Soft Tissue Thickness Determination Using CBCT in Diverse Medical Disciplines

ABSTRACT

Accuracy of facial soft tissue thickness has been an important step in formulating a treatment plan for various procedures in the field of oral, maxillofacial health care as well as forensic science. There are various methods to measure soft tissue thickness but accuracy of these methods is questionable till date. The aim of this article is to make people aware of the new technology i.e., cone beam computed tomography (CBCT) its role, accuracy and its reliability in measuring the thickness of the facial and oral soft tissues, which will further help in improving the treatment plan followed by better results. Therefore, we conducted online searches and with all kinds of evidence exists we have provided the readers an overview on this new imaging modality in measuring the thickness on various soft tissue landmarks. Using routine scanning protocols we found out that cone beam CT images are reliable for measuring soft tissue thickness in the orofacial region and give a good representation of the orofacial soft tissues.

KEYWORDS CBCT, 3D technique, soft tissue thickness, facial reconstruction, facial asymmetry, gingivay

INTRODUCTION

Since decades there are a lot of studies on measuring the soft tissue of the maxillofacial region which included manual techniques, two-dimensional (2D) techniques and three-dimensional (3D) technique (CBCT) technique. The manual techniques like the use of needles and periodontal probes have been documented since 1970s1–4. However, these approaches have been criticised as these techniques are invasive and their reliability is questionable1. Then came the 2D techniques which supports all aspects from diagnosis and treatment planning to assessing outcome and seem to hold obvious appeal over direct measurements of moving subjects5–9, but 2D image techniques have many disadvantages like measurement errors due to subjective analysis, magnification errors, parallax, variation in lighting, variation in head orientation and errors in projection10–12, also the amount of information gained from conventional or digitally captured plain radiographs is limited as the 3D anatomy of the area being imaged is compressed into a 2D image. 2D radiographs reveal limited aspects of the 3D anatomy because of superimposition which requires, several times, combination of different conventional plain films. These problems can be easily overcome by the use of 3D imaging techniques that can quickly produce 3D images of involved structures and surrounding tissues1. Cone beam computed tomography (CBCT) systems have been developed specifically for the imaging of the maxillofacial region13–16. The benefits of 3D medical computed tomography (CT) are well established in many dental specialties17. For example, several studies have supported the use of CBCT for facial reconstruction17–28, facial asymmetry analysis29–44, peri implant graft procedure45, sites for the placement of temporary anchorage devices (TADs)1–45, etc. All the procedures mentioned above needs to measure the soft tissue thickness.

CBCT USED FOR FORENSIC FACIAL RECONSTRUCTION

The main purpose of any forensic facial approximation is to recreate the face of a deceased individual at the time of death based on his/her skull. The most extensive and detailed post-mortem data are useless without any

