Dimensions of the dentogingival tissue in the anterior maxilla. A CBCT descriptive cross-sectional study

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Abstract

Background: The characteristics of the periodontium in anterior teeth influence the outcomes and prognosis of different periodontal, implant, and restorative procedures. In the present study, CBCT images were used to determine alveolar bone thickness and, to a lesser extent, gingival thickness. The aim was to evaluate the use of CBCT to measure the dentogingival complex in the anterior maxilla.

Materials and methods: CBCT scans from 25 healthy patients were taken and the maxillary anterior teeth (n = 138) analyzed in the radial plane. The study provided descriptive data on gingival thickness, alveolar bone thickness (horizontal measurements), and vertical measurements related to biologic width.

Results: The mean distance from gingival margin to bone crest (BC) was 3.4 ± 0.7 mm, and that between the cementoenamel junction and BC was 2.6 ± 1.0 mm. The average mid-labial gingival thickness 1 mm apical of the gingival margin was 1.0 ± 0.3 mm; a thinner gingiva was observed in females ($P = 0.01$) and canines ($P < 0.001$). The average crestal labial bone thickness was 0.8 ± 0.3 mm. In total, 62% of the tooth sites had a thin gingiva (< 1 mm), and 72% had thin labial bone plates; a moderate positive correlation was found between these parameters ($P < 0.001$).

Conclusions: CBCT was effective in providing data on the thickness of the labial plate and gingiva as well as on the relationship among BC, CEJ, and gingival margin. The majority of tooth sites had thin labial bone and thin gingiva, with thinner gingiva observed in females and at canine sites.

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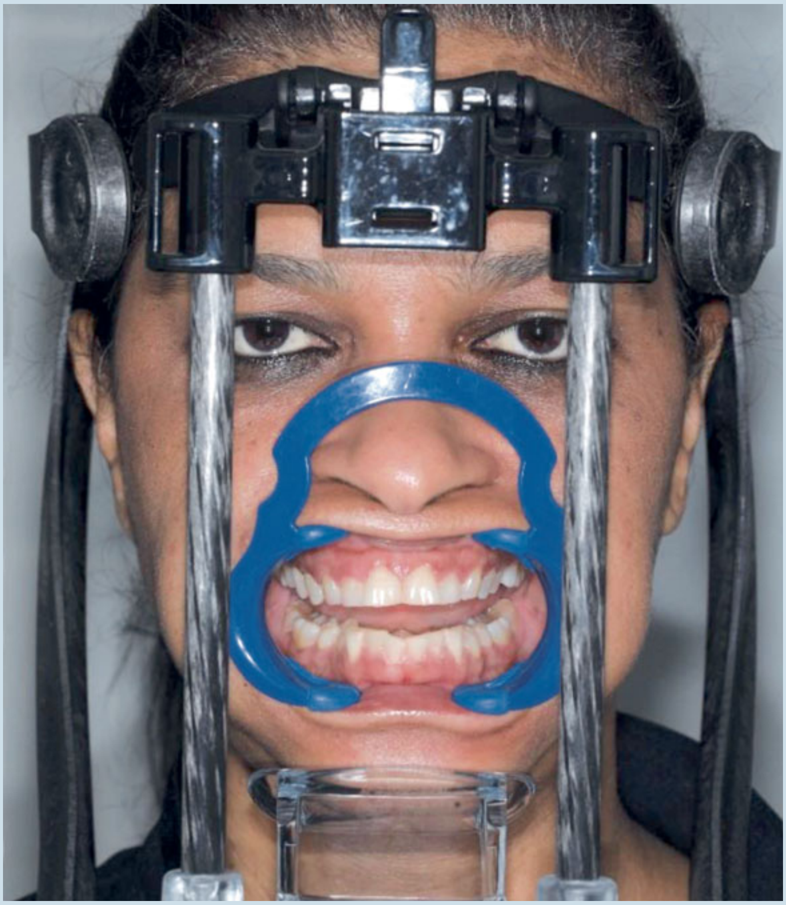

Introduction

Accurate assessment of the dentogingival complex is vital for precise diagnosis and presurgical planning in dentistry.[1] Despite the routine use of traditional 2D radiographs in periodontology and implant dentistry, evaluation of the gingival and alveolar bone thickness is not possible.[2,3] Using average soft and hard tissue measurements from historical data has limitations as there is evidence to support high intra- and interindividual variation in anatomical parameters related to the dentogingival complex in both the maxilla and mandible.[4,5] In the literature, anatomical measurements are grouped to provide average values, which do not always accurately describe all individual patients. However, in clinical decision making, each tooth site needs to be assessed individually to increase precision and predictability of surgical procedures, particularly in the esthetic zone.[6]

