Soft Tissue Cone-Beam Computed Tomography: A Novel Method for the Measurement of Gingival Tissue and the Dimensions of the Dentogingival Unit

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ABSTRACT

The dimensions and relationships of the structures of the dentogingival unit have been greatly overlooked because of the inability to easily and precisely determine them. The purpose of the present study was to develop a soft tissue cone-beam computed tomography (ST-CBCT) to improve soft tissue image quality and allow the determination of the dimensions and relationships of the structures of the dentogingival unit. Two separate CBCT scans were obtained from three patients with different periodontal biotypes. The first was a scan following standard methods; however, for the ST-CBCT the patients wore a plastic lip retractor and retracted their tongues toward the floor of their mouths. With the first scan, only measurements of the distance of the cementoenamel junctional (CEJ) to the facial bone crest, and the width of the facial alveolar bone were possible. In contrast, ST-CBCT allowed measurements of the distance of the gingival margin to the facial bone crest, the gingival margin to the CEJ, and width of the facial gingiva. ST-CBCT scans allowed a clear visualization, measurement of the dimensions, and analysis of the relationship of the structures of the periodontium and dentogingival attachment apparatus.

CLINICAL SIGNIFICANCE

The dimensions and relationships of the structures of the dentogingival attachment apparatus are essential aspects in many fields of dentistry and this report describes a simple, novel, and noninvasive technique to determine them. This technique may aid clinicians in the planning and execution of procedures in several dental specialties.

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INTRODUCTION

A major focus in esthetic dentistry today is the need for an interdisciplinary approach. With this idea in mind clinicians must carefully analyze a number of factors related to the patient's face, smile, teeth, and gingiva during the planning phase of esthetic cases.¹ The indication of periodontal plastic procedures to correct gingival contours, amount and thickness, amount of gingival display when smiling, as well as tooth display, have become common practice prior to esthetic rehabilitation of teeth. In these

*Private Practice, Brasilia, DF, Brazil [†]Assistant Professor, Department of Oral Radiology, School of Dentistry, Catholic University of Brasilia, DF, Brazil [†]Private Practice, Brasilia, DF, Brazil cases, interaction between the restorative dentist and the periodontist is essential to reestablish esthetics and function, respecting biological principles especially those associated with the structures of the dentogingival attachment apparatus.

The dimensions and the relationship of the structures of the dentogingival attachment were first described by Gargiulo and colleagues by studying human autopsy material.² On average the dimensions of what they called physiologic dentogingival unit were 0.97 mm for the junctional epithelium (JE), 1.07 mm for the connective tissue attachment, and a gingival sulcus depth that averaged 0.67 mm. The space over the tooth occupied by the JE and connective tissue attachment has also been known as biologic width.³ In humans, this distance is 2.04 mm on average. However, great variations in the dimensions of the structures of the biologic width were observed, particularly in the JE, which ranged from 1.0 mm to 9.0 mm.² These variations frequently make it difficult for the clinician to clinically determine the precise biologic width, particularly in cases of pre-prosthetic and esthetic crown lengthening. Furthermore, presurgical measurement of the biologic width is somewhat inconvenient for the patient, as it requires an invasive procedure

under local anesthesia known as bone sounding⁴ or transgingival probing.⁵

Another important consideration is the periodontal biotype. It is widely accepted that a number of gingival/ periodontal problems are more likely to occur in patients with a thin biotype.⁶ Moreover, treatment planning of restorative procedures and dental implants must take into account the periodontal biotype.^{7,8} Although a few classifications of the periodontal/gingival biotype have been proposed in the literature,^{9,10} these classifications are relatively subjective and observational. Generally, upon clinical examination the periodontal biotype is considered to be thinscalloped or thick-flat.11 A third type (i.e., a medium type) has also been reported.12 Müller and Eger applied an ultrasonic device to measure gingival thickness and to group individuals into three different gingival phenotypes.¹³ Although this device appears to be an effective method to assess gingival thickness,14 an overall overview of the gingival/periodontal structures and their relationship were not obtained.

In recent years, cone-beam computed tomography (CBCT) has been introduced for the image analyses of the maxillofacial region.¹⁵ CBCT technology offers high-quality diagnostic images for the clinician and has become an essential tool in dentistry. It has been reported that one of the shortcomings of CBCT is its inability to discriminate soft tissues that has rendered CBCT an exclusive tool for hard maxillofacial tissue imaging.¹⁶

In this study we describe a novel method based on CBCT technology called soft tissue CBCT (ST-CBCT) to visualize and precisely measure distances corresponding to the hard and soft tissues of the periodontium and dentogingival attachment apparatus. With this simple and noninvasive technique, clinicians will be capable of determining the relationships among structures of the periodontium such as the gingival margin and the facial bone crest, the gingival margin and the cementoenamel junctional (CEJ), and the CEJ and facial bone crest, as well as measuring the width of the facial and palatal/lingual alveolar bone and the width of the facial and palatal/lingual gingiva.

