Assessment of cone-beam computed tomography accuracy for taking intraoral soft tissue linear measurement

Aya Mohamed Ahmed Hassanine[1*], Maha Ishak Amer[2]

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ABSTRACT
Radiological diagnosis of the oral cavity is challenging because of the proximity of osseous structures with soft tissues. The assessment of intra-oral soft tissue during the examination of oral and maxillofacial radiographs is crucial for dental purposes, such as surgical correction after trauma or in the case of anatomical or developmental deformities, periodontal therapy, orthodontic treatment, restorative procedures, dental implant treatment. In addition, it is significant for the diagnosis of incidental finding of the soft tissue of the oral cavity as a metastatic oral soft tissue lesion.

1. Teaching assistant at oral radiology department, faculty of dentistry, Minia university, Minia, Egypt
2. Professor of oral radiology, faculty of dentistry, Minia university, Minia, Egypt
[*]**Corresponding author contact mail:** Aya.mohamed@minia.edu.eg; Ayatony82@gmail.com

INTRODUCTION

Radiological diagnosis of the oral cavity is challenging because of the proximity of osseous structures with soft tissues. The assessment of intra-oral soft tissue during the examination of oral and maxillofacial radiographs is crucial for dental purposes, such as surgical correction after trauma or in the case of anatomical or developmental deformities, periodontal therapy, orthodontic treatment, restorative procedures, dental implant treatment (1). In addition, it is significant for the diagnosis of incidental finding of the soft tissue of the oral cavity as a metastatic oral soft tissue lesion.

CBCT has become a leading imaging modality in diagnostic radiology of oral and maxillofacial areas due to its potential to obtain images with subjects in the upright position. It provides the radiologists with high-resolution images while exposing the patient to less ionizing radiation than multislice CT, is clinically acceptable, and has high precision regarding all linear, angular, and volumetric measurements of hard tissue with an accuracy of 1.0 mm (1, 2, 3). However, the primary limitation of CBCT imaging is the inability to distinguish between tissue attenuation differences due to poor soft tissue contrast. This limited contrast resolution hinders the expansion of CBCT technologies into diagnostic imaging, where the detection of small changes in soft-tissue attenuation is a priority (4).

Recently the use of CBCT for accurate reproduction of linear dental and hard tissue measurements has garnered considerable attention (5). Several studies have measured the thickness of soft tissue in patients using CBCT. For instance, the thickness of palatal soft tissue was measured in order to place temporary anchorage devices at the correct sites in orthodontic patients (6). In forensic medicine, the reliability of facial soft tissue thickness obtained by CBCT was evaluated for craniofacial reconstruction (7, 8). Moreover, in implant dentistry, soft tissue thickness was investigated prior to planning esthetic crown lengthening procedures and for evaluating periodontal soft tissues(8). Other studies that evaluated the thickness of soft tissue in CBCT in comparison to gingival probing depth (7, 9) demonstrated that CBCT is an effective diagnostic method for visualizing and measuring the thickness of soft tissues.

However, it has also been suggested that dental CBCT does not provide ideal images of soft tissues and that alternative examinations should be performed, such as medical grade CT or magnetic resonance imaging (MRI). The aim of this study was to evaluate the role of CBCT in measuring oral soft tissue thickness.

MATERIALS AND METHODS

The present study was approved by The Research Ethics Committee of the Faculty of Dentistry, Minia University, Minia, Egypt. A sample of seven (5 dry mandible and 2 mandibular models) were obtained from Department of Anatomy, Faculty of Medicine, Bani suef University , Egypt.

Because mandible is an open volume, differing from a skull, and for this reason, more sensitive to any geometrical distortion (10) we decided to make our study only on mandible

Double layer of pink base plate wax was added as a soft tissue simulant. In numerous studies, base plate wax is approved for the simulation of soft tissue.

(9) The wax was adapted carefully to ensure that it was added uniformly without voids or air bubbles **(Figure1).**

A total of 21 different locations were selected. seven holes were located at posterior right side of the mandible. Seven holes were located in the anterior area. Seven holes were located in the posterior left side. The stopper was placed parallel to the wax surface and the length of the spreader till the stopper was measured using a digital caliper to present the physical measured thickness of the pink baseplate wax.

The mandibles were scanned by Pax -i3D green CT CBCT machine (VATECH, KOREA). On field of view 8 x 5 mm ,85 Kvp , 10 mA. EZ 3D plus software used. Using MPR views after slice preparation, the soft tissue thickness was measured just at the created holes . The software automatically displayed the thickness measurements in millimeters, which were recorded for further analysis. These steps were repeated for each region with a total number of 21 measurements in the mandible. **(Figure 2)** After that, measurements compared to the physical measurement on the mandibular models which taken by a digital caliper.

Sample size

Sample size used in this study is small but it is acceptable in terms of invitro studies and in accordance with other similar studies.(11, 12, 13, 14).

STATISTICAL ANALYSIS

The statistical analysis was performed using the R software (R Core Team 3.3.1, the R Foundation for Statistical Computing). Descriptive analysis (Mean, standard deviation ,Median and interquartile range) of both CBCT and physical measurements for all different measurement categories were calculated.

