Assessment of Gingival Thickness Using CBCT Compared to Transgingival Probing and Its Correlation with Labial Bone Defects: A Cross-Sectional Study

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Purpose: The aims of this study were to determine the accuracy and repeatability of CBCT for assessing gingival thickness (GT) as compared to transgingival probing and to investigate the correlation between GT and labial bone defects. Materials and Methods: This cross-sectional study comprised 37 patients who underwent CBCT imaging. A total of 111 sites were examined, and measurements were obtained from the same points on selected index teeth. The GT was measured, and the presence of dehiscence and fenestration defects was evaluated on the CBCT scans. Transgingival probing was performed at the same points as those used on the scans. Intraexaminer reliability for clinical and radiographic measurements and interexaminer reliability for radiographic measurements were tested. Agreement between the measurement methods and the correlations between GT and labial bone defects were assessed using intraclass correlation coefficient (ICC) and chi-square test, respectively. Results: The agreement between both measurement methods was excellent and statistically significant (ICC = 0.888; \( P < .001 \)), with a bias of 0.04 (95% CI: 0.01 to 0.08). Significant differences in the occurrence of fenestration (\( P = .023 \)) and dehiscence defects (\( P < .001 \)) between the thin and thick gingival phenotypes were observed, and the defects were positively correlated with the thin gingival phenotype. Conclusion: CBCT demonstrated high diagnostic accuracy for GT measurements, with minimal discrepancies from the transgingival method. The presence of dehiscence and fenestration defects was positively correlated with thin gingival phenotype. Int J Oral Maxillofacial Implants 2022;37:464–472. doi: 10.11607/jomi.9234

Keywords: cone beam computed tomography, dehiscence, fenestration, gingival phenotype, gingival thickness, transgingival probing

In recent years, several studies have highlighted the relationship between achieving an optimal esthetic outcome via dental implants and the patient’s periodontal phenotype. The use of a connective tissue graft along with immediate implant placement has been suggested in patients who present with a thin periodontal phenotype. Moreover, periodontal phenotype has been found to affect the decisions and outcomes of orthodontic, prosthodontic, and restorative treatment. According to the newest classification of the Periodontal and Peri-Implant Disease and Conditions, published in 2018, the term “periodontal phenotype” includes gingival thickness (GT) and keratinized tissue width (KTW) along with bone morphotype (thickness of the facial bone plate). Furthermore, in a systematic review by Zweers et al., gingival phenotype was classified into the following three categories: thin scalloped, thick flat, and thick scalloped.

GT is considered one of the most important variables for periodontal phenotype. Kan et al. suggested that a GT > 1 mm was indicative of a thick phenotype and ≤ 1 mm was indicative of a thin phenotype. Similar levels of categorization have been proposed in other studies.

Various methods for measuring the GT, including visual assessment, transgingival probing, probe transparency, ultrasonic device measurements, and CBCT, have been proposed in the literature. Visual assessment is the simplest method for evaluating GT. However, a study assessing the validity of this method reported an accuracy rate of only 50%. Another subjective method that lacks numeric measurements is the probe transparency method, which was introduced by Kan et al. In this method, a periodontal probe is inserted into the gingival sulcus, and the gingival phenotype is classified as thin when the color of the probe is visible and thick when it is not.

The transgingival probing method, considered the gold standard by some authors, is currently thought to
be the most objective for GT assessment. This technique is performed under local anesthesia, wherein a periodontal probe is inserted in a perpendicular direction through the mucosa until resistance from the bone is felt. This technique is considered effective because it provides high reliability and accuracy (to the nearest 0.5 mm). However, there are a few drawbacks, such as pain and discomfort caused by injection of the local anesthesia and a transient increase in volume from the injected solution, which has affected the accuracy of the measurements. Ultrasonic evaluation is an alternative method used for GT measurement, but some studies have demonstrated limitations in the accuracy of the results obtained using this method.

CBCT is a valuable imaging technique that provides a 3D analysis of the head and neck region. It allows dentists to plan interventions properly, operate with confidence, and assess the results postoperatively. CBCT is regarded as a tool used to evaluate the hard tissues; however, several studies have suggested the application of CBCT for visualizing and measuring the soft tissues of the dentogingival unit and have developed a specialized technique called soft tissue CBCT (ST-CBCT) to improve the image quality of the soft tissues. In this technique, a lip retractor is used to separate the cheeks and lips from the facial aspects of the teeth, thus allowing for visualization and accurate measurement of the facial gingiva.

