Original Research Article

Evaluation of validity of cone beam CT (CBCT) measurements compared to direct method on human dry mandibles

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Abstract

Introduction: Cone beam computed tomography (CBCT) has its wide range of uses in dentistry most commonly as an aid in preoperative planning of dental implant treatment. However, in order to determine the best application of CBCT in dentistry, it is necessary to analyze the accuracy of data obtained related to distance measurements. The present in-vitro study was undertaken to evaluate the accuracy of radiographic linear measurements on CBCT images by comparing them to direct measurements in human dry mandibles.

Materials and methods: Ten human dentulous dry mandibles were selected for the study. Four anatomical sites (Site A, B, C, and D) with two anatomical reference points for each site were selected on dry mandibles for measurement. The reference points were made as 3 mm depressions on the mandible with Marathon micromotor hand piece and diamond bur. These depressions were filled by guttapercha. All the selected mandibles were scanned using Sorodex Cranex 3Dx CBCT Machine. After the CBCT scan was obtained, the direct measurements at each site were recorded using digital vernier calipers with an accuracy of 0.01mm.

Results: Comparison of CBCT measurements with direct measurements at 4 anatomical sites revealed no statistical difference (p value >0.05). Correlation of CBCT measurements with direct measurements revealed strong correlation at site site A (0.965), site B (r=0.899), D (r=0.975) and moderate correlation at site C (r=0.571).

Conclusion: According to present study, CBCT technique can be recommended for linear measurements in the mandible.

Key words

Cone beam CT, Human dry mandible, Sigmoid notch alveolar ridge, Digital vernier calipers.

Introduction

Diagnosis of various dental conditions are certainly based on radiographs. Appropriate radiographic procedures have to be selected based on suggested guidelines [1] for the patient suspected of having dental and maxillofacial disease.

With the advent of Computed tomography (CT) it is possible to investigate the inner depths of the human anatomy slice by slice through computer reformation of radiographic images. Cone-Beam CT (CBCT) promises the same features of CT along with an additional advantage of reduction in the radiation dose to the patient for a maxillofacial study [2].

In CBCT, a process referred to as multiplanar reformation (MPR) is possible wherein the images can be created in the axial plane, coronal, sagittal and even oblique or curved image planes [3]. In addition, CBCT data are amenable to reformation in a volume, rather than a slice, providing 3-dimensional (3D) information.

CBCT has its wide range of uses in dentistry most commonly as an aid in preoperative planning of dental implant treatment. CBCT provides a three - dimensional (3D) image of the alveolar bone and enables assessment of its architecture and dimensions, as well as identification of osseous defects and anatomical structures, such as the mandibular canal [4]. The value of CBCT imaging in TMJ assessment and pre- and postoperative assessment of craniofacial fractures has been reported [5]. In orthodontics, CBCT imaging is useful in the assessment of growth and development.

However, in order to determine the best application of CBCT in dentistry, it is necessary to analyze the accuracy of data obtained related to distance measurements.

The accuracy of CBCT in producing reliable 3D images has been evaluated in studies that compared linear measurements on radiographic images with direct measurements. Several studies utilized human dry skulls, whereas others recruited patients for in vivo direct measurements. The mean reported difference between the direct and CBCT measurements varied between –0.23 and 0.47 mm (negative values indicate underestimation and positive values indicate overestimation of CBCT compared with direct measurements). Some authors found mean overall minor compression in the CBCT images, whereas others detected overestimation [6, 7].

Also, for the anterior areas compared to the posterior areas of the jaws the diagnostic accuracy of CBCT was found to be poorer. A major drawback of most studies is the lack of a system to enable direct intra bony measurements in actual tissues and their correlations with corresponding measurements on CBCT images [8]. This in-vitro study was undertaken to evaluate the validity of radiographic linear measurements on CBCT images by comparing them to direct measurements on human dentulous dry mandibles.