For comparison between CBCT and physical measurement groups, Non parametric Wilcoxon Signed Rank test was used . The significance level was set $\alpha = 0.05$.

RESULTS

Descriptive analysis for all measurements in different groups (Mean, Median, Standard deviation and Interquartile range) were calculated in **table (1)** which shows that all CBCT measurements are higher than the real measurement as follows**:**

- **Right posterior measurement:** The mean CBCT measurement is 2.88 (±0.47) mm which is higher than the gold standard (2.13 ±0.19 mm).
- **Anterior measurement:** The mean CBCT measurement is 3.03 (±0.5) mm which is higher than the gold standard (2.33 ±0.47 mm).
- **Left posterior measurement:** The mean CBCT measurement is 2.56 (±0.28) mm which is higher than the gold standard (2.21 ±0.39 mm).

All CBCT measurements show overestimated Median **(Figure 3).**

Statistically significant difference was present between all CBCT measurements and the physical measurement obtained from the digital caliper as shown in **table (2).**

- **Right posterior measurement:** The absolute difference in measurement between CBCT and the gold standard is 0.75 (±0.49) mm, which means that the CBCT measurement is 24.47% higher than that of the gold standard. The Wilcoxon Rank Sum test results show that this difference is statistically significant (p-value<0.05).
- **Anterior measurement:** The absolute difference in measurement between CBCT and the gold standard is 0.7 (±0.54) mm, which means that the CBCT measurement is 22.05% higher than that of the gold standard. The Wilcoxon Rank Sum test results show that this difference is statistically significant (p-value<0.05).
- **Left posterior measurement:** The absolute difference in measurement between CBCT and the gold standard is 0.34 (±0.21) mm, indicating that the CBCT measurement is 13.72% higher than that of the gold standard. The Wilcoxon Rank Sum test results indicate that this difference is statistically significant (p-value<0.05).

Figure 1: show all dry mandibles covered by pink wax for soft tissue simulation.

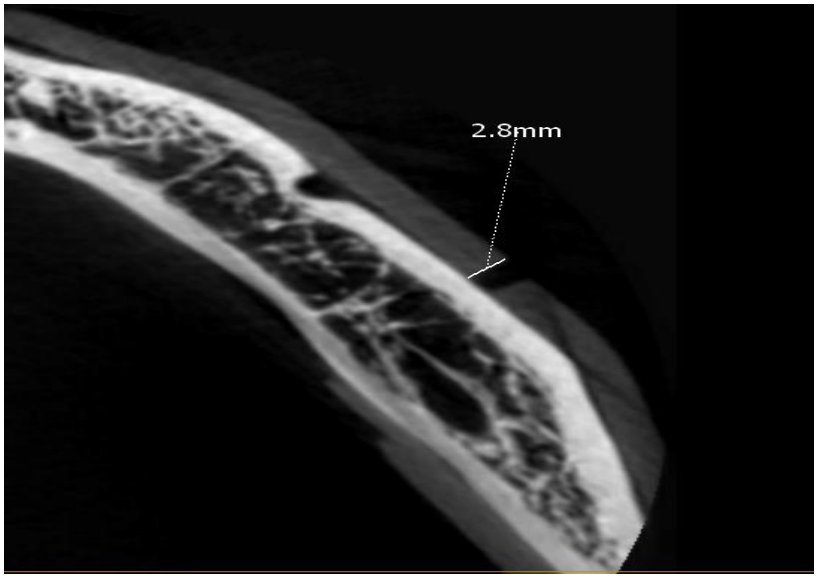

Figure 2: The thickness of simulated soft tissue measured on the CBCT axial cut of one of the mandibular models using EZ3D- I linear measurement tool.

