RESEARCH NOTE

Accuracy of linear measurements using low dose cone beam computed tomography protocol versus direct skull linear measurements: An *in vitro* study [version 1; peer review: 2 not approved]

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Abstract

Background: Cone beam computed tomography (CBCT) imaging has been widely used for different dental applications over the last few years. It delivers a high dose of radiation compared to conventional imaging modalities. This study aimed to compare the accuracy of linear measurements conducted using a low dose CBCT protocol in comparison with direct skull linear measurements.

Methods: Ten dry human skulls were included in the study. 12 linear measurements were measured directly on each skull between 23 chosen anatomical landmarks using a digital calliper. Radio-opaque markers were then glued on these anatomical landmarks. Each skull was then scanned using low dose CBCT protocol operated at 90 kVp, 7.1 mA, for 9 sec.

Results: There was no statistically significant difference in the accuracy of linear measurements conducted using the low dose CBCT protocol when compared with direct linear measurements. Relative Dahlberg Error value ranged from 0.8% to 1.9%.

Conclusion: Reducing mAs using a low dose CBCT protocol does not affect the accuracy of linear measurements used in craniofacial imaging tasks as compared with those taken directly on the skull by a digital calliper.

Keywords

Cone Beam CT, Linear Measurements, Low Dose.

Open Peer Review

Approval Status

	1	2
version 1		
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Any reports and responses or comments on the article can be found at the end of the article.

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Author roles: **Al Abbady NA:** Investigation, Writing – Review & Editing; **Hamdy RM:** Supervision; **El Dessouky SH:** Supervision

Competing interests: No competing interests were disclosed.

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Introduction

Two-dimensional (2D) imaging techniques have been used in dentistry since 1896. Despite its long clinical success, 2D imaging possesses a number of problems, including superimposition and magnification, which may result in interpretation problems of the images, whether it actually represents the anatomical structures and/or pathological conditions¹.

Lately, dental imaging techniques have advanced with the introduction of tomography. Cone beam computed tomography (CBCT) is the most recently introduced tomography that greatly approximates the accepted standard for three-dimensional (3D) maxillofacial imaging that can guide diagnosis, treatment planning, and follow-up^{2,3}. CBCT produces accurate images, leading it to be utilized for many dental fields, such as surgical, endodontics, prosthodontics, and orthodontics^{4,5}.

The radiation dose imparted by a CBCT examination varies as it depends on many variables, such as the type of the CBCT machine, the chosen field of view (FOV), the number of basis images, the mode of exposure (continuous or pulsed), and the exposure parameters used for scanning⁶. Varying the machine's exposure parameters will result in considerable reductions in radiation dose, which is considered advantageous from a biological point of view. However, theoretically reductions in radiation dose may possibly lead to under sampling artifacts or quantum noise that could adversely affect the diagnostic quality of the images, thus affecting the accuracy of measurements obtained from these images⁶.

This study aimed to compare the accuracy of linear measurements conducted using a low dose CBCT protocol in comparison with direct skull linear measurements.

Methods

The current study was conducted on ten dry human skulls that were obtained from the Anatomy Department, Faculty of Medicine, Cairo University.

The study was approved by the Research Ethics committee of Faculty of Dentistry, Cairo University.

Skull preparation

Using a blue permanent marker, 23 anatomical landmarks were identified on each skull by marking small points representing each landmark, then 12 linear measurements were conducted directly on the skull between these anatomical landmarks using an electronic digital calliper (Allendale Electronics Ltd, Hertfordshire, UK) (Figure 1). These linear measurements are shown in Table 1.

Gutta-percha cones, size 80, were cut into 2 mm rod and were glued over the drawn anatomical landmarks on the skull, to be used as radiopaque radiographic markers. After gutta-percha application, the skulls were covered with block of

Figure 1. Example of direct linear measurements between Or (Rt) and Or (Lt) using digital calliper.

Table 1. Linear measurements.