Studies demonstrating the accuracy of CBCT images for the linear measurements of hard tissues are abundant, but only a few have examined their accuracy in soft tissue measurements. Unfortunately, some of these studies were conducted in vitro or are retrospective in nature. Hence, the accuracy of CBCT in measuring soft tissues remains to be elucidated.

Bone morphotype is another major component of periodontal phenotype. The correlation between bone morphotype and GT has been a matter of controversy for many years. Several studies reported a significant positive correlation between these variables, while some found only a weak to moderate correlation and others failed to find any correlation. A recent systematic review by Kim et al concluded there is a disagreement in the association between periodontal phenotype and thickness of the labial bone plate.

The presence of alveolar bone defects, such as dehiscence and fenestration, might be considered an integral subunit of the bone morphotype. Both defects involve a denuded root surface with loss of cortical bone plate in a certain area. Fenestration defects do not involve the alveolar margin, while dehiscence defects do. Anticipating these defects is of paramount importance during treatment planning, which might include a wide range of surgical procedures such as immediate implant placement and mucogingival surgeries. Failure to detect such a defect at the site of soft tissue graft harvesting would compromise the donor site and result in gingival recession.

A positive correlation between labial bone thickness and bone defects could be proven based on CBCT findings. Furthermore, the periodontal phenotype is decided based on GT. Hence, investigating the relationship between GT and alveolar bone defects seems to be a compelling area of research. To the best of the present authors’ knowledge, the presence of such a correlation has not been investigated so far.

Therefore, the aim of this study was to assess the accuracy of CBCT in measuring GT when compared to the transgingival probing method. In addition, the correlation between GT and the presence of alveolar bone defects was assessed. The null hypothesis of the study was that there is no difference in accuracy between the CBCT and transgingival probing methods and no correlation between GT and alveolar bone defects.

**MATERIALS AND METHODS**

**Study Population**

This cross-sectional study was conducted in 37 patients who were referred to the Oral Radiology Department at the Faculty of Dentistry, Alexandria University, Egypt, between January 2020 and March 2020.

**Inclusion and Exclusion Criteria**

Adult and systemically healthy patients between 20 and 50 years of age requiring CBCT evaluation of at least one maxillary quadrant before undergoing various surgical procedures not related to the study were included. Pregnant women and those who presented with periodontitis in the selected teeth, patients who had previously undergone surgical procedures such as crown lengthening, soft tissue grafting, or flap surgeries, and patients who had received head and neck radiotherapy in the past 6 months were excluded from the study.

**Ethical Approval**

This study was conducted in accordance with the principles of the modified Helsinki code for human clinical studies (World Medical Association Declaration of Helsinki, 2013) and approved by the Ethics Committee of the Faculty of Dentistry, Alexandria University (IRB 00010556, IORG 0008839). The purpose and nature of the study were explained to the patients, and informed consent was obtained.

**Sample Size Estimation**

The sample size was estimated based on the following assumptions: a confidence level of 95% and a study power of 80%. The alternative hypothesis (H1)
was based on the mean difference in the anterior GT measured by transgingival probing vs CBCT scanning (0.14 mm with a pooled SD of 0.275). In H1, the mean difference = 0.27. The sample size was calculated as 37, and a total of 111 sites were examined.

**Clinical and Radiographic Procedures and Outcome Measures**

GT was measured at the same points on the selected index teeth (maxillary central incisor, lateral incisor, and canine) using the two different methodologies: transgingival probing and CBCT.

**Initial Preparation of Patients**

Standardization of the measurement points was achieved by fabricating a radiopaque button-shaped marker made of composite resin material (Tetric EvoCeram, Ivoclar Vivadent) with a hole in the center, where both clinical and radiographic measurements were undertaken.

**Composite Button Fabrication**

The attached gingiva corresponding to each index tooth was air dried to ensure the stability and adherence of the composite button, which was placed midfacially on the facial gingiva of each index tooth. After the composite resin material was applied on the gingiva, a central hole with a diameter corresponding to that of the periodontal probe was created, and the button was light cured. The distance between the gingival margin and the center of the hole of the button was 3 mm (Fig 1a).

