Influence of Two Software Programs on The Accuracy of Linear Measurements of Cone-Beam Computed Tomography. In Vitro Study.

Wessam M. Youssef* [1], Ahmed M. Hossam El-Din* [2]

1 Researcher *- Surgery and Oral medicine department, Oral and Dental research institute, National Research Center, Egypt

2 Associate Professor – Oral & Maxillofacial Radiology Department, Faculty of Dentistry-MSA University, Egypt.

Corresponding author: Wessam M. Youssef*

ahossam@msa.edu.eg,wessam2004@gmail.com

ABSTRACT

Background: Using two distinct CBCT programs. (ONDEMAND 3D and NNT software).

Methods: The sample consisted of seven implant bone models marked with radiopaque markers of gutta-percha, which were glued on the marked positions, linear measurements were conducted on the implant models using digital caliper to provide gold standard measurements. The models were scanned using ***NewTom GIANOHR 3D*** CBCT machine, and images were exported into (DICOM) file and then imported into two software programs. The same linear measurements were conducted on the scanned images using the measure length tool of NewTom's NNT software and Ondemand software programs. **Results**: Interclass correlation coefficient within all measurement methods at each point had shown excellent reliability (ICC>0.9). Pearson correlation coefficient r between Ondemand and the gold standard and between NNT and the gold standard has shown a very high positive correlation (r>0.9). Comparison between on-demand and gold standard has shown no statistically significant difference (P>0.05) for height (B), height (C) and BL (A,B,C), while there was a statistically significant difference (P≤0.05) for height (A) and MD (B,C). Comparison between NNT and the gold standard has shown no statistically significant difference (P>0.05) for all measurements except for BL (C) (P = 0.0198). NNT has shown less measurement error compared to the Ondemand method (P = 0.0001), when compared to the gold standard direct measurement. **Conclusions:** NNT software is more reliable than Ondemand 3D software.

Keywords: Cone Beam CT, Linear measurements, , Software.

Background: For craniofacial structures, CBCT provides clear resolution, distortion-free, and exact views without the limitations of two-dimensional images' magnification and superimposition. Numerous studies have noted the value of CBCT in terms of the accuracy of linear measurements since it allows for precise and reliable readings. Although CBCT has several advantages, but unfortunately, the radiation dose it produces is still debatable because it exposes patients to more radiation than two-dimensional imaging does.[1, 2, 3]

CBCT is a volumetric reconstruction method and imaging modality that enables us to compute linear measures. In oral and maxillofacial surgery, CBCT can be used for surgical assessment and treatment planning, including orthognathic surgery, implant procedures, and the evaluation of maxillofacial injuries.[4,5]

Today, a wide range of different types of third-party software are highly recommended in the field of dentistry for assessment and analysis of many measurements to achieve proper treatment plans, such as the construction of surgical guides, the placement of implants, and the identification of the bone interface. Therefore, it is highly recommended to choose appropriate software for obtaining high accuracy linear measurements by length measurement tool. [6,7,8,9,10,11,12,13]

A prior study evaluated the precision of CBCT measurements in cases of surgically treated lesions, and a different study evaluated the precision of linear measures from CBCT pictures using various software tools.[14,15]

The objective of this study is to evaluate the accuracy of the linear measurements recorded from CBCT images using NNT 3D imaging software and Ondemand 3D software. Digital calliper was used to measure the linear measurements, which denote the gold standard. It is highly recommended to attain greater accuracy of the linear measurements obtained from 3rd party software for accurate treatment planning especially for implant and orthognathic surgeries pre and postoperatively.

Materials And Methods

1. <u>Setting and location:</u>

Procedures of the study including implant bone models preparations, marking of the measurements sites and measurements of the gold standard were performed in the Oral and Maxillofacial surgery department, , National Research Center. While Procedures of the study including imaging process, software manipulation of the resultant images and CBCT measurements were performed in Oral and Maxillofacial Radiology Department, Faculty of Dentistry, October six university for modern science and arts.

2. <u>Recruitment and sampling:</u>

The implant bone models were recruited consecutively from Safwan Egypt Co. the agent of Nissin Dental Products, Inc*. in Egypt.

3. <u>Data collection:</u>

Data collection was planned before the index test and reference standard have been performed (prospective study).

4. Test methods

A-Sample preparation

The implant bone models were randomly numbered by the principal researcher, and then on each model at the incisors region three positions were selected and marked on the model with a permanent blue marker.

