical landmarks: A retrospective study in vietnam. Cureus 2024; 16(4): e59337.
http://dx.doi.org/10.7759/cureus.59337 PMID: 38817523

[14] AlAli F, Atieh MA, Hannawi H, et al. Anterior maxillary labial bone thickness on cone beam computed tomography. Int Dent J 2023; 73(2): 219-27.
http://dx.doi.org/10.1016/j.identj.2022.03.007 PMID: 35527034

[15] Gluckman H, Pontes CC, Toit DJ. Radial plane tooth position and bone wall dimensions in the anterior maxilla: A CBCT classification for immediate implant placement. J Prosthet Dent 2018; 120(1): 50-6.
http://dx.doi.org/10.1016/j.prosdent.2017.09.005 PMID: 29195817

[16] Januário AL, Barriviera M, Duarte WR. Soft tissue cone-beam computed tomography: A novel method for the measurement of gingival tissue and the dimensions of the dentogingival unit. J Esthet Restor Dent 2008; 20(6): 366-73.
http://dx.doi.org/10.1111/j.1708-8240.2008.00210.x PMID: 19120781

[17] Kloukos D, Koukos G, Doulis I, Sculean A, Stavropoulos A, Katsaros C. Gingival thickness assessment at the mandibular incisors with four methods: A cross-sectional study. J Periodontol 2018; 89(11): 1300-9.
http://dx.doi.org/10.1002/JPER.18-0125 PMID: 30043972

[18] Montanha-Andrade K, Crusoé-Rebello IM, Araujo NS, Barreto MA, Santos JN, Cury PR. Evaluation of the morphometric relationship between the alveolar bone and gingival dimensions in the maxillary anterior teeth using cone-beam computed tomography imaging: A cross-sectional study. J Clin Images Med Case Rep 2021; 2(3): 2.
http://dx.doi.org/10.52768/2766-7820/1113

[19] Wang XYS, Shi YW, Zhou S, Chen YH. Evaluation of the accuracy of cone-beam computed tomography for measuring intraoral soft tissue thickness. Int J Clin Exp Med 2022; 15(1): 37-44.

[20] Gharpure AS, Latimer JM, Aljofi FE, Kahng JH, Daubert DM. Role of thin gingival phenotype and inadequate keratinized mucosa width (<2 mm) as risk indicators for peri-implantitis and peri-implant mucositis. J Periodontol 2021; 92(12): 1687-96.
http://dx.doi.org/10.1002/JPER.20-0792 PMID: 33856690

[21] Barootchi S, Tavelli L, Gianfilippo DR, et al. Soft tissue phenotype modification predicts gingival margin long-term (10-year) stability: Longitudinal analysis of six randomized clinical trials. J Clin Periodontol 2022; 49(7): 672-83.
http://dx.doi.org/10.1111/jcpe.13641 PMID: 35561034

[22] Das G, Ahmed AR, Suleman G, et al. A comparative evaluation of dentogingival tissue using transgingival probing and cone-beam computed tomography. Medicina 2022; 58(9): 1312.
http://dx.doi.org/10.3390/medicina58091312 PMID: 36143989

[23] Cao J, Hu WJ, Zhang H, et al. A novel technique for measurement of dentogingival tissue by cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol 2015; 119(2): e82-7.
http://dx.doi.org/10.1016/j.oooo.2014.10.022 PMID: 25577421

[24] Stein JM, Lintel-Höping N, Hammächer C, Kasaj A, Tamm M, Hanisch O. The gingival biotype: Measurement of soft and hard tissue dimensions - a radiographic morphometric study. J Clin Periodontol 2013; 40(12): 1132-9.
http://dx.doi.org/10.1111/jcpe.12169 PMID: 24102580