MATERIALS AND METHODS

Three patients undergoing dental treatment were selected for a CBCT scan according to their different periodontal biotypes. Written informed consent was obtained from the patients. The CBCT scans were taken with an iCAT (Imaging Sciences International, Inc., Hatfield, PA, USA), and the images were acquired with



Figure 1. A, Patient positioned for a regular cone-beam computed tomography (CBCT) scan. B, The same patient positioned for the second CBCT scan wearing the plastic lip retractor (soft tissue CBCT) in an inverted position to avoid hitting the chin stabilizer.

the iCAT software on a computer. The patients were seated with their chins and heads stabilized for the CBCT scanning. Figure 1A shows a patient positioned for the CBCT scanning. A scan was then taken of the maxilla (scan dimensions of 6×17 cm) for 40 seconds with the following setting of the iCAT—voxel size: 0.2 mm; gray scale: 14 bits; focal spot: 0.5 mm; image detector: amorphous silicon flat panel; image acquisition: single

360° rotation. The images were generated in XORAN files and saved in the patients' folders until analysis. Following this first CBCT scan, a second scan was performed of the same region on the same patient with the same settings as described earlier. However, at the time of this second CBCT scanning, the patients were asked to wear a plastic lip retractor and to retract their tongues toward the floor of their mouths. This approach was called ST-CBCT. Figure 1B shows the patient wearing the plastic lip retractor for the second CBCT scanning. With these procedures, the soft tissues of the lips and cheeks were positioned away from the gingival tissue and the tongue remained lower in the oral cavity. The images of this second scan were saved in the same manner as described earlier. Images of the upper right central incisor were analyzed with the



Figure 2. A, Clinical intraoral picture of a patient with a medium periodontal biotype. B, Image of the cone-beam computed tomography (CBCT) scan taken without the lip retractor showing that the lip (L) collapses onto the facial aspect of the tooth and that the tongue (T) completely occupies the oral cavity. C, Image of the soft tissue CBCT scan showing a dark space (asterisks) on the facial and palatal/lingual aspects allowing the clear visualization of the facial (arrow) and palatal (arrowhead) gingiva.

iCAT software by the same radiologist. The measurement of the distance of the facial bone crest to the CEJ was performed on images of the first scan, whereas measurements of the distance of the facial bone crest to the gingival margin and distance of the CEJ to the gingival margin were performed on images of the second scan. These measurements were performed on the facial aspect of the tooth parallel to the long axis of the same tooth. The thickness of the facial bone (first scan) and facial gingival thickness (second scan) were also measured, and in this case, these measurements were performed perpendicular to the tooth surface.

RESULTS

Figure 2A shows a clinical intraoral picture of a patient with a medium periodontal biotype.

Figure 2B shows the image of this patient's upper right central incisor representing the first (without soft tissue retraction) CBCT scan. Figure 2C shows the image of the same tooth taken with soft tissue retraction (ST-CBCT). A marked difference can be noted in terms of clarity of the images and ease of identifying structures when the two scans are compared. By retracting the soft tissues of the lip, cheeks, and tongue away from the gingiva in both facial and palatal aspects, there is an evident dark space created between these structures. This dark space is not present on the image of the first scan because it is occupied by the lip and cheek that collapse onto the facial gingiva and prevent the clear visualization of the facial gingival tissue. Likewise, the tongue placed lower toward the floor of the

mouth allowed a clear visualization of the palatal gingiva.

Figures 3A and 4A show clinical intraoral pictures of patients with periodontal biotypes that are considered thin and thick, respectively. Figure 3B (without soft tissue retraction) and 3C (with soft tissue retraction) show the CBCT scan of the upper right central incisor of the patient with a thin biotype. Figure 4B (without soft tissue retraction) and 4C (with soft tissue retraction) show the CBCT scan of the upper right central incisor of the patient with a thick biotype. Although the tongue in Figure 4C was not retracted enough at the time of the scan, this image is clearer than the one on Figure 4B.

In order to demonstrate the possibility of a few measurements, the



Figure 3. A, Clinical intraoral picture of a patient with a thin periodontal biotype. B, Image of the cone-beam computed tomography (CBCT) scan taken without the lip retractor. C, Image of the soft tissue CBCT scan (arrow: facial gingiva, arrowhead: palatal gingiva). L = lip; T = tongue.