Then at the marked position three radio-opaque ‘RO’ markers “gutta-percha pieces” were glued on the model surfaces as following; two pieces on the facial surface one occlusally (at the alveolar crest) and one apically (at the inferior border of the model) both were on the same vertical line and perpendicular to the horizontal plane, while the third one was placed on the lingual surface opposing the occlusally placed buccal piece.

The RO markers were obtained by cutting gutta-percha cones size 60 using sharp scissors into small pieces of nearly 1-1.5 mm length and the cut pieces were glued to the selected landmarks using a cyanoacrylate gel*.

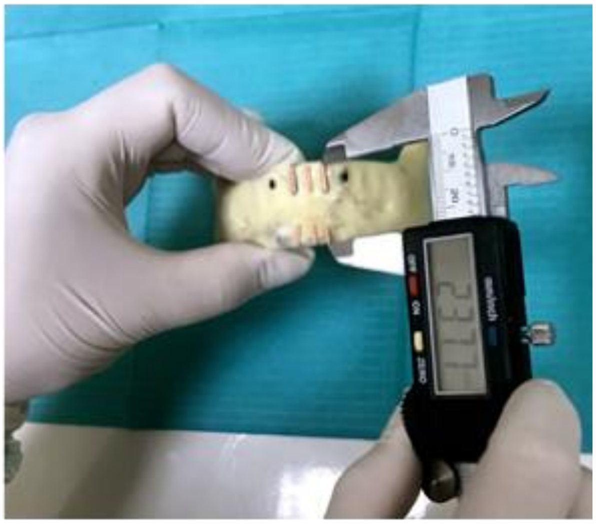
B-Imaging procedures

CBCT examinations of each bone model were performed using ***NewTom GIANO HR 3D machine,*** Each bone model was properly positioned in the machine with the help of the laser beam indicators of the machine such that the vertical laser beam coincided with the mid-sagittal plane (perpendicular to the floor) and the horizontal laser beam coincided with the occlusal plane (parallel to the floor). Each model was scanned at FOV(10X10) with standardized tube current and voltage of 12.5 mA and 90 kVp.

C-The Reference Standard:

The reference standard in this study was the real linear measurements that were obtained directly on the implant bone models using high precision sliding electronic digital caliper* with 0-150 mm internal and external measuring range and 0.01 mm resolution accuracy.

- **a- Bone Height:** this was measured on the facial surface of the model as the distance between superior end of the occlusally placed gutta-percha piece and inferior end of the apically placed one **(Fig. 1)**.
- **b- Bucco-lingual “BL” Bone Thickness:** this was measured as the distance from superior end of the occlusally placed facial gutta-percha piece to superior end of the gutta-percha piece placed on the lingual surface **(Fig. 2)**.
- **c- Mesio-Distal “MD” Bone Width:** This was measured as the distance between the superior ends of two adjacent gutta-percha pieces on the facial and lingual surfaces **(Fig. 3)**.



Figure(1) Direct linear measurement of bone height using electronic digital caliber

Figure(2) Direct linear measurement of bone thickness using electronic digital caliber

Figure 3 Direct linear measurement of bone width using electronic digital caliber.

D-Index test:

The index test in the current study was the CBCT linear measurements obtained from CBCT images of implant bone models using (10X10) FOV. CBCT images were exported in Digital Imaging and Communications in Medicine (DICOM) format. Where CBCT DICOM files were exported into two third party software ***NNT 3D imaging software and Ondemand 3D software*** for CBCT linear measurements to be taken on a personal computer (13.3-inch LED-backlit display; 2560x1600 native resolution at 227 pixels/inch), The CBCT scans were displayed on ***MPR screen*** [displaying the volumetric data set in axial, coronal, and sagittal image slices, (**fig 4)**]. The CBCT linear measurements were taken on each of the marked areas for linear measurements using ***distance icon*** on the tool bar, in each point, bone height, BL thickness, and

MD width measurements were made exactly as those made on the bone model with the digital caliper. Both height and thickness measurements were taken on the corrected sagittal images, while width measurements were taken on the corrected axial images.