Linear measurements	Description
ANS-PNS	From the most anterior point on the maxilla at the nasal base to the tip of the posterior nasal spine of the palatine bone
OR F-OR F	From the middle of the inferior border of the right orbital foramen to that of the left side.
Or-Or	From the lower most point on the lower margin of the right orbit to that of the left side.
MORw-MORw	From the middle of the right medial orbital wall to that of the left side.
LORw-LORw	From the middle of right lateral orbital wall to that of the left side.
Or-P	From the lower most point on the lower margin of the right orbit to the highest point on the upper margin of the external auditory meatus of the right side.
ZY F-ZY F	From the middle of the inferior border of the right zygomatic foramen to that of the left side.
GP-GP	From the medial wall of the right greater palatine foramen to that of the left side.
CO-CO	From the most superior posterior point on the head of the mandibular condyle of the right side to that of the left side.
GO-GO	From the middle of the curvature of the angle of the mandible of the right side to that of the left side.
ANT R-ANT R	From the most posterior point on the curve of the right anterior border of the ramus to that of the left side.
Mental F-Mental F	From the inferior border of right mental foramen to that of the left side.

pink wax of 10-12 mm thickness, which was adapted carefully on the facial surface of the skull from the inferior border of the mandible till above the frontonasal suture for soft tissue simulation^{7,8}.

CBCT radiographic examination

CBCT examinations were performed using Planmeca ProMax 3D Mid CBCT unit (Planmeca, Helsinki, Finland).

The skulls were mounted on the machine, and the laser beams were adjusted to centralize the skull within the scanning field. The skulls were then scanned with a low dose protocol of 90 kVp, 7.1 mA, 9 sec, 600 μ m voxel size and 20×20 cm FOV.

After scanning each skull, the reconstructed images were viewed on the computer screen using Romexis Viewer 4.4.O.R software. The same linear measurements conducted on the skulls were conducted on CBCT orthogonal images (Figure 2; Table 1).

The CBCT and linear measurements were conducted by two observers; the first observer repeated the reading two times with a time interval of one month between each reading.

Statistical methods

Statistical analysis was performed using SPSS (version 17), and Microsoft office Excel was used for data handling and graphical

presentation. For assessment of the agreement between all measurements Dahlberg error (DE) and Relative Dahlberg Error (RDE) were used together with Intra-class Correlation Coefficients (ICC), including the 95% confidence limits of the coefficient calculated assuming analysis of variance two-way mixed model ANOVA with absolute agreement on SPSS. For both inter and intra observer reliability analysis, DE and RDE were used with ICC, including the 95% confidence limits of the coefficient. Significance level was set at $P < 0.05$ and two tailed test assumption was applied.

Results

There was no statistically significant difference between the low dose CBCT measurements when compared to direct skull measurements. Using the low dose protocol, mean DE was recorded as 0.83. RDE ranged from 0.8% to 1.9% for almost all measurements (Table 2).

Reliability

The ICC for inter- and intra-observer reliability analysis for all measurements were excellent, ranging from 0.96–1.00.

Discussion

For many CBCT machines, it is possible to optimize one or more of the investigated exposure parameters and therefore reduce the patient's radiation dose, while maintaining diagnostic image quality and accuracy for some diagnostic tasks^{9,10}. Accordingly, the current study aimed to investigate the effect of reducing the

Figure 2. Cone beam computed tomography sagittal image showing ANS-PNS horizontal linear measurement, measuring 50.24 mm.

Table 2. Mean and SD of measured, direct skull and measured low dose value, DE, RDE, and ICC between direct skull and low dose protocol. SD, standard deviation; DE, Dahlberg error; RDE, Relative Dahlberg error; ICC, Intraclass Correlation Coefficient.