**CBCT Scanning and Analysis**

- A CBCT scan was performed on all patients at the Oral Radiology unit, Faculty of Dentistry, Alexandria University, after the initial preparation.
- A plastic lip retractor was placed during the scan to separate the soft tissues of the lips and cheek from the gingiva (Fig 1b).
- CBCT images were acquired using ProMax 3D (Planmeca) using the following x-ray parameters: 90 KVp; 6.3 mA for 12 seconds; voxel size = 200 μm; field of view = 8 × 8 cm; and a single 200-degree image rotation. After reconstruction of the raw data, DICOM (Digital Imaging and Communications in Medicine) files were generated for each patient.
- The images were processed using OnDemand3D version 1.0 software (CyberMed) on a computer consisting of an Intel Core 7 processor and the Microsoft Windows 10 program.
- Measurements were performed on the multiplanar reformation (MPR) images using nonorthogonal sagittal cuts (1-mm slice interval and 1-mm slice thickness).

- At the center of the composite button on each index tooth, a line was drawn perpendicular to the long axis of the tooth (similar to the direction of the insertion of the probe), and the thickness of the gingiva was measured as the distance from the external side of the gingival tissue (undersurface of the composite button) to the bone surface or dental structure (Fig 2a).
- In the axial plane, the reference line was oriented to pass through the center of the examined tooth perpendicular to the long axis of the tooth and buccal alveolar bone. Bone defects were measured from the cross-sectional cut where the cementoenamel junction (CEJ) was identified. The absence of cortical bone around the root in at least three consecutive views was considered an alveolar defect. Dehiscence was identified when alveolar bone height was > 3 mm from the CEJ, whereas fenestration was identified when the defect did not involve the alveolar crest (Fig 2b and 2c).
- All measurements were performed two times on different days by two examiners (M.K. and S.A.).

**Transgingival Probing**

1. Xylocaine spray (10% lidocaine; AstraZeneca) was used to reduce pain before probing. The injection of a local anesthetic was avoided to prevent any anesthesia-induced transient increase in gingival volume. Then, a periodontal probe (CP15, Kohler) was inserted in a perpendicular direction through the hole of the composite button until resistance of the bone surface or dental structure was felt.
2. Flowable composite resin was applied circumferentially around the distal part of the probe shaft and cured to fix the composite button to the periodontal probe, allowing it to act as a stopper marking the GT after probe removal (Figs 1c and 1d).
3. The periodontal probe was removed, and the thickness of the gingiva was measured as the distance from the tip of the probe to the undersurface of the button using a digital caliper (reading to 0.01 mm; Mini Digital Caliper, Insize). The gingival biotype was considered thin if the measurement was ≤ 1.0 mm and thick if it was > 1.0 mm, as described previously.
4. This procedure was performed on each index tooth by a periodontist (Y.G.).

**Reliability**

Intraexaminer reliability was analyzed for clinical measurements. The index teeth of 10 volunteers (recalled to the clinic 2 days after initial examination) were re-examined by the same clinician. CBCT measurements were performed by the same two examiners at two different time points. Intraexaminer and interexaminer reliability tests for CBCT measurements were conducted.
Fig 1  
(a) Composite buttons were placed on the attached gingiva corresponding to each index tooth. (b) A plastic lip retractor was used to retract the cheek from the labial gingiva at the time of scanning. (c) A periodontal probe was inserted in a perpendicular direction through the hole of the composite button until resistance from the bone surface or the dental structure was felt. (d) The probe was removed with the composite button attached to it.

Fig 2  
Cross sections of a CBCT image used to obtain the measurements. (a) Gingival thickness measured from the central hole on the composite button to the bone or tooth surface (thickness = 1.11 mm; yellow line, perpendicular to the long axis of the tooth). (b) Labial bone fenestration (red arrow). (c) A dehiscence of 4.26 mm was observed.
Method Error Assessment (Accuracy)
A digital caliper accuracy assessment was performed before taking measurements for possible errors. The periodontal probe was mounted with the composite button set at a length of 2 mm, as defined by the standard probe calibrations. The distance between the composite button and the tip of the probe was repeatedly measured (10 times) with a digital caliper by the same clinician. The mean of the differences of the 10 measurements was calculated and used to estimate the bias, which was used as a measure of accuracy.