The importance of the anatomical characteristics of the osseous–gingival complex at the anterior teeth cannot be underestimated as they influence the outcomes and prognosis of different periodontal, implant, and restorative procedures.[7,8] Lack of knowledge of the facial plate and gingival thickness can lead to inadequate surgical planning, iatrogenic injury, complications, and decreased predictability of postsurgical outcomes.[6]

Direct measurements (probing to bone level under local anesthetic), ultrasonic measurements, and the probe transparency method have frequently been used to investigate gingival thickness and biologic width.[9] However, all these techniques have inherent disadvantages that limit their practical application, and none of them provide information on bone thickness.[8-11]

CBCT, which has been successfully employed in implant dentistry over the past decades, is now considered an indispensable tool for diagnosis and planning due to the high-quality 3D images it provides as well as its ability to provide linear and volumetric data.[12] In addition to providing information on alveolar bone thickness, CBCT has also been used to investigate the gingival soft tissue.[13] Precise measurements of the dentogingival unit for individual teeth and sites through 3D imaging can significantly improve treatment outcomes.[14]

The present study aimed to evaluate the use of CBCT for measuring critical anatomical aspects of the dentogingival unit in the anterior maxilla. The scans were performed with lip retraction to allow for visualization of both the hard and soft tissue.[13] The null hypothesis was that gingival thickness measured through CBCT images is not correlated to alveolar bone thickness.

Material and methods

Study sample

The present observational study was performed according to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE). It was conducted following criteria defined by the Helsinki Declaration.[15] The study analyzed CBCT scans of 25 patients referred to a private dental clinic for dental treatment from October to December 2019. Inclusion criteria included the presence of at least four maxillary anterior teeth in systemically healthy patients without dentoalveolar defects; exclusion criteria included root fractures, crown restorations, root resorption, and severe scattering in the CBCT images.

CBCT imaging

CBCT scans were performed with a CS 9300 (Carestream Health) 3D scanner, regardless of the field of view (5×5, 8×8, 10×5, 10×10, 17×6, 17×11, 17×13.5), according to the manufacturer's recommended parameters. A plastic lip retractor was placed in each patient's mouth before the scan to separate the lips from the labial gingiva and to allow for the identification of the gingival tissue in the resulting 3D images, as described previously (Fig 1).[13] Datasets resulting from the scans were saved in DICOM format. Images were analyzed using specific software (Kodak Dental Imaging Software; Carestream Health) and reconstructed by using cross-sectional slices in the radial plane, perpendicular to the alveolar ridge at 0.9-mm intervals. The cross-section of each tooth in the radial 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.

Labial bone thickness was measured, as described previously.[16] Then, lines were drawn central to each tooth and its long axis, with a second line perpendicular at its apex. Horizontal bone thickness was measured in three different locations parallel to the apical plane: A (crestal), B (mid-root), and C (apex). Crestal bone thickness at A was measured 1 mm from the most crestal bone aspect; thickness at C was measured at the apical line; thickness at B was measured midway between points A and C.

Gingival thickness was measured perpendicular to the long axis of the tooth in three different locations: at the cementoenamel junction (CEJ), 1 mm from the gingival margin, and 3 mm from the CEJ. The vertical distances from bone crest (BC) to CEJ, from BC to gingival margin, and from CEJ to gingival margin were measured mid-facially (Fig 2).[17]