Figure 4. A, Clinical intraoral picture of a patient with a thick periodontal biotype. B, Image of the cone-beam computed tomography (CBCT) scan taken without the lip retractor. C, Image of the soft tissue CBCT scan (arrow: facial gingiva, arrowhead: palatal gingiva). L = lip; T = tongue.

image in Figure 4B (without soft tissue retraction) was selected for the following measurements: distance of the facial bone crest to the CEJ (Figure 5A), and thickness of the facial bone (Figure 5B). On the other hand, when the image in Figure 4C (with soft tissue retraction) was subjected to measurements, we were able to obtain the same measurements as those from Figure 4B as well as measurements of the relationship of soft and hard tissues, such as the facial gingival thickness (Figure 6A), the distance of the facial bone crest to the gingival margin (Figure 6B), and the distance of the CEJ to the gingival margin (Figure 6C). In fact, the measurement in Figure 6B represents the biologic width of this patient, which had not been possible to be measured to date by a noninvasive technique.

DISCUSSION

In the present report we describe a novel, noninvasive, CBCT-based technique to visualize, measure the dimensions, and analyze the relationship of several structures of the periodontium and dentogingival attachment apparatus. This simple method called ST-CBCT has ample application in several dental specialties such as periodontology, implant dentistry, orthodontics,



Figure 5. A, Measurement of the distance of the facial bone crest to the cementoenamel junction performed on the image of the patient with a thick periodontal biotype (without lip retractor). Dotted line represents the long axis of the tooth. B, Measurement of the thickness of the facial bone. L = lip; T = tongue.

prosthodontics, and operative dentistry. Furthermore, this method helps dentists of different specialties to better communicate for an interdisciplinary approach. It is important to mention that this is a quantitative method and not a qualitative one, because discrimination of specific macro and microscopic characteristics of the tissues cannot be visualized. For example, an inflamed gingiva would have a similar appearance on the ST-CBCT scans as a healthy gingiva. Similarly, it is not possible to distinguish different types of soft tissues (i.e., gingival epithelium and gingival connective tissue exhibit the same appearance on the ST-CBCT scans).

The clear visualization of both soft and hard periodontal structures was possible by conducting CBCT scans with soft tissue retraction. We have selected the upper right central incisor for the measurements; however, the same procedure can be applied for all teeth in the dentition providing that the soft tissues of the lips, cheeks and tongue are properly retracted. To date, CBCT without soft tissue retraction has been extensively used in dentistry for hard tissue imaging.^{15,17} We noticed that the soft tissues of the lips and cheeks collapse onto the facial gingiva and the tongue occupies most of the space of the oral cavity, thus completely preventing the visualization of the soft tissues of the periodontium. Despite the fact that several CBCT systems have recently become available,^{17–19} one of the



Figure 6. A, Measurement of the thickness of the facial gingiva performed on the image of the patient with a thick periodontal biotype (soft tissue cone-beam computed tomography scan). B, Measurement of the distance of the gingival margin to the facial bone crest. C, Measurement of the distance of the gingival margin to the cementoenamel junction. Dotted lines represent the long axis of the tooth.

greatest limitations of these systems is their inability to discriminate soft tissues. Kobayashi and collegues reported that this limitation of a particular CBCT system was due to its low contrast resolution.²⁰ Nevertheless, for the scans performed in the present study we utilized the iCat system, which is a commercially available and commonly used system. Although we have not compared the capabilities of different CBCT systems to scan soft tissues of the periodontium when soft tissue retraction is applied, it is likely that other systems will perform similarly to the iCat.

A few reports have described different techniques to measure gingival thickness and distances between structures of the periodontium.^{13,21-23} Bone sounding⁴ or transgingival probing²⁴ have been widely applied for these purposes; however, this method is inconvenient for the patient because it is invasive and must be performed under local anesthesia. Furthermore, it is sometimes difficult to precisely determine the position of a few structures such as the CEJ and the bone crest. Alpiste-Illueca developed an interesting radiograph-based technique called parallel profile radiograph to determine the dimensions of the dentogingival unit.23 However, our method provides a higher quality image, allows a clear visualization of the gingival tissue, and, because of the nature of the CBCT scan, is easily reproducible. Furthermore,

the patient only needs to wear a regular plastic lip retractor during the CBCT scan. Müller and colleagues have extensively applied an ultrasonic measuring device to determine gingival thickness.^{13,21,22} They reported difficulties in obtaining reliable measurements of gingival thickness in different parts of the oral cavity and suggested averaging of repeated measurements to overcome this problem.²¹ In contrast to transgingival probing and the ultrasonic device, our method provides an image of the tooth, gingiva, and other periodontal structures. Moreover, measurements can be repeatedly taken at different times with the same image obtained by ST-CBCT, which is not feasible by other methods. These measurements can

be reliably performed either by means of a software or directly on the scan print, because it has been reported that images obtained by CBCT scanning maintain an aspect ratio of 1:1.^{25,26}

In summary, we describe a novel, noninvasive, and powerful method to obtain clinical data regarding the dimensions and relationship of several structures of the periodontium and dentogingival attachment apparatus. This method will certainly aid clinicians in the planning and execution of a number of procedures in dentistry with increased predictability.

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