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ORIGINAL RESEARCH

Comparative Evaluation Accuracy Test of CBCT

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ABSTRACT

This study aimed to analyze the accuracy of linear and angular measurements in different CBCT machines in comparison with the measurements obtained with a stereomicroscope in a dry human mandible. Eight landmarks on a dry human mandible were marked with 1mm gutta-percha round markers. Four linear and six angular distances between these landmarks were measured once with a Stereomicroscope and then compared with the 2D CBCT multiplanar images rendered by different CBCT systems. The different systems like Carestream 9600, Dentium, Soredex, Myray ,HDX Will, New Tom and Carestream 8200 have measured values using measurement tools of each of their softwares (CS, Rainbow, On- demand, iRYS, On-demand, NNT Viewer and CS) respectively. All measurements were made independently by three trained observers to avoid observer bias. All factors remain constant, the measurements made in all the systems have been compared and a highly significant Pearson correlation coefficient has been obtained for both linear as well as angular measurements. As the measurements are highly accurate and reproducible, we recommend the use of CBCT for better prognosis and treatment planning

Key words: CBCT, Accuracy, Linear measurement, Angular measurement, Radiography, 3-D imaging (imaging, three-dimensional), 3-D reconstruction, CBCT measurement, Computed tomography

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INTRODUCTION

Cone Beam Computed Tomography is an advanced Imaging technique which enables us to visualize the images in a multi-planar format.[1] It is an essential part of treatment planning in implantology, periodontics, orthodontics, endodontics and image- guided surgeries.[2-5] For implant placement, during the treatment planning phase, certain linear parameters like mesiodistal distance, implant diameter, bone density, height, and width have to be measured.[6,7] Angular measurements are required during all-on-four implant placement or while using angulated abutments.

The measurements which we obtain from the scans should be equivalent to the measurements seen in the oral cavity or the alveolar bone. Even a small deviation in any of it may end up causing certain mishaps. This study is being done to evaluate all these factors and avoid any inaccuracies which might occur. Also, because of factors such as availability, radiation dose considerations and cost, most dental practitioners have limited their usage of any of the advanced imaging techniques. However, Multiplanar imaging has provided opportunities for dental practitioners to make use of cone-beam computed tomography (CBCT), especially in the maxillofacial region. CBCT makes use of a process called multiplanar reformation (MPR) in which the "real-time" images are created in various axes such as sagittal, axial, coronal, curved or even oblique image planes.[8,9]

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Another advantage is that the image data in CBCT is reformed in a volumetric format rather than just 3-D slicing which provides the information 3-dimensionally.[10] The purpose of this article is to measure the accuracy of linear and angular measurements of different CBCT machines using a Stereomicroscope (an optical microscope which gives the 3-D view of a specimen) as a standard reference.

MATERIALS AND METHODS

Gutta-percha points were fixed on mesial, distal, buccal and lingual surfaces around the first molar on the right and left halves of the dry human mandible. The mesiodistal distances (M1D1 and M2D2 respectively) were measured on certain marked points of the gutta-percha points placed around the molars. The lower canine sockets with sharp edges were also measured and named JK and HI for the left and right sockets respectively. The above four distances were considered for the measurement of linear accuracy. Two points of sharp edges of the canine sockets were taken for the cross arch measurement. It is easier to accurately pin point them as they are sharp with a minimal chance of errors; And as the canines are corners of the arch, any form of distortion due to rotation from CBCT can also be recorded. For the angular measurements, the mesio-bucco-distal of the left molar and bucco-mesio-lingual angles of the right molar were taken into consideration. The actual distance was measured using a stereomicroscope which was taken as a standard reference. These measurements were compared with the digital measurements from the software. All the measurements were recorded by three different observers separately in a random order to avoid observer bias. The mean of all three measurements was taken into consideration. Figure 1 depicts the linear and angular measurements of the prepared dry mandible. Later dry human mandible was exposed to CBCT under different machines which include Carestream 8200, Dentium, Soredex, Myray,HDX Will, New Tom and Carestream 9600. The images were obtained using their respective softwares which are CS Imaging, Rainbow, On-demand,iRYS,