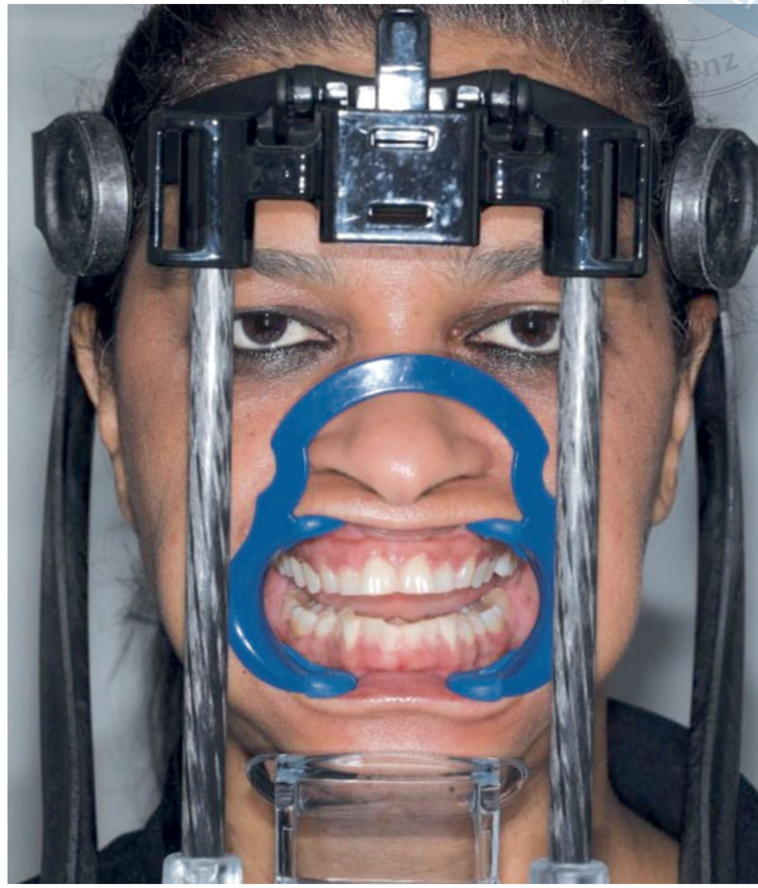

Fig 1 Patient in position for CBCT scan with inverted plastic lip retractor in place.

Examiner reliability

All CBCT measurements were performed by a single examiner (CCP) who was blinded to the clinical characteristics of the patients. To evaluate intraexaminer reliability, 13 patients were randomly selected for repeated measurement of gingival thickness, bone thickness, and distance between CEJ and BC, 1 week after the first measurement. The intraclass correlation coefficient (ICC) was 0.81 for gingival thickness, 0.84 for bone thickness, and 0.93 for CEJ to BC distance. The average ICC was 0.86, indicating excellent reliability.[18]

Statistical analysis

The unit of the present study was the tooth. All measurements were summarized in terms of descriptive statistics using absolute and relative frequencies, average, standard

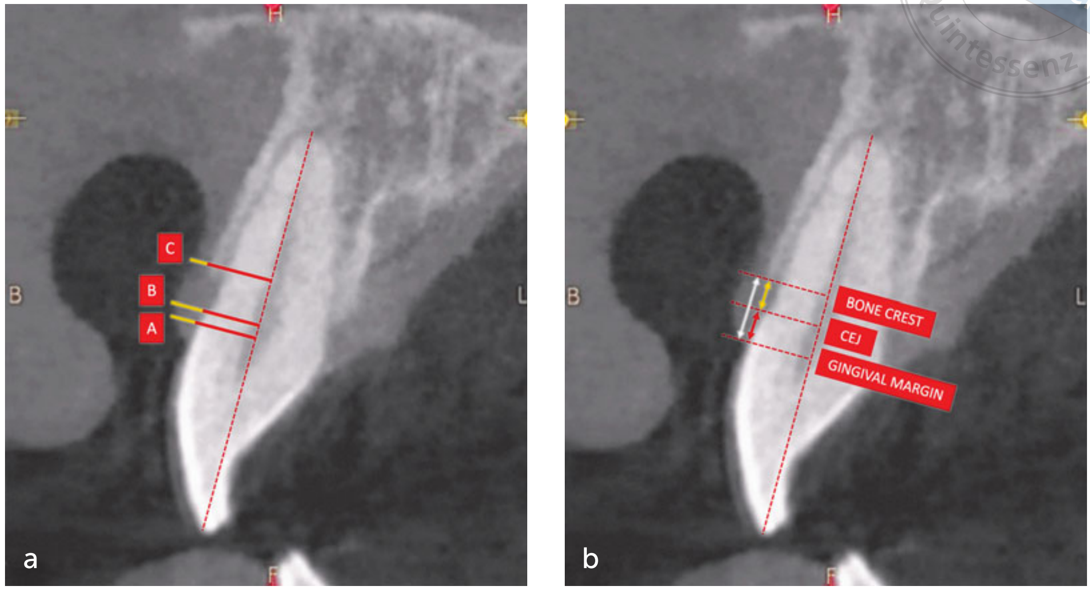

Fig 2 (a) Horizontal measurement of gingival thickness in three locations: A: 1 mm from the gingival margin; B: at the cementoenamel junction (CEJ); C: 3 mm from the CEJ. (b) Vertical measurements from the gingival margin to the bone crest (BC), from the CEJ to the BC, and from the gingival margin to the CEJ.

deviation, and range. For intraexaminer reliability, the ICC was used based on a two-way mixed-effect model and absolute agreement. Gingival and bone thickness were categorized as thin (> 1 mm) and thick (≥ 1 mm), according to Kan et al,[19] and evaluated for association with gender and tooth type using the chi-square test.

