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The Influence of reduced Bit-Depth on The Accuracy of Linear Measurements of Cone Beam Computed Tomography. Diagnostic Accuracy Study

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ABSTRACT

Purpose: This study aimed to assess the influence of reduced bit depth on CBCT linear measurements accuracy.

Materials & Methods: This study was executed on six implant bone models. On each model surfaces, nine radio-opaque markers "gutta-percha pieces" were glued. CBCT radiographic examination of each bone model were performed. For real measurements, the distance between each two markers was measured using digital caliper. The resultant images were evaluated using Fiji software at 16 and 8 bit-depths.

Results: Intra and inter-observer reliability was more than 0.99. 8 and 16-bit images measurements showed statistically significant difference with (p value<0.05). 16-bit images measurements and caliber ones showed no statistically significant difference (p value>0.05) for Paired T and Wilcoxon tests. 8-bit images measurements and caliber ones showed statistically significant difference p value=0.001 for both Paired T and Wilcoxon tests. Mann-Whitney Test showed no significant

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difference between 16 bit and 8-bit depths regarding the absolute measurement error (AME) where p value>0.05.

Conclusion: This study concluded that the effect of using 8-bit CBCT images on precision of the linear measurements was not translated to the clinical relevance, so general dentist can make benefits from the advantages of that reduced bit depth images to encourage electronic communication of a full image, take up less storage space and rapid image display.

KEY WORDS Measurement accuracy, Cone-beam CT, Fiji.

Introduction

Cone Beam Computed Tomography (CBCT) is a leap in the field of oral and maxillofacial radiography; it has been specifically designed to offer three dimensional scans of the dental and maxillofacial structures. CBCT is a valuable achievement in the field of oral and maxillofacial radiology which all made it one of the key constituents in the field of digital dentistry. [1]

The accuracy of linear measurements in CBCT scanning is a significant parameter to visualize impactions, precise localization of foreign bodies, and assessment of bone condition pre-operative and post-operative to implant insertion. Various researches have been provided on the influence of various parameters on the precision of linear measurements of CBCT scans. As a reference to Ganguli, Ramesh, and Pagni probing the influence of voxel size and fields of view (FOV) on the precision of linear measurements. [2] Their results proved that linear measurements of CBCT scans are precise despite the fluctuations of voxel sizes or FOV settings. Nevertheless, for greater distances, the measurements were less consistent compared to tighter ones. [3]

Radiographic image compression in CBCT scanning is performed aiming to reduce the definite size of the digital image file to conquer a minor space for archiving and storage and to permit rapid transmission or saving on a compact disc or the network, while critical image data are saved. Nonetheless, this may adversely affect the ultimate image quality. [4, 5] Also, specific tools in certain software necessitate the conversion of image bit depth into 8-bit depth to gain benefit from these specific tools. [6]

Image compression can be implemented at altered distinctive bit depths. The bit depth of a CBCT imaging is the number of shades of gray offered to exhibit differences in attenuation. Advanced bit depths and resolutions intensify the diagnostic precision and accuracy as well as image details visualization. [7, 8] Contrastingly, they necessitate a larger space for storage, greater hardware competencies, and longer period of time for data transfer and monitor display. [9]

Therefore, this study aimed to broaden the investigation on the influence of bit depths alteration on the precision of linear measurements in CBCT scans.

Materials & Methods

The study was accomplished on six implant bone models obtained from Nissin Dental Products, Nissin Dental Products, Inc.is a Japanese manufacturer of dental training and simulation systems, anatomical and patient educational models, as well as dental materials.

A-study population

1. Data collection:

Data collection was planned before the index test and reference standard have been performed (prospective study). A sample size calculation was made prior to conducting this study using the P.S software version 3.1.2 according to the results of a previous study by [10], whereas, the mean difference between the CBCT measurements and the physical mandible measurements were found to be 0.24 mm with a standard deviation of 0.49 mm. Based on these findings with the assumption of a type I error of 0.05 and a power of 0.8, a sample of 60 readings per group is required to detect a significant difference between the groups of the current study.

TABLE 1. Paired sampled p-value significance with confidence interval 95% of the tested values

	No.	p-value*	95% confidence interval		Sig
			Lower	Upper	
16-bit vs 8 bit	60	3.65E-05	0.094	0.25	Yes
8-bit vs caliber	60	0.001	-0.28	-0.07	Yes
16-bit vs caliber	60	0.96	-0.067	0.064	No

* *≤ 0.05*

TABLE 2. Median and p-value significance of Wilcoxon signed rank test

	No.	p-value*	Median		Sig
16-bit vs 8 bit	60	1.07E-05	5.91	5.61	Yes
8-bit vs caliber	60	0.001	5.61	5.97	Yes
16-bit vs caliber	60	0.98	5.91	5.97	No