Statistical Analyses
Categorical data were presented as frequencies and percentages. Chi-square test of association was used to assess the different correlations. Numeric data were explored for normality by checking the data distribution, calculating the mean and median values, and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Parametric distribution was observed, and the data were presented as mean ± SD values. Method error assessment was conducted using one-sample t test, and differences between measurements were assessed using paired t test. Interrater, intrarater, and methods agreement were analyzed using intraclass correlation coefficient (ICC), which was interpreted as follows: < 0.40 = poor; 0.40 to 0.59 = fair; 0.60 to 0.74 = good; and ≥ 0.75 = excellent. The significance level was set at P ≤ .05 for all tests. Statistical analysis was performed using the R statistical analysis software, version 4.0.2, for Windows.

RESULTS
Method Error Assessment
No significant difference between the 10 measurements made using the digital caliper (2.00 ± 0.01 mm) and the actual measurement (2 mm) was noted in the present study (P = .468).

Intra- and Interexaminer Reliability
The interexaminer reliability of GT measurement using CBCT showed an excellent and statistically significant agreement between both observers (M.K. and S.A.; ICC = 0.931, P < .001). Additionally, there was complete agreement between both raters for the fenestration measurements (kappa = 1; P < .001), and the intrarater agreement with regard to the dehiscence defects was excellent (kappa = 0.924; P < .001).

Similarly, no significant difference between the first (1.07 ± 0.23 mm) and second (1.07 ± 0.23 mm) radiographic measurements of the GT was observed (ICC = 0.986; P < .001). Excellent intrarater agreements were reported for dehiscence (κ = 0.919; P < .001) and fenestration defects (κ = 0.929; P < .001). The ICC analysis demonstrated excellent intrarater agreement for clinical measurements of the GT (ICC = 0.986; P < .001).

Agreement Between Clinical and Radiographic Measurements of GT
The mean clinical measurement (1.12 ± 0.28 mm) was significantly higher than the mean radiographic measurement (1.07 ± 0.23 mm; P = .027), although the agreement between both measurements was excellent and statistically significant (ICC = 0.888; P < .001).

As shown in the Bland-Altman plot (Fig 3), the bias was 0.04 (95% CI: 0.01 to 0.08), the SD of the difference was 0.12, the lower limit of agreement was −0.18 (95% CI: −0.25 to −0.12), and the upper limit of agreement was 0.27 (95% CI: 0.2 to 0.34; Table 1).

Correlation Between GT and Labial Bone Defects
Fenestration. Fenestration was observed only in cases with thin gingival phenotype. A significant difference in the occurrence of a fenestration was noted between patients with thick and thin gingivae (P = .023).

Dehiscence. Dehiscence was detected in 22 (31.9%) cases with thin gingival phenotype and in two cases (4.8%) with thick gingival biotype; a significant difference in the occurrence of dehiscence was noted between thin and thick gingival phenotypes (P < .001; Table 2 and Fig 4).

DISCUSSION
The implementation of CBCT as a routine imaging tool in various dental fields has considerably increased over the past decade.25,41 Its use as a hard tissue imaging modality is well established, and its accuracy has been confirmed in multiple studies.24–26 However, the precision of CBCT for soft tissue measurements has been examined in a few studies,6,15,19,27,28 and only three among them were conducted in a clinical setting.

It is important to standardize the point of measurement when assessing the diagnostic accuracy of a certain methodology. In the present study, this was achieved using a composite button that was retained in place during both CBCT imaging and clinical measurements, thus assuring that both measurements were obtained from the same point (central hole of the button).

In a study comparing soft tissue thickness measurements obtained by three different modalities, Gürek et al19 used a punched Mylar matrix strip that was fixed onto the keratinized tissue with cement. The hole on the strip, which was created by piercing the center with a periodontal probe during transgingival probing, was filled with the same cement material. A rubber stopper mounted on the probe was used to demarcate the GT.
El Khaifa et al

CBCT imaging was performed while the Mylar strip and cement were fixed onto the keratinized tissue of the gingiva, and measurements were obtained from the undersurface of the cement in its central area to the bone. The use of a composite button as a stopper on the periodontal probe in the present study was thought to increase the accuracy of the measurements compared to the use of the rubber stopper in the study by Gürlek et al, where the thickness of the cement layer filling the hole in the strip was inevitably included in GT measurements.