The normality assumption of the data was based on graphical evaluation of histograms and box plots as well as on the summary statistics. One-way repeated measures ANOVA with Bonferroni adjustment for multiple comparisons was used to determine whether there were differences in average measures for biologic space concerning different tooth types. Means according to gender and age group were compared using *t* tests. The Pearson correlation was used to evaluate a potential association between gingival thickness and crestal bone thickness. Data were analyzed using the statistical package Stata 15.1, 2017 (Stata Corp). An alpha level of 0.05 was used to determine statistical significance.

Results

The study sample included 25 patients with an average age of 41.1 ± 9.3 years (age range 26 to 65). Regarding ethnicity, 16 participants were Caucasians, 7 were black Africans, and 2 had mixed ancestry. The study included 17 females (68%) and 8 males (32%), with a total of 138 teeth, of which 42 (30%) were central incisors, 49 (36%) lateral incisors, and 47 (34%) canines. The reasons for not including 12 teeth in the study were: 6 teeth were missing, from which an implant had replaced 4 teeth, 1 tooth had a crown, another tooth was ectopic, and 4 teeth presented shaky CBCT images.

CBCT vertical measurements related to biologic width

The gingival margin was located above the CEJ in 99 teeth (71.7%), at the CEJ in 15 teeth (10.9%), and below the CEJ (gingival recession) in 24 teeth (17.4%). The average

Table 1 Descriptive statistics for the included variables (mm)

	Variables (mm)	Mean	Median	SD	Minimum	Maximum
Biologic space	GM–BC	3.4	3.3	0.7	1.8	5.5
	CEJ–BC	2.6	2.5	1.0	0.9	5.9
	CEJ–GM	1.1	1.0	0.8	1.2	3.0
Gingival thickness	1 mm from GM	1.0	1.0	0.3	0.4	1.7
	3 mm from CEJ	0.9	0.9	0.4	0.4	1.8
Facial plate thickness	Crestal	0.8	0.8	0.3	0.4	1.9
	Mid-root	0.7	0.7	0.3	0.3	2.5
	Apical	1.5	1.2	1.1	0.2	7.7

SD: standard deviation; BC: bone crest; CEJ: cementoenamel junction; GM: gingival margin

distance between the gingival margin and BC was 3.4 ± 0.7 mm mid-facially, while that between the CEJ and BC was 2.6 ± 1.0 mm. The mean distance between the CEJ and gingival margin was 1.1 ± 1.0 mm (Table 1). There was no association between the biologic space variables according to gender and tooth type (Table 2).

Horizontal gingival thickness and gingival phenotype

Average gingival thickness 1 mm from the gingival margin was 1.0 ± 0.3 mm, and 3 mm from the CEJ was 0.9 ± 0.3 mm. In total, about two-thirds of the patient cohort (62.0%) had a thin gingival phenotype. There was no association between gingival phenotype and gender. Concerning tooth type, 79% of central incisors, 61% of lateral incisors, and 48% of canines presented with a thick phenotype (*P* = 0.01; Fig 3).

Average gingival thickness, measured 1 mm from the gingival margin at the mid-facial position, was slightly higher in males (1.1 ± 0.2 mm) than in females (1.0 ± 0.2 mm, *P* = 0.01). Central incisors presented thicker gingiva (1.1 ± 0.3 mm) than lateral incisors (1.0 ± 0.2 mm, *P* = 0.02) and canines (0.9 ± 0.2 mm, *P* < 0.001; Fig 4).

At 3 mm from the CEJ, the average gingival thickness was similar for males and females (0.9 ± 0.3 mm for both groups). At this location, the gingival tissue was thinner at the canines (0.8 ± 0.2 mm) compared with the central and lateral incisors (1.0 ± 0.3 mm for both tooth types, *P* = 0.04).

Facial bone thickness

The average facial plate thickness was 0.8 ± 0.3 mm at the crest, 0.7 ± 0.3 mm at the mid-portion of the root (mid-root), and 1.5 ± 1.2 mm at the apical point (apex). A thin facial plate was present in 73% of all teeth at the crest, 85% at the mid-root, and 36% at the apex (Fig 5). None of the included teeth had thick facial bone (≥ 2mm) at the crestal level, 2% had thick walls at mid-root, and 23% at the apex (see Fig 3).

Table 2 Biologic space variables by gender and tooth type (mm)

Biologic space variables (mm)		GM–BC		CEJ–BC		CEJ–GM	
		Mean	SD	Mean	SD	Mean	SD
Tooth type	Central incisor	3.5	0.7	2.6	1.0	1.2	0.7
	Lateral incisor	3.4	0.8	2.5	1.0	1.1	0.8
	Canine	3.4	0.7	2.8	1.2	1	0.9
Gender	Males	3.4	0.8	2.4	0.8	1.3	1.0
	Females	3.4	0.7	2.7	1.1	1.0	0.8

SD: standard deviation; BC: bone crest; CEJ: cementoenamel junction; GM: gingival margin

Alveolar facial bone thickness was not associated with gender or tooth type. In total, 75.5% of females and 65.9% of males had thin crestal bone.