* *≤ 0.05*

B-Test methods

Sample preparation: The implant bone models were randomly numbered from 1 to 6 by the principal researcher, and then on each model at the anterior region a total of nine positions were selected and marked on the model with a permanent blue marker. At each marked position, radio-opaque 'RO' marker size 60 "gutta-percha" was glued to the selected landmarks using a cyanoacrylate gel on the model surfaces as following; three markers on the facial surface occlusally (at the alveolar crest), three apically (at the inferior border of the model) both were on the same vertical line and perpendicular to the horizontal plane, while the rest of RO markers were placed on the lingual surface opposing the occlusally placed ones. All at different distances for each model. Figure 1

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), voxel size 0.15mm with standardized tube current and voltage of 12.5 mA and 90 kVp. Then, a total of sixty linear measurements (ten for each model) were taken from CBCT images for each bit depth. The ten measurements were obtained via four Mesio-Distal "MD" Width measurements, three Bone height measurements and three Bucco-lingual "BL" Bone Thickness measurements for each model.

a- 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. Figure 2a

b- Bucco-lingual "BL" Bone Thickness: this was measured as the distance from superior end of the oc-

TABLE 3. Mean, standard deviation and p value of Absolute Measurement Error (AME)

	16-bit		8-bit		P- value
	Mean	SD	Mean	SD	
AME* (mm) width	0.14	0.12	0.2	0.2	0.51
AME (mm) thickness	0.14	0.14	0.25	0.23	0.11
AME (mm) height	0.22	0.23	0.39	0.41	0.24

*≤ 0.05

Absolute Measurements Errors

clusally placed facial gutta-percha piece to superior end of the gutta-percha piece placed on the lingual surface. Figure 2b

c- 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. Figure 2c

Index test: The index test in the present study was the CBCT linear measurements at 16 and 8 bit-depths, attained from CBCT DICOM files which were exported to NIH Fiji software (National Institutes of Health, Bethesda, MD). Changing the bit depth of the displayed CBCT image was done by typing on the software status bar Image>Type>8-bit. Figure 3 Adjustment of the optimum measuring condition of the image was done by typing Image>Adjust>Brightness and Contrast.

CBCT linear measurements were taken on each of the marked areas as the image slices with the radio-opaque markers are in the best visible condition (optimum visibility) using distance icon on the status bar, at 16 and 8 bit-depths, in each area. 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 which were achieved as follow Image>Stacks>Reslice, while width measurements were taken on the axial images.

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.

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 the principal researcher, they were taken twice with one-week interval and the average of both readings was considered the gold standard. While for CBCT linear measurements (index test) they were taken twice by the aforementioned researcher who has 10 years of experience in the field of oral and maxillofacial radiology with one-week, and once more by another radiologist who has more than 10 years of experience.

To guarantee blinding in this study, the direct measurements were tabulated and kept hidden from the investigators while they were taking the CBCT measurements, and each investigator was blinded to the other one's readings.

C-Statistical analysis: The Statistical analysis done on excel 365 with real statistics resource pack v 7.1 as add in. data was tested for normality using Shapiro-Wilk test. Intra- and interclass correlation coefficients were calculated for each parameter to assess the reliability of measurements with the following scale; 0.50: poor, between 0.50 and 0.75: moderate, between 0.75 and 0.90: good, above 0.90: excellent. Paired T test and Wilcoxon signed rank tests were applied to test the measured values. with Alpha value 0.05, confidence interval 95% thus P value

Fig. 1. Top view of Implant bone model with Gutta-percha pieces attached on the facial and lingual surfaces at the predetermined positions in incisors region.

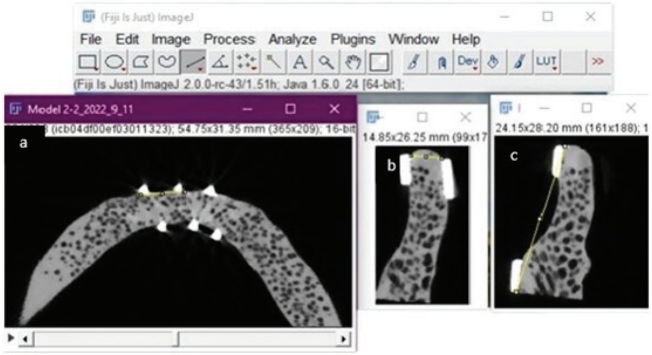

***Fig. 2.** CBCT linear measurement of the model width (a), thickness (b) and height (c)*

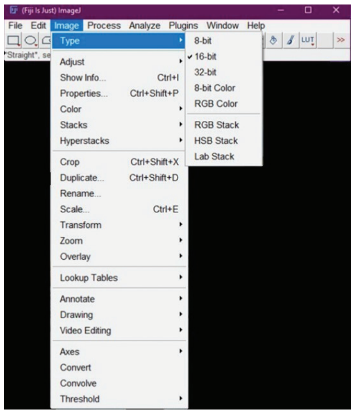

***Fig. 3.** Fiji status bar illustrating the sequence of image bit depth alteration.*

less than 0.05 is consider Significant. Absolute measurement error (AME) was calculated according to the following equation: Absolute measurement error (AME) = [the tested variant– the gold slandered], and was presented as mean and standard deviation where the significance of the difference was tested by using Mann-Whitney Test, p value less than 0.05 is considered significant.