Materials and methods

The present in vitro study was conducted in the Department of Oral Medicine and Radiology, Sri Sai College of Dental Surgery, Vikarabad. The study protocol was approved by the institutional ethical committee. Ten human dentulous dry mandibles of cadavers aged between 15 years to 50 years were obtained from the Department of Anatomy, Gandhi Medical College, Hyderabad, for the study. The selected human dry mandibles were free of any pathological lesions.

On the dry mandibles 4 anatomical sites were selected for measurement designated as Site A, Site B, Site C, and Site D. Each site has two

anatomical reference points. A total of 8 reference points were selected. The reference points were made as 3 mm depressions on the mandible with Marathon micromotor hand piece and diamond bur.

Preparation of dry mandibles for measurements

Anatomical reference points

Four anatomical reference points were placed at the crest and lower border of the mandible at 1st premolar region on both right and left sides.

Four anatomical reference points were placed below the sigmoid notch and lower border of the mandible on both right and left sides.

Anatomical sites

At site A, superior reference point (SRP) was 5mm below the deepest point of the sigmoid notch on right side. While, the inferior reference point (IRP) was 5mm above the inferior border of the mandible on right side. These 2 points were placed such that they were in a straight vertical line.

At site B, SRP was placed 5mm below the crest of the alveolar ridge in premolar region on right side. Whereas the IRP was 5 mm above the inferior border of the mandible on right side. These 2 points were placed such that they were in a straight vertical line. At site C, SRP was placed 5mm below the crest of the alveolar ridge in the premolar region on left side. Whereas the IRP was 5mm above the inferior border of the mandible on left side. These 2 points were placed such that they were in a straight vertical line. At site D, superior reference point (SRP) was 5mm below the deepest point of the sigmoid notch on left side. While the inferior reference point (IRP) was 5mm above the inferior border of the mandible on left side. These 2 points were placed such that they were in a straight vertical line.

All these sites were then drilled with a Marathon micromotor hand piece. A Tungsten Carbide no 12 bur of 3mm diameter was used to drill the depressions at the sites. 2 holes were made at each site. Thereby a total of 8 holes were made for each mandible.

Once the depressions were made, these were filled guttapercha. Gutta-percha was softened with heat using a spirit lamp and condensed into the holes with a ball burnisher.

CBCT Imaging

All the selected mandibles were scanned using Sorodex Cranex 3Dx CBCT Machine. It also has Clear Touch control panel with simplified selections located conveniently in the unit column.

Human dry mandibles were aligned on the chin rest of the CBCT machine according to the FOV guidelines prescribed by the manufacturer and was stabilized using adhesive tape. Parameters used for the scan were 90Kv, 5 mA and 8.5 seconds of exposure time and a field of vision (FOV) of 13x15. A 200^{o} rotation of the machine was done to scan the entire mandible.

After the CBCT scan was obtained, the measurements at each site was measured and recorded. At measurement sites A, B, C and D measurements were (**Figure - 1, 2**) obtained using sagittal sections of the CBCT scans. Thereby, a total of 40 measurements were obtained from CBCT scan of 5 mandibles.

Direct measurements using Digital Vernier Calipers

Measurements were made at each reference site using a Digital Vernier Calipers with an accuracy of 0.01mm. Thereby a total of 40 measurements were obtained at sites A, B, C and D (**Figure - 3, 4**).

Statistical analysis

Measurements obtained by CBCT and Digital Vernier Calipers were tabulated for each mandible and at each site. These measurements were analyzed statistically. Statistical analysis was done using SPSS version 20. Paired t test was used for comparison of CBCT and Direct

measurements. Paired samples correlation was done using pearson correlation co-efficient (r).

Figure - 1: Sagittal section of CBCT image of human dry mandible showing site A.

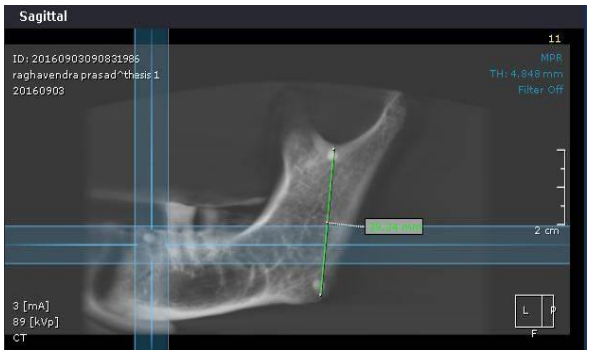

Figure - 2: Sagittal section of CBCT image of Human Dry Mandible showing site B.