In total, 73.8% of central incisors, 69.4% of lateral incisors, and 72.5% of canines had a thin alveolar crest. In the mid-root location, 86.3% of males and 85.0% of females had thin alveolar bone. Regarding tooth type, 87.8% of central incisors, 83.7% of lateral incisors, and 85.1% of canines had thin facial bone. In the apical area, the majority of teeth had thick bone (64.2%).

There was a borderline significant association between gingival phenotype and crestal facial bone thickness (thin > 1 mm, thick ≥ 1 mm, $P = 0.05$). For tooth sites with a thin gingival phenotype, 82.7% also had thin crestal bone; for those with a thick gingival phenotype, 32.9% also had thick crestal bone. The Pearson correlation ($r = 0.3227$, $P < 0.001$; Fig 6) for average gingival thickness and average crestal bone thickness indicated a moderate positive correlation, as gingival thickness tends to increase with increasing crestal bone thickness.

Discussion

Results from the present study confirm that CBCT can be a useful tool to evaluate soft tissue and alveolar bone thickness and measurements related to the biologic width in the anterior maxilla when a lip retractor is used during the scan. In total, two-thirds of all included teeth had a thin gingiva (< 1 mm). A thin gingival phenotype was more prevalent in canines. A thin alveolar BC was observed in 72% of all teeth, and a moderate positive correlation was observed between gingival and bone thickness.

Soft tissue CBCT scanning was first introduced in a case report by Januário et al.[13] In this 2008 study, plastic lip retractors were used during scanning to avoid contact between the soft tissue from the lip and the facial gingiva. The resulting CBCT images allowed for assessment of both the soft and hard facial tissue in the anterior maxilla. Other researchers achieved similar results using cotton rolls[17] or the 'puffed cheek' method[20] during the CBCT scan. The 2013 study by Dvorak et al[20] suggests that the puffed cheek method does not seem reliable compared with direct measurements for gingival thickness using needle probing. From a practical point of view, not all patients might be able to keep their cheeks puffed for the entire duration of the scan. Other studies suggested the use of radiopaque impression materials during CBCT scanning to aid in the evaluation of soft tissue thickness. This alternative method was created to bypass potential dimensional alterations

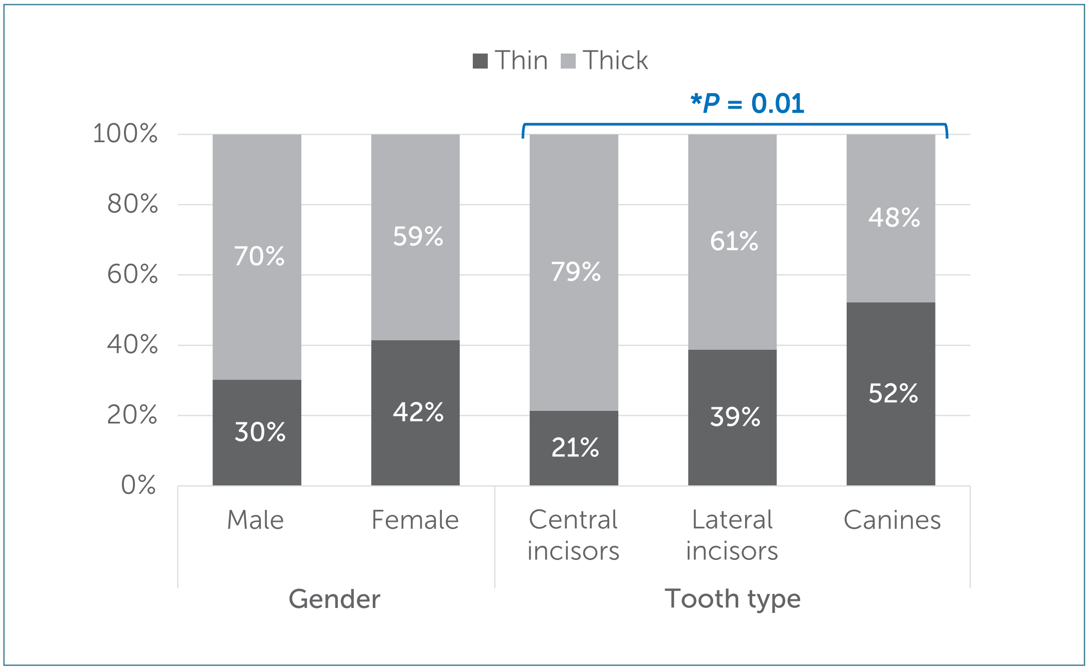

Fig 3 Gingival phenotype in relation to gender and tooth type: thin < 1 mm, thick ≥ 1 mm (*P = 0.01).