Results

The intra and interclass correlation coefficient was used to estimate the reliability of measurements made by the same observer and between the two observers. Inter class correlation coefficient was calculated between the two observer's different measurements reading separately on the 8 bit and 16-bit images and both yield strong correlation with ICC value 0.99. Intraclass correlation coefficient was also calculated between the two readings of the 1st observer and the results showed strong correlation with ICC value 0.99.

Checking data distribution using Shapiro-Wilk test showed non-normal (non-parametric) distribution. Paired T and Wilcoxon signed rank tests were applied to test the measured values. with a significance level of 0.05 (α value) for all variables and measurements. 16-bit images measurements and 8-bit ones showed statistically significant difference with p values of (3.65x10-05 and 1.07 x10-05) for Paired T and Wilcoxon signed rank tests respectively. 16-bit images measurements and caliber ones showed no statistically significant difference (0.96 and 0.98) for Paired T and Wilcoxon signed rank tests respectively. 8-bit images measurements and caliber ones showed statistically significant difference p=0.001 for both Paired T and Wilcoxon signed rank tests (table 1&2).

Mann-Whitney Test showed no significant difference between 16 bit and 8-bit depths regarding the absolute measurement error (AME) with p= 0.51 for width measurements, 0.11 for thickness measurements and 0.24 for height measurements. Mean and standard deviation were shown in table 3.

Discussion

Measurement accuracy (validity) is stated as the standard to which a measurement signifies the actual value of a parameter (physical versus image measurements).[11] Various authors have assessed the linear measurement accuracy of CBCT images,[3] but to our knowledge no study has addressed the influence of bit depth on measurement accuracy of CBCT images.

Image characteristic is affected by the gray scale bit depth of the CBCT system used. The contemporary CBCT systems uses gray scale bit depth ranging from 12-bit to 16-bit gray scale.[12] By using lower bit depth systems, HU allocated for dense materials image voxel may be reduced due to bit depth saturating at high CT number,[13] which intern could lead to un precise measurements. Since the computer monitors may be presented in lesser grayscale and some image processing modes can be only working with 8bit depth images, some people suppose that it would not be meaningful to exceed these levels. [14] Nonetheless, this methodology collapses to take into consideration that the reconstruction software uses the bigger bit depth to increase its primary and secondary reconstructions, resulting in a neater and more well-defined volume. [15]

Many studies have estimated the consequences of using diverse imaging parameters and/or protocols on CBCT linear measurement precision. Some authors altered one or more selected parameter intentionally and discovered no results on measurement precision. This involved voxel size (Ganguly et al., 2016; Luangchana et al., 2015; Tolentino et al., 2018),[2, 10, 16] scan times (Al-Ekrish,2012; Waltrick et al., 2013),[17, 18] software castoff for analysis and evaluation, (Tolentino et al., 2018; Vasconcelos et al., 2015),[16, 19] and display monitor (Al-Ekrish et al., 2013).[20] Elshenawy et. al. 2019 assessed the influence of using altered FOVs on the accuracy of linear measurements in CBCT imaging and concluded that augmenting the FOV size together with voxel size could unfavourably affect the precision of CBCT linear measurements, particularly when small distances are to be considered. [21] An author probed the usage of two different CBCT units and found no distinction in measurement precision (Luangchana et al., 2015).[10] Torres et al. (2012) advocated a voxel size of 0.3 to 0.4 mm3 as a good conciliation between image quality and reduced radiation exposure.[22]

In the current study, we appraised the consequences of altering the CBCT image bit depth on the accuracy of linear measurements and according to Paired t-test we found a statistically significant difference between 8-bit depth image measured values in comparison to the caliber as a gold slandered, while there is no statistically significant difference between 16-bit depth measured values and the caliber. There is an absolutely statistically significant difference between the measured values obtained with 16- and 8-bit depth images. Measuring the AME significant difference between the current study tested variants (16 and 8 bits) and the gold standard revealed no clinically significant difference between the tested variants as $p>0.05$ for height, thickness and width measurements which is the maximum clinically accepted and permissible relative error in the medical field. [23]

Since the image export facilities do not always deliver the same image resolutions as the one saved in the original CBCT system own software; it could be interpreted as a higher bit depth image or been exported as a lower bit depth one, so regarding the linear measurement accuracy we can make benefits from using 8-bit depth images to take up less storage space and rapid image display without interpreting the statistical difference to the clinical applications. [9] Pour et al., 2020 investigated the result of using variable bit depths (12- and 15-bit depths) in the precise detection of the inferior alveolar canal (IAC) in CBCT images and concluded that there was a significant difference between the aforesaid bit depths for suitable IAC visualization when combined with diminution of image resolution.[24]

Conclusion

Our study concluded that the effect of using 8-bit CBCT images on precision of the linear measurements was not translated to the clinical relevance, so general dentist can make benefits from the advantages of that reduced bit depth images to encourage electronic communication of a full image, take up less storage space and rapid image display.

Declarations

There are no sources of funding or financial conflict of interest.

This article does not contain any studies with human or animal subjects performed by the any of the authors. R

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