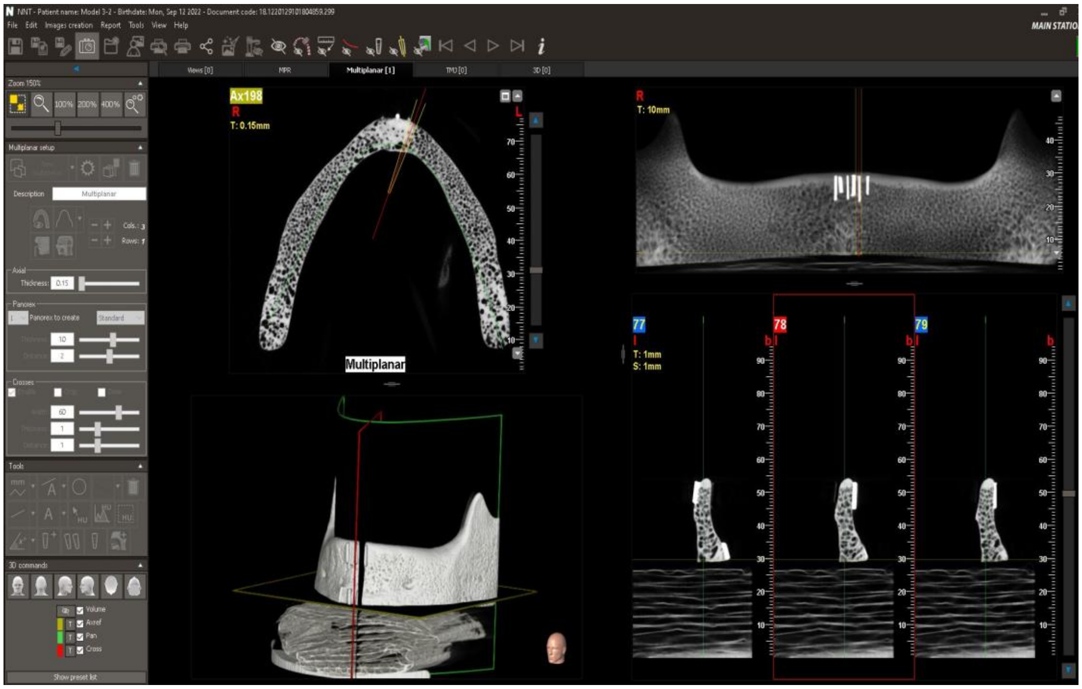


Figure 4 *CBCT MPR presentation using NNT software*

E-Number of persons executing and reading the index tests and the reference standard:

The direct linear measurements, which represent the reference standard in this study, were taken by one researcher, they were taken twice and the average of both readings was considered the gold standard. While for CBCT linear measurements (index test) they were taken once by the principal researcher who has 10 years of experience in the field of oral and maxillofacial radiology, and once more by another radiologist who has more than 20 years of experience.

F-Blinding:

To ensure blinding in the study, the direct measurements were tabulated and kept hidden while the CBCT measurements were taken. and each investigator was blinded to the other one's readings.

5- Statistical analysis

The measurements of the current study were calculated using the Medcalc version 19 for windows. The reliability of the gold standard direct measurements, the Ondemand and NNT measurements were measured using the intra class correlation coefficient. Data was explored for normality using Kolmogrov Smirnov test and Shapiro Wilk test. Continuous data showed normal distribution and were described using mean and standard deviation. Pearson correlation with correlation coefficient r was used to correlate between ondemand and gold standard, and between NNT and gold standard measurements. Paired t test was used to compare between on demand and gold standard, and between NNT and gold standard. Absolute measurement error between on demand and gold standard, and between NNT and gold standard was done followed by overall mean measurement error assessment and difference between overall errors of both methods compared to the gold standard, statistical significance was set at a P-value ≤ 0.05 and all tests were two tailed.

<u>Results:</u>

Interclass correlation coefficient within all measurement methods at each point had shown excellent reliability (ICC>0.9).

Pearson correlation coefficient r between on demand and gold standard and between NNT and gold standard has shown very high positive correlation (r>0.9).

Comparison between on demand and gold standard has shown no statistically significant difference (P>0.05) for height (B), height (C) and BL (A,B,C), while there was statistically significant difference (P≤0.05) for height (A) and MD (B,C).

Comparison between NNT and gold standard has shown no statistically significant difference (P>0.05) for all measurements except for BL (C) (P = 0.0198).

NNT have shown less measurement error compared to on demand method (P = 0.0001), when compared to the gold standard direct measurement.