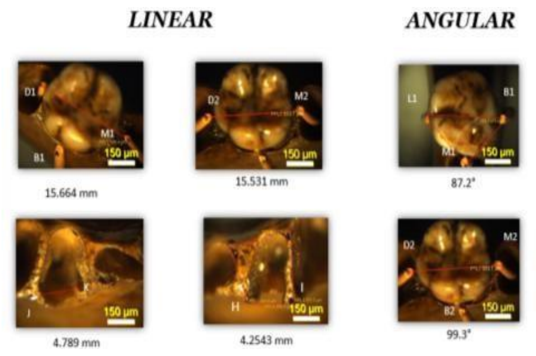

Figure 1: Linear and angular measurements obtained with a stereomicroscope.

On- demand, New Tom and CS Imaging. Before exposing the dry human mandible, all the machines were calibrated to obtain images at 80-90 kv and 7-10 mA with an exposure time of 15-20s. A total of 7 sets of images have been obtained. Figure 2 shows iRYS software's 3D reconstructed image of the dry mandible with angular measurements.

Stereomicroscope - an optical microscope with Image Pro Insight (Fig 3) which is an image analyzing software, was used to view the mandible and obtain images with an accuracy of 0.001 mm. Functions to view, and measure distances in µms. and angles in degrees were also available options in the software. All the CBCT machines with their respective software performed a wide array of functions including zoom, contrast, brightness adjustment, selection of the axial slice and measurement of distances and angles.

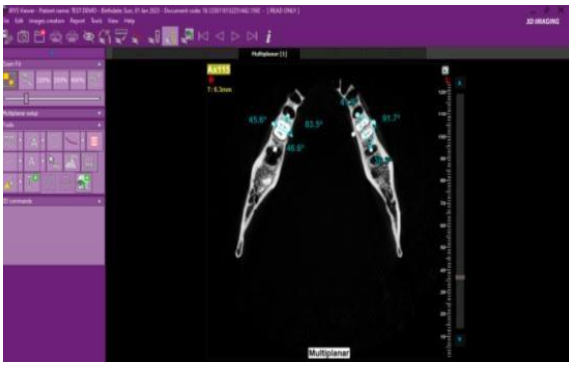

Figure 2: 3-D reconstructed image obtained by iRYS software of MYRAY CBCT machine.

All the softwares includes Rainbow, Care Stream Imaging, On-demand, iRYS and NNT Viewer. All of these are stand-alone and unique softwares with executable applications. They enable us to view 3-D images without the installation of any specific software. Image analysis and treatment becomes hassle-free with the use of these softwares as a single scan can be reconstructed multiple times at different levels of resolution, without re-scanning the patient. Different multi-sectional and cross-sectional views of the images can be obtained with preset formats. The stereomicroscope was considered the "Standard reference" to which all the CBCT measurements have been compared.

Figure 3: Stereomicroscope which has been used for reference measurements.

All the measurements obtained from Stereomicroscope and CBCT images were noted by three independently trained observers in a random order to avoid observer bias. Images were viewed in a moderately lit room on a 16.3' Dell laptop screen with a screen resolution of 1366 x 768 pixels. Linear and angular accuracy was assessed by calculating the Pearson correlation coefficient with the level of significance set at $p < 0.05$.

RESULTS

Pearson correlation coefficient values ranged from 0.960 to 1.000 for linear measurements whereas the range varied from 0.949 to 1.000 for angular measurements. This range indicates the highly significant correlation among the different measurements of linear and angular taken in this study. (Table 1-6)Among the different imaging systems, the results show the overall mean of the readings from three observers regarding linear measurements (M1D1, M2D2, HI, and JK) in different CBCT machines wherein the highest mean (10.5250 + 5.42) is seen with Myray and the least mean (9.6392 + 5.48) is seen with NewTom. The Overall mean of the readings from three observers regarding angular measurements (L1M1B1, L1B1M1, B1L1M1, B2M2D2, B2D2M2, and M2B2D2) in different CBCT machines wherein the highest mean (60.30 + 24.43) is seen with Care Stream8200 and the least mean (57.6 + 25.06) is seen with Care Stream9600.