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link to the ante-mortem data. In these cases, forensic facial approximation can be considered as a last resort to identify the deceased\textsuperscript{9–11}. Forensic facial reconstruction of faces on skulls is attempted for the purpose of individual identification\textsuperscript{10,11}. For correct facial reconstruction of the human face it is necessary to know the average facial soft tissue thickness of specific sites on the face. This requires establishing a database of soft tissue thickness related to age, sex, race and ethnicity\textsuperscript{11}. This facial thickness then is used as a guide to reconstruct the face. The soft tissues are duplicated on the skull or a model of the skull by the use of modeling clay\textsuperscript{12}. Since the first attempts in the late 19\textsuperscript{th} century, manual or computer-aided reconstruction techniques have been developed\textsuperscript{11,13–17}. There are two basic methods\textsuperscript{11,18–20} of modelling faces: a morphoscopic method using an anatomical approach of reconstructing the musculature, fat and skin\textsuperscript{11,13,18,19} and a morphometric method which rests heavily on the idea of measuring the average facial soft tissue depth measurements that have been gathered by various researchers\textsuperscript{10,11,13,18,19,21}. Methods employed to measure facial tissue thickness are needle puncturing on cadaver\textsuperscript{10,22,23}, lateral cranial radiographs\textsuperscript{10,24} and ultrasonic probing\textsuperscript{10,25}. Magnetic resonance imaging (MRI) and computerised tomography (CT) scanning have also been used\textsuperscript{10}. Needle puncturing on a cadaver is not an accurate method due to tissue deformation after post-mortem changes such as dehydration and shrinkage, as well as the deformation of tissue while puncturing\textsuperscript{10,12}. Fourie et al. have suggested that CBCT images can be used to derive accurate measurements that can establish a database for soft tissue\textsuperscript{11}. Farman et al. reported that the soft tissue definition with CBCT is sufficient to determine air-/soft boundaries, including the patient’s lateral profile, greater clarity of soft tissue definition could improve the assessment of bulk and insertion patterns of the maxillofacial musculature\textsuperscript{11,26}. Moerenhout et al. used phantom heads to determine the 3D surface accuracy of soft tissue acquired form a CBCT scan of a mannequin head and using two commercial 3D image processing software programs, they found that 3D surface of the facial soft tissues segmented and reformatted from a CBCT scan proved to be accurate\textsuperscript{11,27}. Heiland et al. stated that integration of flat panel detectors in mode CBCT systems results in an improved visualisation of soft tissues in cadavers. CBCT visualises high-contrast in sufficient quality with a remarkable low level of metal artefacts. However, they stated that the image quality of corresponding CT and MRI proved to be superior in most of the evaluated criteria\textsuperscript{11,28}. The 0.3-mm slice thickness gives an accurate data collection of the soft tissue. For more fine and accurate data collection of the facial soft tissue thickness form the CBCT, the 0.3 voxel size scan is recommended\textsuperscript{11}. The results of the study by Fourie Z et al. suggest that CBCT images of the face using routine scanning protocols are a reliable method of measuring the soft tissue thickness in the facial region and give a good representation of the facial soft tissues. His study confirmed that CBCT soft tissue measurements are accurate for establishing a soft tissue thickness database for any population. Kim et al. found the same with the MRI in 2005\textsuperscript{11,18}.

**CBCT USED FOR FACIAL ASSYMETRY ON SOFT TISSUE REFERENCE USING CBCT**

Facial appearance and esthetics has become the main motto for an individual nowadays. Although the soft tissue morphology is known to reflect the underlying hard tissue structure, the hard tissue structure may not be fully expressed on the soft tissue images. The soft tissue may compensate for this asymmetry or be more asymmetric\textsuperscript{29–31}. The aim of orthodontic and surgical treatment of patients is to achieve not only an ideal occlusion, but also, more significantly, a harmonious facial appearance\textsuperscript{31,32}. Patient satisfaction with treatment decision making and treatment outcomes is determined subjectively\textsuperscript{33,34}. Moreover, a patient and his or her family evaluate the success of the orthodontic treatment or orthognathic surgery mainly by visual cutaneous changes\textsuperscript{31}. However, the results of cephalometric analysis of skeletal asymmetry may differ from the results of soft tissue analysis\textsuperscript{14,35}. In other words, although skeletal asymmetry exists, it may be disguised by the soft tissues, or even though a face may possess skeletal symmetry, it could be asymmetric because of asymmetric soft tissues. Accordingly, considerations of the soft tissues are as important as those of the hard tissues when diagnosing facial asymmetry\textsuperscript{10,35}.