Correlation and comparison between ondemand and direct methods							
Direction	Point	Measurement	Minimum	Maximum	Mean	95% CI	SD
Height	A	On demand	23.150	23.790	23.467	22.672 to 24.262	0.3201
		Direct	23.650	24.100	23.917	23.330 to 24.504	0.2363
		Correlation r	0.9466				
		Measurement error	0.4500±0.1229				
		Significance	P = 0.0240*				
	B	On demand	22.990	24.800	23.970	21.699 to 26.241	0.9143
		Direct	23.830	25.300	24.483	22.624 to 26.343	0.7485
		Correlation r	0.9452				
		Measurement error	0.5133±0.3202				
		Significance	P = 0.1089				
	C	On demand	22.720	23.920	23.277	21.775 to 24.779	0.6047
		Direct	22.820	24.350	23.653	21.730 to 25.576	0.7741
		Correlation r	0.9616				
		Measurement error	0.3767±0.2542				
		Significance	P = 0.1242				
BL	A	On demand	4.200	4.740	4.527	3.813 to 5.240	0.2873
		Direct	4.590	5.000	4.790	4.280 to 5.300	0.2052

		Correlation r	0.9246				
		Measurement error	0.2633±0.1250				
		Significance	P = 0.0676				
	B	On demand	3.260	4.680	4.073	2.254 to 5.892	0.7322
		Direct	3.820	4.780	4.377	3.139 to 5.614	0.4980
		Correlation r	0.9997				
		Measurement error	0.3033±0.2346				
		Significance	P = 0.1545				
	C	On demand	4.130	5.890	5.017	2.830 to 7.203	0.8801
		Direct	4.830	6.050	5.430	3.914 to 6.946	0.6102
		Correlation r	0.9991				
		Measurement error	0.4133±0.2715				
		Significance	P = 0.1188				
MD	B	On demand	4.500	9.100	6.530	0.700 to 12.360	2.3471
		Direct	5.700	9.690	7.403	2.291 to 12.516	2.0580
		Correlation r	0.9989				
		Measurement error	0.8733±0.3073				
		Significance	P = 0.0389*				
	C	On demand	5.090	8.300	6.403	2.223 to 10.583	1.6826
		Direct	5.890	8.860	6.987	2.937 to 11.036	1.6302
		Correlation r	0.9928				
		Measurement error	0.5833±0.2060				
		Significance	P = 0.0391*				

Correlation and comparison between NNT and direct methods							
Direction	Point	Measurement	Minimum	Maximum	Mean	95% CI	SD
Height	A	NNT	23.660	24.020	23.890	23.394 to 24.386	0.1997
		Direct	23.650	24.100	23.917	23.330 to 24.504	0.2363
		Correlation r	0.9587				
		Measurement error	0.02667±0.07234				
		Significance	P = 0.5885				
	B	NNT	23.800	25.200	24.433	22.671 to 26.196	0.7095
		Direct	23.830	25.300	24.483	22.624 to 26.343	0.7485
		Correlation r	0.9996				
		Measurement error	0.05000±0.04359				
		Significance	P = 0.1853				
	C	NNT	22.810	24.320	23.617	21.728 to 25.505	0.7603
		Direct	22.820	24.350	23.653	21.730 to 25.576	0.7741
		Correlation r	0.9994				
		Measurement error	0.03667±0.03055				
		Significance	P = 0.1732				
BL	A	NNT	4.530	4.990	4.760	4.189 to 5.331	0.2300
		Direct	4.590	5.000	4.790	4.280 to 5.300	0.2052

		Correlation r	0.9991				
		Measurement error	0.03000±0.02646				
		Significance	P = 0.1885				
	B	NNT	3.790	4.750	4.353	3.108 to 5.598	0.5012
		Direct	3.820	4.780	4.377	3.139 to 5.614	0.4980
		Correlation r	0.9998				
		Measurement error	0.02333±0.01155				
		Significance	P = 0.0728				
	C	NNT	4.800	6.030	5.407	3.879 to 6.935	0.6152
		Direct	4.830	6.050	5.430	3.914 to 6.946	0.6102
		Correlation r	1.0000				
		Measurement error	0.02333±0.005774				
		Significance	P = 0.0198*				
MD	B	NNT	5.300	9.640	7.247	1.771 to 12.722	2.2042
		Direct	5.700	9.690	7.403	2.291 to 12.516	2.0580
		Correlation r	0.9974				
		Measurement error	0.1567±0.2113				
		Significance	P = 0.3277				
	C	NNT	5.820	8.820	6.940	2.871 to 11.009	1.6380
		Direct	5.890	8.860	6.987	2.937 to 11.036	1.6302
		Correlation r	0.9999				
		Measurement error	0.04667±0.02082				
		Significance	P = 0.0604				

Absolute measurement error between on demand and direct, and between NNT and direct methods			
Direction	Point	On Demand	NNT
Height	A	0.45	0.02667
	B	0.5133	0.05
	C	0.3767	0.03667
BL	A	0.2633	0.03
	B	0.3033	0.02333
	C	0.4133	0.02333
MD	B	0.8733	0.1567
	C	0.5833	0.04667
Mean measurement error		0.4721±0.1536	0.04917±0.04462
Difference in measurement error		0.4229±0.1536	

Sample size calculation:

Sample size was calculated based on a previous study by Ahmed 2021, where correlation coefficient between direct and on demand measurements was a minimum of 0.9. By adopting type 1 error of 5% and a power of 80% a minimum of 7 models are required to reject the null hypothesis that means of the index and reference tests are equal. Sample size was calculated using Medcalc version 19 for windows.