A more laborious standardization method was used in a similar study by Borges et al, where a tomographic guide was fabricated using a silicone impression material. A diamond bur was used to mark areas 3 mm above the gingival margin of the teeth, which were then filled with a radiopaque material and used during CBCT scanning. During transgingival probing, the guide was placed in position, and a periodontal probe was used to pierce it and to mark a point on the gingival surface. Subsequently, the guide was removed, and a periodontal probe with a rubber stopper was used to measure the GT at the marked points. This standardization method was thought to be extremely tedious and harbored multiple sources of inaccuracy.

The mean GT values in the present study were 1.31 ± 0.26 mm for the central incisors, 1.15 ± 0.36 mm for the lateral incisors, and 0.89 ± 0.26 mm for the canines (a total of 60 sites with thin gingiva and 51 with

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Mean ± SD Clinical</th>
<th>Mean ± SD Radiographic</th>
<th>Mean difference (95% CI)</th>
<th>SEM</th>
<th>ICC (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor</td>
<td>1.31 ± 0.32</td>
<td>1.22 ± 0.27</td>
<td>0.09 (0.03, 0.16)</td>
<td>0.03</td>
<td>0.763 (0.537, 0.879)</td>
<td>.005*</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>1.15 ± 0.36</td>
<td>1.09 ± 0.31</td>
<td>0.06 (0.01, 0.10)</td>
<td>0.02</td>
<td>0.906 (0.809, 0.953)</td>
<td>.016*</td>
</tr>
<tr>
<td>Canine</td>
<td>0.89 ± 0.26</td>
<td>0.91 ± 0.24</td>
<td>−0.02 (0.07, 0.03)</td>
<td>0.02</td>
<td>0.849 (0.727, 0.919)</td>
<td>.365</td>
</tr>
<tr>
<td>Overall mean</td>
<td>1.12 ± 0.28</td>
<td>1.07 ± 0.23</td>
<td>0.04 (0.01, 0.08)</td>
<td>0.02</td>
<td>0.888 (0.781, 0.942)</td>
<td>.027*</td>
</tr>
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SEM = standard error of the mean; ICC = intraclass correlation coefficient.
*Significant (P ≤ .05).
thick gingiva). Similar results were registered in several studies\textsuperscript{33,42} and in the most recent consensus of the American Academy of Periodontology.\textsuperscript{7}

In the present study, high interexaminer reliability for all radiographic measurements was observed, with an ICC of 0.931 for GT measurement and a \( \kappa \) of 0.924 for bone defect measurement. Similarly, the intrarater reliability of both the radiographic and clinical measurements showed excellent agreement, with no significant difference between the first and second measurements.

Excellent agreement was observed with regard to the correlation between the clinical and radiographic measurements. The ICC values for the central incisors, lateral incisors, and canines were 0.763, 0.906, and 0.849, respectively, with an average ICC of 0.888. Despite the excellent agreement observed, the clinical measurements were significantly higher than the radiographic measurements with a mean difference of 0.04, and similar results were noted in several studies.\textsuperscript{6,15,19,27,28} It is important to note that the aforementioned studies were executed in a clinical setting, whereas dehiscence defects were exclusively associated with thin gingiva, whereas dehiscence defects were predominantly observed in cases with thin gingiva.

The search for clinical predictors of fenestration and dehiscence defects is of the utmost importance for surgical treatment planning. For example, the exposure of dehiscence defects during surgical procedures might harbor a risk of gingival recession due to the absence of crestal bone support. On the basis of the findings of the present study, it can be concluded that a thin gingival phenotype might be considered a clinical predictor of fenestration and dehiscence defects.
However, further research is highly recommended to establish this phenomenon.

Despite the positive results of the present study, it has some limitations. Additional clinical studies with a larger sample size are needed to confirm the findings. Comparisons between CBCT and other new digital methods, such as intraoral scanning and laser scanners, must be made. Additionally, the combination of these methods to assess GT should be investigated. The clinical impact of dehiscence defects on patients with a thin gingival phenotype needs to be evaluated in future prospective studies.

CONCLUSIONS

In the present study, CBCT demonstrated high diagnostic accuracy for GT measurements, with minimal discrepancies from the clinical assessment method. The presence of dehiscence and fenestration defects was positively correlated with the thin gingival phenotype.

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