Since the external appearance of asymmetry is of great importance for patients and essential for treatment planning, the soft tissue features of facial asymmetry, need to be evaluated\textsuperscript{11}. Accurate judgement of the degree of asymmetry is necessary when diagnosing and planning treatment for facial asymmetry, because the prescribed treatment will vary depending on the recognition of the severity of the asymmetry and the symptoms of facial asymmetry\textsuperscript{15}. Severt and Proffit\textsuperscript{36} found that the frequencies of asymmetry were 5\% in the upper face, 36\% in the middle face and 74\% in the lower face. Farkas et al.\textsuperscript{37} found that the incidence of periorcular asymmetry was less than 2\% in the normal population and that the periorcular tissues were more symmetric than the nose (7\%) or mouth (12\%)\textsuperscript{35}. There are several studies conducted to diagnose facial asymmetry using CBCT and CT. Studies have reported that the linear accuracy of CBCT was similar to that of CT\textsuperscript{18,19}. The mean difference between the actual measurement on the skull and measurement on CT was 0.83% in the study by Cavalcanti and Vannier\textsuperscript{18} and −1.13 ± 1.47% in the study of Perigo et al\textsuperscript{19}. The accuracy of the linear measurement on CBCT was acceptable for 3D facial analysis\textsuperscript{18}. 3D cephalometry has the potential advantage of being able to better detect and localise existing asymmetries. However, quantification of asymmetries using
3D cephalometry heavily depends on the operator’s understanding of 3D landmark definition and the ability to reproduce reliably those landmarks. Study by Hwang et al. reported that overall differences between right and left side were determined not only by transverse differences but also by sagittal and vertical differences, indicating that 3D evaluation would be essential in the facial soft tissue analysis. To judge the soft tissue asymmetry in individuals there are a some aspects that should be taken care of like reorientation of the image and selection of the reference plane. Image reorientation is a critical step because the midsagittal reference plane is determined by appropriate reorientation, and quantitative judgements of right and left facial asymmetry can be done using this reference plane as 3D CBCT enables reorientation using software, avoiding the need for physical restraints unlike conventional cephalometric imaging studies, a cephalostat, such as an ear rod or head holder, was used to standardise subject positioning. Study by Lee et al. have reported that the inclusion of soft tissue landmarks, especially those around the eye, in an analysis of facial asymmetry provides an effective means of establishing an appropriate facial midline in 3D CBCT image reorientations.

**CBCT USED TO MEASURE GINGIVA**

Esthetics is one of the major concerns of patients. Clinicians must carefully analyse a number of factors related to the patient’s face, smile, teeth and gingiva during the planning phase of esthetic cases. 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 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. There are various methods of measuring the gingival thickness like transgingival probe, ultrasonic method and bone sounding technique. The dimensions and the relationship of the structures of the dentogingival attachment were first described by Gargiulo et al. by studying human autopsy material. 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. 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. 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 anaesthesia known as bone sounding or transgingival probing. Müller and Eger applied an ultrasonic device to measure gingival thickness and to group individuals into three different gingival phenotypes. Although this device appears to be an effective method to assess gingival thickness, an overall overview of the gingival/periodontal structures and their relationship were not obtained. In recent years, CBCT has been introduced for the image analyses of the maxillofacial region. CBCT technology offers high-quality diagnostic images for the clinician and has become an essential tool in dentistry. This novel method for measuring the gingival tissue and dimensions of dentogingival unit is based on CBCT technology called soft tissue CBCT (ST-CBCT), to visualise 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 are able to determine the relationships between Gingival margin and the facial bone crest, gingival margin and the cemento-enamel junction (CEJ), and CEJ and facial bone crest.

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 visualised. 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 visualisation of both soft and hard periodontal structures is possible by conducting CBCT scans with soft tissue retraction, as soft tissues of the lips and cheeks collapse onto the facial gingival and the tongue occupies most of the space of the oral cavity, thus completely preventing the visualisation of the soft tissues of the periodontium. Kobayashi et al. reported that this limitation of a particular CBCT system was due to its low contrast resolution. Müller et al. have extensively applied an ultrasonic measuring device to determine gingival thickness, 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. In contrast to transgingival probing and the ultrasonic device, ST-CBCT 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.
CBCT USED FOR PALATAL THICKNESS