	N	Minimum	Maximum	Mean	Std. Deviation
Stereomicroscope	12	3.91	16.11	10.0477	5.81905
Carestream9600	12	4.10	16.80	10.1725	5.90224
Dentium	12	4.80	15.97	10.1225	5.25750
Myray	12	4.90	17.43	**10.5250**	**5.42090**
NewTom	12	3.80	15.45	9.6392	5.48833
HDXWill	12	4.50	16.37	10.3025	5.54761
Carestream8300	12	3.30	16.65	9.9500	5.74217
Serodex	12	3.87	16.43	9.9000	5.48440

Table 1 : Overall mean of the readings from three observers regarding LINEAR measurements (M1D1,M2D2, HI,JK) in different CBCT machines.

DIFFERENT MEASUREMENT SYSTEMS		STEREO	CARESTREAM 9600	DENTIUM	MYRAY	NEWTOM	HDXWILL	CARESTREAM 8300	SERODEX
STEREO	Pearson Correlation	1	0.995**	0.995**	0.980**	0.992**	0.997**	0.991**	0.992**
	Sig. (2-tailed)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	12	12	12	12	12	12	12	12
CARESTREAM 9600	Pearson Correlation	0.995**	1	0.997**	0.971**	0.993**	0.994**	0.986**	0.992**
	Sig. (2-tailed)	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	12	12	12	12	12	12	12	12
DENTIUM	Pearson Correlation	0.995**	0.997**	1	0.969**	0.996**	0.996**	0.984**	0.988**
	Sig. (2-tailed)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
	N	12	12	12	12	12	12	12	12
MYRAY	Pearson Correlation	0.980**	0.971**	0.969**	1	0.970**	0.967**	0.991**	0.960**
	Sig. (2-tailed)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
	N	12	12	12	12	12	12	12	12
NEWTOM	Pearson Correlation	0.992**	0.993**	0.996**	0.970**	1	0.993**	0.987**	0.985**

Table 2 : OVERALL Comparison of the accuracy of LINEAR measurements (M1D1, M2D2, HI, JK) in different CBCT machines with the Stereomicroscope measurement.

	N	Minimum	Maximum	Mean	Std. Deviation
Stereomicroscope	9	37.90	99.60	59.7556	26.82942
Carestream9600	9	39.00	92.50	57.6000	25.06940
Dentium	9	38.40	92.40	57.8889	24.85148
Myray	9	36.30	93.70	57.9444	26.07015
NewTom	9	37.90	96.80	58.1667	27.42968
HDXWill	9	41.90	91.20	58.8222	23.23073
Carestream8300	9	42.90	95.60	**60.3000**	**24.43450**
Serodex	9	35.90	99.50	59.6333	29.70261

Table 3 : OVERALL mean of the readings from three observers regarding ANGULAR measurements (B2M2D2, B2D2M2, M2B2D2) in different CBCT machines.

DIFFERENT MEASUREMENT SYSTEMS		STEREO	CARESTREAM 9600	DENTIUM	MYRAY	NEWTOM	HDXWILL	CARESTREAM 8300	SERODEX
STEREO	Pearson Correlation	1	0.981**	0.987**	0.974**	0.981**	0.984**	0.977**	0.969**
	Sig. (2-tailed)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	9	9	9	9	9	9	9	9
CARESTREAM 9600	Pearson Correlation	0.981**	1	0.996**	0.990**	0.992**	0.994**	0.995**	0.991**
	Sig. (2-tailed)	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	9	9	9	9	9	9	9	9
DENTIUM	Pearson Correlation	0.987**	0.996**	1	0.990**	0.990**	0.994**	0.993**	0.985**
	Sig. (2-tailed)	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001
	N	9	9	9	9	9	9	9	9
MYRAY	Pearson Correlation	0.974**	0.990**	0.990**	1	0.998**	0.997**	0.995**	0.996**
	Sig. (2-tailed)	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
	N	9	9	9	9	9	9	9	9
NEWTOM	Pearson Correlation	0.981**	0.992**	0.990**	0.998**	1	0.999**	0.996**	0.998**

Table 4 : OVERALL Comparison of the accuracy of ANGULAR measurements (B2M2D2, B2D2M2, M2B2D2) in different CBCT machines with the Stereomicroscope measurement.