Discussion

In this investigation, two software that had never before been looked at for this purpose were used to assess the linear measurement's accuracy. The measurement error between the two programmes did not significantly differ statistically, although NNT demonstrated reduced measurement error than the on-demand approach ($P = 0.0001$) when compared to the gold standard physical measurements taken by the digital caliper.

This in-vitro study was conducted on the implant bone models where nine anatomical landmarks were identified on each model avoiding any human samples like dried mandibles.

In this research, the gutta-percha rods (size 60, 1.5 mm) were attached on the indicated anatomical landmarks on each model to identify them. Then, the linear measurements—the gold standard—were assessed on each model.

The same linear measurements were evaluated by using the function “Measure Length” of the both software : (NNT) and (OnDemand).

Then, the linear measurements of both soft ware were compared to the gold standard measurements.

The main benefit of this study stems from the use of implant bone models rather than dry mandibles or on humans, where the models were stabilised properly with the avoidance of patients' voluntary or involuntary movements. However, this study evaluated the accuracy of linear measurements on implant bone models that are recorded by using two software programmes avoiding any human or animal biological samples.

The current study focused on two software programmes: NNT software and Ondemand software, among the growing number of CBCT software used to manage DICOM files. By standardising the position of the models, the accuracy and consistency of the linear measurements obtained for this investigation were made possible.

Although the NNT software programme in this study had high accuracy of linear measurements, but this could not be compared to other earlier studies that looked at the validity of various measurements taken with a different cone beam computed tomography equipment and using a different software programmes.[7,8,9,10,12,13]

The degree to which measurements accurately reflect the actual measurements is known as accuracy. Numerous authors have evaluated the precision of CBCT images, but only a small number of studies have looked at how software reconstruction affects the precision of linear measurements.[16]

The present study concluded that comparison between Ondemand and gold standard has shown no statistically significant difference (P>0.05) for height (B), height (C) and BL (A,B,C), while there was statistically significant difference (P≤0.05) for height (A) and MD (B,C). While comparison between NNT and gold standard has shown no statistically significant difference (P>0.05) for all measurements except for BL (C) (P = 0.0198).

The present results are consistent with the findings and results of **Baumgaertel Set al 2009, Periago DR et al 2008, Poleti ML et al 2016 and, Ballrick JW et al 2008** which reported the high accuracy of linear measurements in relation to the gold standard**. (Ballrick *et al* 2008).** [17,18,19,20]

The findings of the current study are consistent with those of a previous study that compared linear measurements of dry mandibular CBCT scans obtained using different software programmes and found no statistically significant difference between the results.[15]

These results are aligned with the results of **Vasconcelos et al. (2015) and Silva et al. (2017)** which conveyed no statistically significant difference between linear measurements via other software programs **(Vasconcelos et al., 2015, Silva et al., 2017, Asma et al 2021, Abou Alnour et al 2023).** The programs investigated by **Vasconcelos et al. (2015)** were KDIS 3D, OnDemand, and XoranCat, and **Silva et al. (2017)** investigated the accuracy of another software program such as Imaging Studio. While **Abou Alnour et al (2023)** investigated fiji J software with Ondemand software program.[11,13,21,22]

The findings of the current study should not be interpreted as showing a full discrepancy in accuracy between the various software packages. However, the findings of this study should be contrasted with those of earlier studies that identified the many causes of linear measurement inaccuracy by various CBCT software.

The main limitation in this investigation and research that the CBCT DICOM files in the current study were produced using a specific CBCT device and set of exposure parameters, opposed to the numerous other CBCT devices, software programmes, and exposure parameters, which may affect the significant results of measurements accuracy and precision.

Conclusions

When compared to physical measurements, linear measurements made using NNT software showed higher precision.

When compared to physical measurements, measurements of anatomical distances using Ondemand software showed lesser accuracy.

NNT has shown less measurement error compared to Ondemand method (P = 0.0001), when compared to the gold standard direct measurements.

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