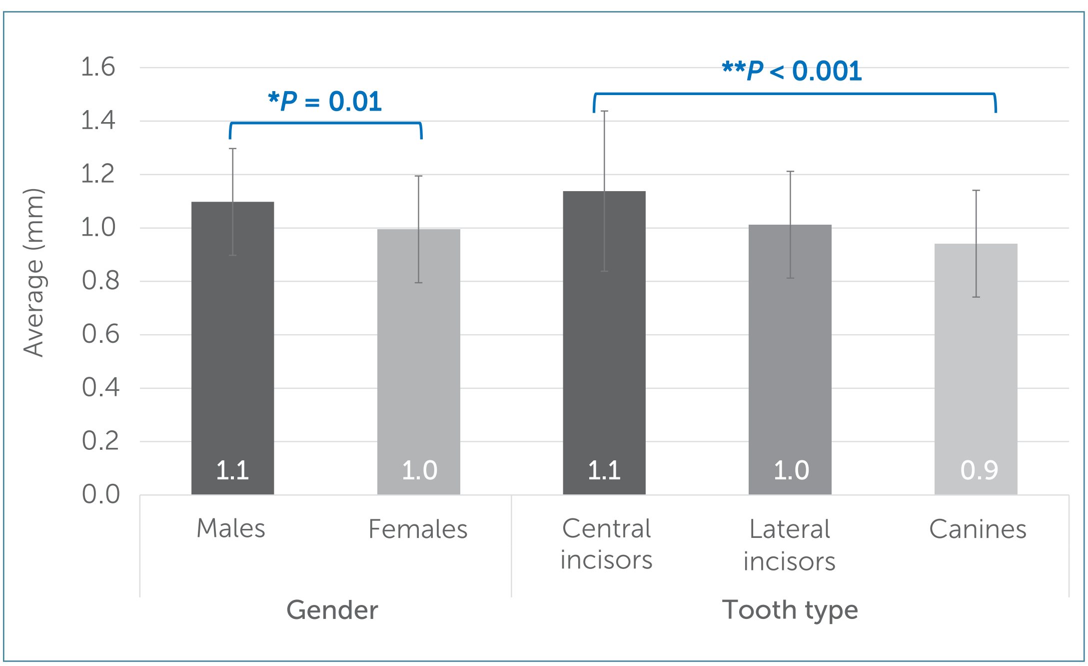

Fig 4 Average thickness (mm) of the gingiva measured 1 mm from the gingival margin at the midfacial position by gender (*P = 0.01) and tooth type (**P < 0.001). For tooth type, the Bonferroni adjusted significance of the difference between the central and lateral incisors was P = 0.02, and between the central incisors and canines was P < 0.001.