	Valid Cases		Cases Missing		Measure of Agreement Kappa Value
	N	PERCENT	N	PERCENT	
M1D1O1 * M1D1O2	8	100.0%	0	0.0%	0.000
M1D1O1 * M1D1O3	8	100.0%	0	0.0%	0.000
M1D1O2 * M1D1O3	8	100.0%	0	0.0%	0.000

Table 5 : indicates the degree of agreement (Kappa value) of nominal assessments by three observers of the linear measurement (HI),

	Valid Cases		Cases Missing		Measure of Agreement Kappa Value
	N	PERCENT	N	PERCENT	
L1M1B1O1 * L1M1B1O2	8	100.0%	0	0.0%	0.000
L1M1B1O1 * L1M1B1O3	8	100.0%	0	0.0%	0.000
L1M1B1O2 * L1M1B1O3	8	100.0%	0	0.0%	0.000

Table 6 : Comparison of the Inter-observer agreement of ANGULAR measurements (L1M1B1) in different CBCT machines with the Stereomicroscope measurement.

DISCUSSION

The present study showed the linear and angular accuracy of specific distances on dry human mandible using different CBCT imaging units. The effectiveness of the different imaging systems can be seen in the similarities obtained in the measurements among all the units. Since the aim of our study was to analyse the measurements in linear and angular parameters, soft tissue or its equivalent was not utilized which could be a drawback in this study as all the CBCT systems assessed only the bony structure of the dry human mandible. Our findings are similar to that of the study which showed that the accuracy of surface model measurements was not affected by increased voxel resolution.[11] In our study, highly accurate and reproducible results were obtained which are in line with a previous study wherein 13 landmarks were measured on a dry human skull using New Tom 9000 CBCT. It seemed that the actual measurements were approximately more than the CBCT image distances marked on the dry human skull; however, for the measurements of the skull base, only statistical significance was observed when CBCT and direct measurements were compared.[12] The different systems tested by various observers have different calibration or hardware/software capabilities which might have caused the slight discrepancy. Due to the usage of metal spheres (2mm. in diameter attached to the skull), beam hardening and scatter may have caused an effect on observer performance as well. Our study is in line with a previous study that found a <1% error wherein highly accurate data was obtained compared to physical measurements. The machines used in the study were the itachi MercuRay (Hitachi Medico Technology, Tokyo, Japan) and the NewTom QR DVT 9000 (Aperio Inc., Sarasota, FL) [13] In this study, we have compared CBCT machines with each other and Stereomicroscope, however for linear measurements CBCT has already been proven to be superior than 2-D cephalometric radiography. [14,15] A previous study has shown similar results when a linear measurement of the temporomandibular joint was compared using CBCT and digital cephalometric radiography.[16] Moreover, the accuracy and reliability of measurements were not affected by the orientation of the skull during the CBCT scan. [17-20] With CBCT, significantly higher reliability has been observed by both intra-observer and inter-observer in the anatomical structures and landmarks identification when compared to 2-D measurements.[21] In terms of linear measurements, both 3-D measurements of CBCT and multi-slice CT have shown similarly accurate results wherein lower effective radiation dose was observed in CBCT rather than CT. [22, 23] As there are similarities between our study and previous findings [24,25] in terms of accurate measurements, we recommend the usage of CBCT units for diagnosis, treatment planning and follow-up in the dentofacial region

CONCLUSION

In the present study, similarities of accuracy and reproducibility of pre-determined measurements of the mandible were seen in the images obtained with the different CBCT systems i.e., Carestream 8200, Dentium, Soredex, Myray, HDX Will, New Tom and Carestream 9600 (with no differences in intra-observer or inter-observer agreement.) Among the different imaging systems, linearly the results show the highest mean (10.5250 + 5.42) is seen with Myray and the least mean (9.6392 + 5.48) is seen with NewTom. Regarding angular measurements in different cbct machines wherein the highest mean (60.30 + 24.43) is seen with Carestream8200 and the least mean (57.6 + 25.06) is seen with carestream9600. The similarity among linear and angular measurements is clinically significant which implies the recommended usage of CBCT machines for treatment planning in the maxillofacial region.

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