Assessment of the thickness of the palatal masticatory mucosa is required for treatment planning of periodontal and peri-implant graft procedures\(^4,5,35\). Harvesting a graft of even thickness is essential, for a thinner graft (<0.7 mm) which has a strong tendency to shrink\(^45\). Mucosal thickness in the mid-palatal region is also important for orthodontic temporary anchorage devices (TADs) because thinner mucosa provides a more stable base for the TAD implantation\(^35,54\). In the past, palatal mucosal thickness has been measured using several methods. Physical measurement methods include bone sounding using endodontic reamer\(^45,57\) and periodontal probe after local anaesthetic administration\(^45,58\). An ultrasonic measurement is less invasive and easy to perform; however, it is technique-sensitive and less reliable, especially in thick areas\(^45,53\). Study by Lawson and Jones\(^59\) found that the ultrasonic technique was completely unreliable when mucosal thickness exceeded 6 mm because of the attenuation of the signal in the tissues and reflection artifacts from adjacent structures when assessing undulating anatomy such as high palatal vault. Recently, CT has been introduced for measuring thickness of oral mucosa\(^45,60,61\). A major disadvantage with the use of CT is high radiation dose during its operation\(^45,62\). With a lower output and a shorter exposure time, CBCT provides an accurate hard tissue assessment with a reduced radiation dose\(^45,63\). For these reasons, CBCT is now the most commonly used imaging modality for implant assessment\(^53,64\). Barriviera et al.\(^65\) reported palatal mucosal measurement using CBCT. CBCT provided an accurate assessment on mucosal tissue thickness, with the measurement value being very similar to previous reports that employed physical measurement\(^2,45,58\). Its potential drawbacks include higher image noise and lower contrast resolution from scattered radiation\(^1,66\). In a study by Ueno et al.\(^60\) assessment on the accuracy of spiral CT in oral mucosal thickness measurement showed a relatively high correlation between physical measurement and CT except for the thin mucosa. In a study by Dvorak et al.\(^67\) evaluating buccal mucosa with CT, physical and CT measurements were similar (1.17 ± 0.31 mm versus 1.11 ± 0.31 mm). Study by Ueno et al.\(^65\) on measurement of palatal mucosal thickness using CBCT have reported that palatal mucosal thickness were either consistent or gradually increased from anterior to posterior, except for first molar where mucosal thickness decreased. A positive correlation was also observed between mucosal thickness and distance from the gingival margin\(^15,61,65,68\). The stability of TADs in the palate depends on both the quantity and the quality of the soft and hard tissues\(^3,69,70\). Therefore, for maximum retention and minimum inflammation, the desirable profile of a successful TAD placement site is thicker cortical bone underlying thinner attached gingival tissue\(^3\). In a study by Vu et al.\(^3\) investigation is that the midpalatal suture and its adjacent areas have thinner soft tissue coverage regardless of gender, age and the AP position. These results may help clinicians to select an appropriate TAD design, especially for the tissue collar or neck part, for better soft tissue adaptation, reduced inflammation and greater success. The accuracy of CBCT for both soft tissue and bone thickness measurements in the maxillary anterior region has recently been confirmed, and a simple technique is now available for assessing the thickness of the palatal masticatory mucosa by CBCT\(^53,7,47\).

CONCLUSION

To conclude, continued development associated with earlier imaging modalities has led us to the current state of knowledge in respect to CBCT and its applications in soft tissue measurements as described in this review. CBCT is a viable tool for measurement of oral and facial soft tissue thickness, its high spatial resolution, reduced radiation exposure, affordability, lower acquisition and maintenance has made it a good imaging tool for maxillofacial region. CBCT has a number of advantages over other methods of soft tissue thickness measurement like increased speed of data collection, less invasiveness and the ability to obtain a 3D archive of the subject’s facial morphology. CBCT will certainly aid clinicians in the planning and execution of a number of procedures in dentistry with increased predictability. Continuous improvement of current techniques with development of new techniques, is mandatory to achieve new horizons in the applications of CBCT.

REFERENCES