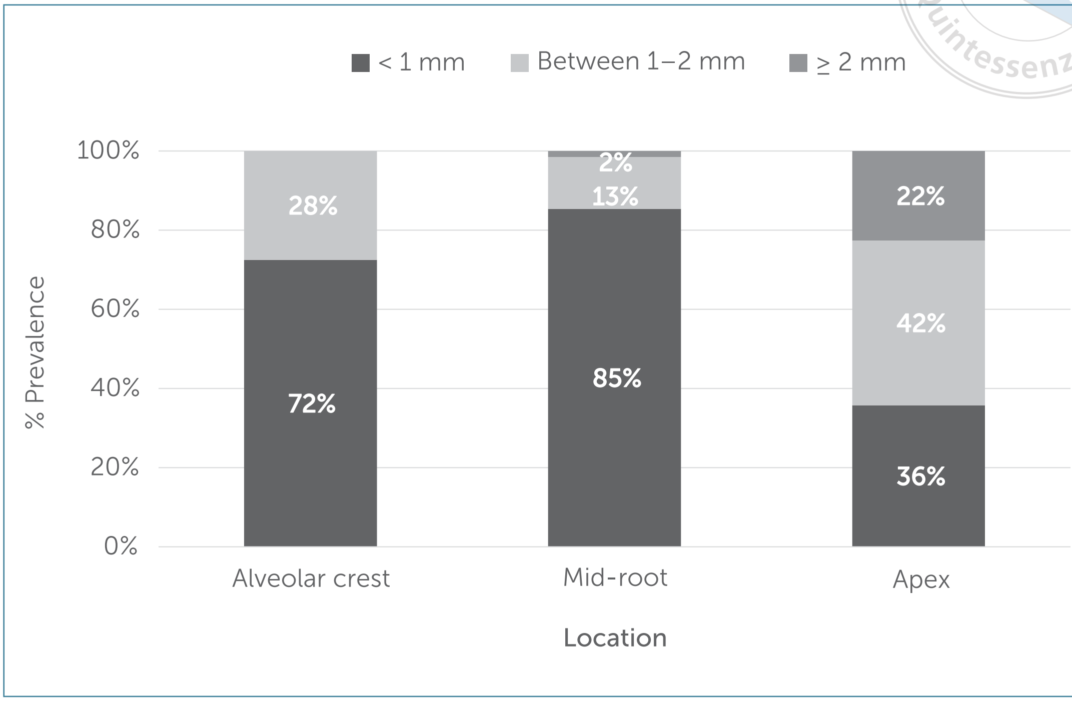

Fig 5 Percentage prevalence of facial bone thickness (< 1 mm, between 1–2 mm, and ≥ 2 mm) according to location (alveolar crest, mid-root, and apex).

in the soft tissue caused by lip retractors and cotton rolls.[21,22] No studies have compared these different CBCT techniques.

Despite small variations in the location for the measurements, CBCT results from the present study and that from a 2016 study by Nikiforidou et al[17] are in agreement in terms of average gingival thickness (1.0 vs 1.2 mm for the present study and that study, respectively), crestal bone thickness (0.8 mm for both studies), distance between the BC and CEJ (2.6 vs 2.0 mm, respectively), and distance between the BC and gingival margin (3.4 mm for both studies). The main difference between the present study and that study is that those authors used cotton rolls as opposed to lip retractors during the CBCT scanning.

The dimensions of the soft and hard tissue in the dentogingival unit are crucial. These directly influence treatment planning and prognosis for restorative, periodontal, and implant-related surgical procedures.[23] Different methods have been used to assess gingival thickness, including probe transparency[11] as well as ultrasonic,[10] direct,[9] and CBCT[13,17] measurements. Direct measurements have been criticized due to the lack of precision of the probe (which only measures to the nearest 0.5 mm), probe angulation, subjective tactile sensation, and distortion of the soft tissue during measurement; low reproducibility has been linked to ultrasonic measurements, while low reliability has been linked to the probe transparency method.[24] Furthermore, probe transparency does not provide actual values, and neither this method nor ultrasonic devices provide an overview of the dentogingival unit.

Thin gingiva has been suggested to respond differently to trauma and inflammation and has been linked to a worse