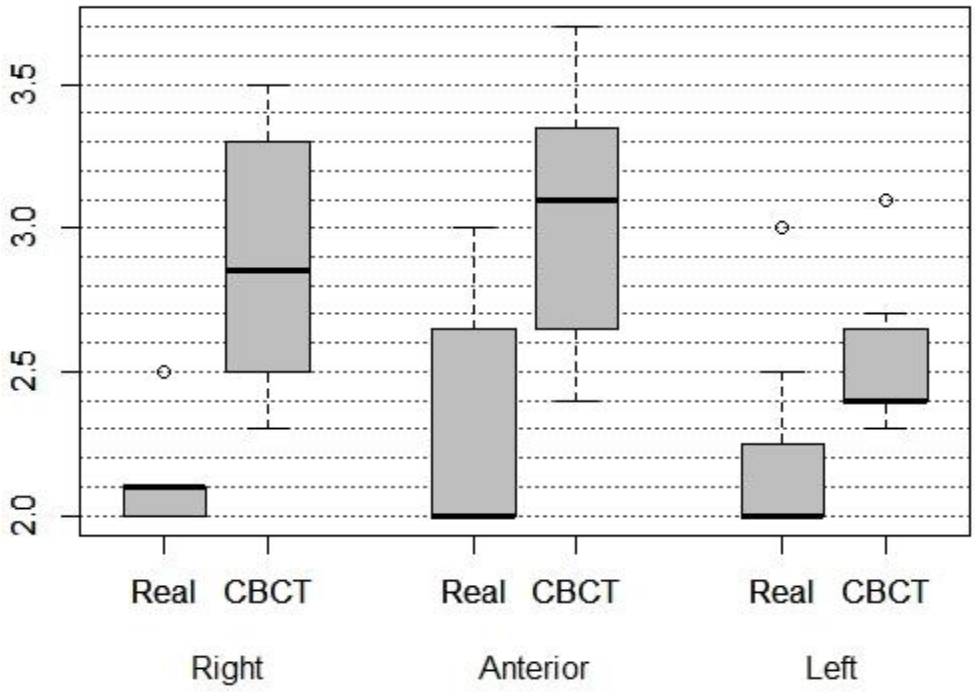

Figure 3: Box plot showing how CBCT measurements in different groups are overestimated in comparison to physical measurement (gold standard) on the mandibular model.

Table (1): Descriptive analysis of soft tissue thickness regarding each group:

		Mean	SD	Median	Interquartile Range
Right	**CBCT**	2.88	0.47	2.1	2.55 – 3.23
	Gold Standard	2.13	0.19	2.85	2.03 – 2.1
Anterior	**CBCT**	3.03	0.50	2	2.65 – 3.35
	Gold Standard	2.33	0.47	3.1	2 – 2.65

Left	**CBCT**	2.56	0.28	2	2.4 – 2.65
	Gold Standard	2.21	0.39	2.4	2 – 2.25

Table (2): Absolute and Relative difference between CBCT and Gold standard measurements regarding soft tissue thickness and results of the between-group comparison:

	Absolute Error		**Relative (Percentage) Error**		**Wilcoxon Rank Sum test for paired data**	
	Mean	**SD**	**Mean**	**SD**	**p-value***	**Interpretation**
Right measurement	0.75	0.49	24.47	12.76	0.0355	Statistically significant difference
Anterior measurement	0.7	0.54	22.05	15.63	0.0223	Statistically significant difference
Left measurement	0.34	0.21	13.72	7.99	0.0213	Statistically significant difference

**Significance level at p-value ≤0.05.*

DISCUSSION

CBCT is a commonly used imaging technique for dental implant planning and other pre-operative examinations. In recent years, numerous attempts have been made to determine the accuracy of CBCT measurements of soft and hard tissues. CBCT accurately measures the linear dimensions of hard tissues, such as the mandible (5), and assesses periodontal defects (15).

Because of the low-density resolution and contrast of CBCT, qualitative evaluation of soft tissues has been limited. However, CBCT has been proven beneficial for quantitative linear measurements. The combination of CBCT and digital 3D reconstruction technology can also obtain high measurement accuracy (16).

Most previous studies compared the measurement accuracy of CBCT with that of other methods as the study of Patcas et al., who compared the accuracy of CBCT and multidetector CT in the measurement of hard tissues and verified the effectiveness of CBCT in measuring oral soft tissues. They illustrated that CBCT was less affected by metal artifacts and that the accuracy of intraoral soft tissue measurements using CBCT was comparable to that of hard tissue measurements (17), but few studies have examined the accuracy of soft tissue measurements using CBCT.

Fourie et al. demonstrated the accuracy of CBCT measurements of facial soft tissue by measuring benchmarks on cadaveric heads for extra-oral soft tissue measurement. There was no clinically significant difference between the measurements made on the CBCT images and the physical measurement**.** Compared to physical measurements, the cone beam computed tomography measurements were highly accurate (0.962 to 0.999). They considered the mean absolute error clinically significant if it exceeded 1.5 mm, which is unsuitable for oral mucosal measurement (18, 19).

Regarding the intra-oral soft tissue measurement, A systematic review of the accuracy of linear measurement in CBCT images revealed a wide range of errors, with no clear trends indicating whether measurements are consistently underestimated or overestimated relative to the gold standard (20).

Januario et al. exposed the buccal gingiva using soft tissue using retraction to overcome the interference that occurs when the lips, tongue, and cheeks collapse on the facial gingiva during CBCT scanning. They demonstrated that CBCT is effective in soft tissue measurements (21).

In a study by Moudi et al. (1), different thicknesses of pink baseplate wax were applied to a dry human skull. The skull was scanned using two CBCT scanners with 0.01- and 0.15-mm voxel sizes. Results showed no significant difference between CBCT and digital caliper measurements in thickness less than 2.0 mm, while a significant difference was observed for thicknesses greater than 2.0 mm ($P < 0.05$).

In this study, there was a statistically significant difference between all groups and the gold standard with a mean absolute error ranging from 0.3 to 0.7 mm with a tendency of CBCT to overestimate the linear measurement compared to the real physical measurement.

Our findings concur with those reported by Xue et al., who evaluated the accuracy of measuring soft tissue thickness in different areas of the jaw. They found that the measurements were significantly greater than those in the control images (22). Our findings contradict the results of this study in which the linear measurements on CBCT images were underestimated compared to the physical measurements with no significant difference in thicknesses over 2mm for four different voxel sizes (23). Variations in observer performance and a larger sample size in this study could account for disparities between the studies' findings.

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