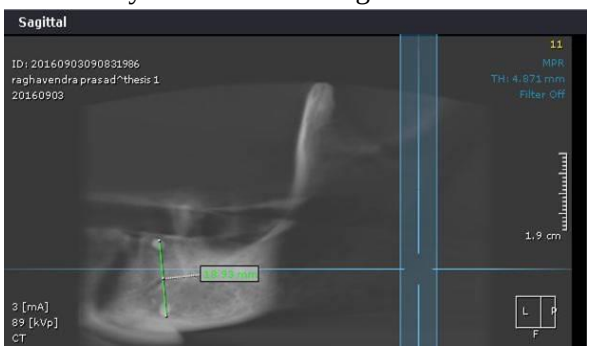

Figure - 3: Linear measurement at site A using digital vernier calipers on human dry mandible.

Figure - 4: Linear measurement at site B using digital vernier calipers on human dry mandible.

Results

For each mandible 4 measurements were obtained, one at each measurement site both from CBCT scans and Digital Vernier Calipers (**Table – 1, 2**). Differences in the means for measurement values obtained using CBCT and Digital Vernier Calipers were slightly under estimated for CBCT at site A (-0.1588), site C (-0.3141), at site E (-0.8047) and were slightly over estimated for CBCT at site G (0.0371) (**Table - 3**). Comparison of CBCT measurements with direct measurements at 4 anatomical sites revealed no statistical difference (p value >0.05) (**Table - 4**). Correlation of CBCT measurements with direct measurements revealed: strong correlation at site site A (0.965), site C (r=0.899), G (r=0.975) and moderate correlation at site E (r=0.571) (**Table - 5**).

Discussion

The CBCT technology introduces an innovation in modes of image scanning and volumetric reconstruction of CT data. Due to rapid volumetric image acquisition (as low as 18 sec) from a single low radiation dose scan of the patient and the low mA, the effective dose with the CBCT technique is significantly smaller than that achieved with other CT imaging methods and is within the range of traditional dental imaging modalities.

Table - 1: CBCT linear measurements on dry mandibles.

	N	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation
Site A	40	31.58	45.76	37.52	4.115
Site B	40	7.68	22.25	16.02	3.396
Site C	40	9.59	20.88	15.40	3.022
Site D	40	29.93	47.07	36.91	4.484

Table - 2: Direct linear measurements on dry mandibles using digital vernier calipers.

	N	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation
Site A	40	31.83	46.11	37.68	4.135
Site B	40	8.34	22.16	16.33	3.225
Site C	40	9.36	20.37	16.20	2.816
Site D	40	29.63	47.12	36.88	4.645

Table - 3: Difference in CBCT and direct measurements at each site.
M_C – Measurements obtained by CBCT, M_D– Measurements obtained by Digital Vernier Calipers

	Minimum (mm)	Maximum (mm)	Mean (mm)	Standard Deviation
SITE A (M_C-M_D)	-1.12	3.89	-.1588	1.08661
SITE B (M_C-M_D)	-3.88	4.14	-.3141	1.49677
SITE C (M_C-M_D)	-9.56	3.93	-.8047	2.70944
SITE D (M_C-M_D)	-2.11	2.52	.0371	1.02664

Table - 4: Comparison of CBCT and direct measurements at each site.

	CBCT		DIRECT		p-value
	Mean (mm)	SD	Mean (mm)	SD	
SITE A	37.35	4.056	37.30	4.169	0.853
SITE B	15.85	3.133	16.20	3.105	0.358
SITE C	15.60	2.873	15.90	2.827	0.622
SITE D	36.95	4.249	36.90	4.400	0.804

* Statistically significant ($p \leq 0.05$)

Table - 5: Correlation among CBCT and direct measurements at each anatomical site.