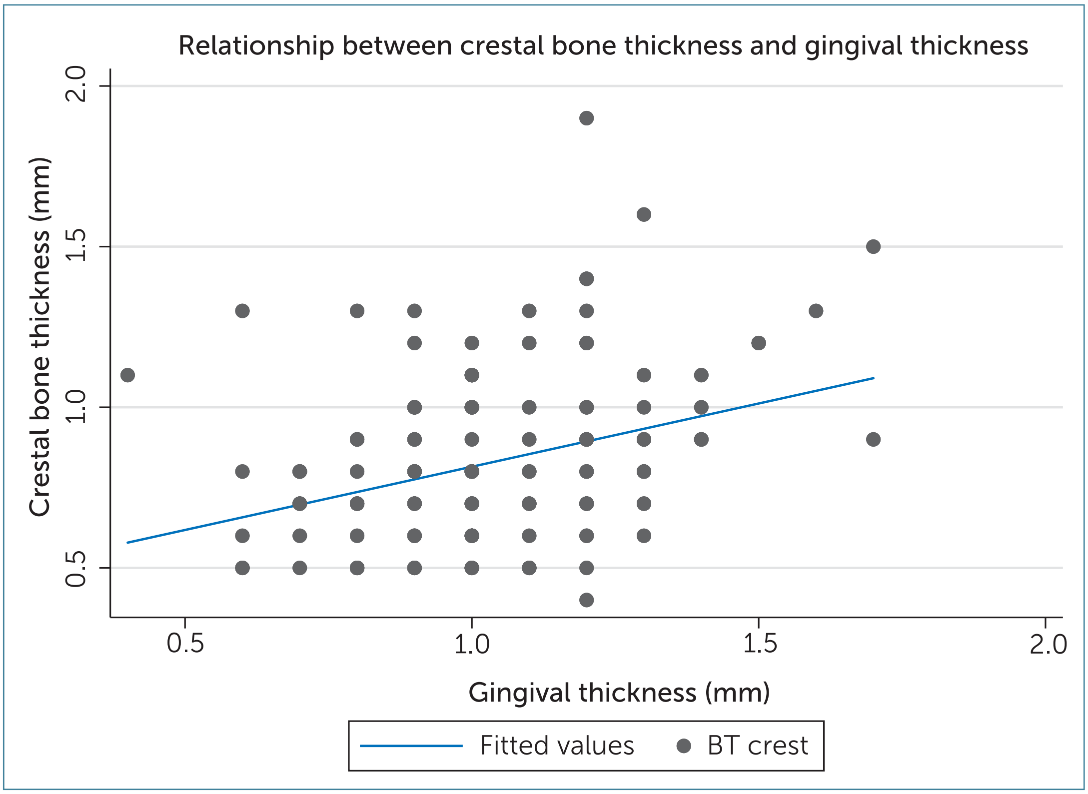

Fig 6 Scatterplot for the relationship between crestal bone thickness and gingival thickness.

prognosis after periodontal surgery and restorative treatment, higher risk for recession around implants, and unsatisfactory results after immediate implant placement.[25-29] In the present study, canine sites had the thinnest gingival tissue, and females presented slightly thinner gingiva than males, which accords with findings from previous studies.[10,30]

Several studies have reported CBCT measurements for facial bone thickness in the anterior maxilla. While mean bone thickness 1 mm from the BC was similar in both the present study and that by Younes et al[31] (1.0 vs 0.9 mm, respectively), the prevalence of a thin facial wall was lower in the latter study (68% of central incisors, 44% of lateral incisors, and 57% of canines) compared with the present study (74% of central incisors, 69% of lateral incisors, and 73% of canines). In a previous study by the present author group, 83% of all anterior maxillary teeth had thin facial walls, compared with 72% in this study.[16] Additional studies have reported varying prevalence of thin facial bone, from 69% to 86%.[32-34] In a 2010 multicenter clinical study by Huynh-Ba et al,[35] the average thickness of the facial alveolar wall measured in fresh extraction sockets was 0.8 mm. Despite the variations, previous studies and the present study agree on the predominance of thin alveolar bone in the facial aspect of the esthetic zone. In 2011, Cook et al[36] estimated the average difference between thin and thick gingival phenotypes to be 0.6 mm.

The moderate positive correlation between gingival and bone thickness in the present study supports similar findings by Nikifouridou et al,[17] Younes et al,[31] and Fu et al.[24] These findings suggest that in clinical practice, thin gingival phenotypes are likely to be supported by thin bone walls and might require specific treatment strategies to avoid complications and optimize treatment outcomes.

The accuracy of CBCT measurements of soft and hard tissue was confirmed in the Fu et al[24] study. These authors experimented on cadaver heads, concluding that CBCT measurements were highly accurate compared with actual clinical measurements in the anterior maxilla; however, formalin-fixed tissue tends to shrink. CBCT reliability and accuracy were also confirmed by Timock and coworkers,[37] who reported a mean absolute difference of 0.1 mm for bone thickness measured directly or through CBCT. The high precision and non-invasiveness of CBCT suggests its suitability for detecting clinical alveolar bone and gingival changes over time.[38]

Despite the advantages of CBCT, each case needs to be assessed individually, as the benefits of this procedure need to be higher than the potential hazards.[39] Dose optimization measures to reduce exposure to radiation, cost, and potential for image artefacts near metallic objects should be taken into consideration.[40] Healthcare providers must be aware that patient exposure during CBCT should be 'as low as diagnostically acceptable' (ALADA).[41] The limitations of the present study include the limited sample size and the lack of inter-examiner comparison. In future studies, it will be interesting to correlate CBCT dimensions to clinical parameters such as the width of the keratinized gingiva.

The clinical significance of the present study lies in the importance of assessing soft and hard tissue dimensions for the diagnosis and planning of surgical periodontal and implant-related procedures to minimize complications related to the resorption of the facial bone in the esthetic zone.[25]

Conclusions

CBCT allows the clinician to assess gingival soft tissue, alveolar bone thickness, and biologic width utilizing a noninvasive diagnostic tool that can improve clinical decision making, treatment planning, and outcomes. CBCT was effective in providing data on the facial plate and gingiva as well as on the relation between the CEJ and the gingival margin. Overall, the majority of tooth sites had a thin gingiva, with a thinner gingiva observed in females and in canine sites. The majority of teeth had thin facial bone walls, and a moderate positive association was present between bone and gingival thickness. Despite the apparent benefits of CBCT for periodontal and dental implant treatment, not all patients require it, and potential risks must be taken into account.

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