Site	Correlation coefficient (r)	P value
SITE A	0.965	0.001*
SITE B	0.899	0.001*
SITE C	0.571	0.010*
SITE D	0.975	0.001*

* Statistically significant ($p \leq 0.05$)

The CBCT software provides some useful tools for clinical practice, such as tools to measure distances and angles, to zoom, invert the gray scale, adjust the contrast, and gamma changes. One of the major uses of CBCT is pre surgical implant planning.

The linear measurement of distances is often used in pre surgical implant planning for the determination of the exact amount of alveolar bone (height and width) and consequently the size of the dental implants. Also, linear measurements are used in orthodontic analysis and in the definition of jaw tumor size. The measurement error is generally less than 1mm on images using CBCT [9].

Different morphological studies were done using CBCT to study the anatomy, relative positions and accuracy in morphology. In the orofacial region, CBCT was used to study different structures like maxillary sinus, nasopalatine canal, TMJ and others [10-14].

Most studies done in the past have evaluated the accuracy of CBCT using animal models (porcine mandibles), human dry skulls etc. There is scarcity of studies using human mandibles to evaluate the accuracy of CBCT measurements. The present study evaluated the accuracy of CBCT by comparing direct measurements obtained using Digital Vernier Calipers on human dry mandibles with those taken using CBCT (SoredexCranex 3Dx CBCT Machine) [5, 15].

The mean difference between direct and CBCT measurements is <1mm for all the sites indicating a good correlation between the two measurements. Correlation co –efficient (r) was found to be >0.5 for all the sites, suggesting a good correlation between both the measurements.

The present study results are in accordance with the studies done previously to assess the correlation between CBCT based measurements and actual distances in human dry mandibles, human dry skulls or in patients [15, 16].

Halperin–Sternfield, et al. compared CBCT based measurements to direct measurements on porcine mandibles to evaluate the diagnostic accuracy of CBCT showed no statistically significant differences between CBCT and direct measurements [5]. This study showed strong correlation between CBCT and direct measurements with a slight under estimation of CBCT relative to actual distances. These findings were in accordance with the results of the present study.

Rumpa, et al. performed a study to determine the accuracy of CBCT measurements with physical measurements using cadaver heads in the presence and absence of soft tissue. They stated that no statistically significant difference was found between the medians of the physical measurements obtained with calipers and the medians of the CBCT measurements which support the results of the present study [17].

In the present study, among 4measurement sites, 3 sites showed underestimation of CBCT measurements (site A -0.1588, site C -0.3141, site E -0.8047). Similar results were obtained by studies conducted by Loubele, et al. [18] and Waltrick, et al. [7]. The study conducted by Waltrick, et al., reported that image-based measurements were underestimated in 60.7% of measurements [7].

In contrast to the above mentioned studies, a study has reported an overestimation of the CBCT- based measurements when compared to the actual distances [18].

An in vivo study conducted by Chen et al in humans over-estimated the CBCT measurements up to 8 mm when compared to the direct measurements. This could be due to difference in the manner in which the measurements were obtained. CBCT measurements were obtained by placing radiographic guides in the jaws whereas direct measurements obtained without the radiographic guides and by surgical exposure of the bone [6].

The present study is an in vitro study on human dry mandibles. Variations between images obtained in in-vitro and actual clinical conditions have to be considered while correlating the findings.

The limitation of the study was that the measurements were made by a single observer which may introduce bias. Soft tissue simulation has to be done for imaging the dry mandibles. The above inadequacies should be addressed in any future studies on CBCT.

Conclusion

Based on the results of the present study it can be concluded that the CBCT technique is a reliable for linear measurements in the mandible which is an important requisite for pre-operative assessment for dental implant, orthognathic surgeries etc. There has to be a safety margin for surgical interventions in the mandible to compensate for the slight under or over estimation of distances when using CBCT.

Further studies with a bigger sample size and soft tissue simulation are recommended to validate the results of the present study.

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