Linear measurements used		Mean	SD	DE	RDE	Mean of difference (Reference - measured)	SD of the difference	ICC	95% confidence limits	
									Lower	Upper
ANS-PNS	Direct Reference	51.35	2.88	0.99	1.9%	0.83	1.19	0.94	0.70	0.99
	Low Dose	50.52	2.92							
ORF-ORF	Direct Reference	54.04	4.94	0.94	1.7%	0.47	1.32	0.98	0.93	1.00
	Low Dose	53.56	4.95							
Or-or	Direct Reference	64.80	4.54	0.59	0.9%	-0.37	0.80	0.99	0.96	1.00
	Low Dose	65.17	4.70							
MOR-MOR	Direct Reference	21.37	1.51	0.73	3.4%	-0.42	0.99	0.89	0.58	0.97
	Low Dose	21.79	1.69							
LOR-LOR	Direct Reference	97.08	3.91	0.86	0.9%	0.09	1.28	0.98	0.90	0.99
	Low Dose	97.00	4.05							
Or-P	Direct Reference	82.35	4.23	0.65	0.8%	-0.30	0.92	0.99	0.96	1.00
	Low Dose	82.90	4.59							
ZYF-ZYF	Direct Reference	96.03	6.06	0.90	0.9%	-0.69	1.14	0.99	0.94	1.00
	Low Dose	96.72	5.97							
GP-GP	Direct Reference	30.46	2.19	0.56	1.9%	0.37	0.75	0.97	0.86	0.99
	Low Dose	30.09	2.17							
CO-CO	Direct Reference	99.61	3.82	1.04	1.0%	-0.75	1.34	0.96	0.83	0.99
	Low Dose	#####100.36	3.68							
GO-GO	Direct Reference	92.78	7.27	1.23	1.3%	-1.03	1.52	0.99	0.92	1.00
	Low Dose	93.67	8.06							
ANT R-ANT R	Direct Reference	82.70	2.65	0.80	1.0%	-0.53	1.05	0.95	0.81	0.99
	Low Dose	83.23	2.68							
MENTAL F-MENTAL F	Direct Reference	44.82	2.18	0.62	1.4%	-0.53	0.74	0.95	0.75	0.99
	Low Dose	45.35	1.96							

mA and exposure time on the accuracy of CBCT linear measurements as compared with a digital calliper.

The results of the present study revealed that the RDE of almost all the measurements ranged from 0.8% to 1.9%, which didn't exceed 5%. This percentage has been considered as clinically

acceptable and permissible relative error in the medical field, as reported by Tarazona-Álvarez *et al.*¹¹ and Rogn *et al.*¹².

The highest accepted RDE was recorded on the MORw-MORw horizontal linear measurements, 3.4%. The inverse relation between the RDE and the mean of the gold standard of

MORw-MORw among all conducted measurements clearly explained its high RDE relative to its low mean of gold standard, which was 21.37%.

The results of Hidalgo *et al.*¹³ was in accordance with this study as it showed that the coefficient of variation for measurements was between 1.0% and 1.3% using different tube voltage and tube current. They concluded that a low dose protocol of 80 kV and 3 mA could be used for clinical practice, which represented as much as a 50% dose reduction compared with manufacturer's recommendations, while giving the operator the freedom to adjust the mA by +0.5 mA on the basis of their judgments of the patient's size.

Further confirmation was obtained from Vasconcelos *et al.*¹⁴. They concluded that there was no association between the increase in milliamperage and the reliability of the measurements, and recommended the use of low dose protocols when the purpose of the examination is to obtain linear measurements. They added that the 2 mA and 4 mA should be avoided because they could cause degradation to the image and could affect the visualization of the mandibular cortical bone.

In accordance with the current study, Al-Ekrish⁶ results revealed that on decreasing exposure time the reliability and dimensional accuracy of linear measurements for implant site evaluation were not affected.

In conclusion, the results of this study support the idea that decreasing mA and/or exposure time will not affect the accuracy of linear measurements when craniofacial imaging tasks is required.

Data availability

Underlying data

Open Science Framework: Dataset 1. Measurements for all 12 linear measurements for both methods: digital calliper and CBCT for both repeats of the experiment, and inter/intra observer measurements, <https://doi.org/10.17605/OSF.IO/NH8FE>¹⁵.

Extended data

Open Science Framework: Dataset 1. Additional images of the process of linear measurements using both the digital calliper and CBCT, <https://doi.org/10.17605/OSF.IO/NH8FE>¹⁵.

Data are available under the terms of the [Creative Commons Zero "No rights reserved" data waiver](#) (CC0 1.0 Public domain dedication).

Grant information

The author(s) declared that no grants were involved in supporting this work.

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Maman Hermana

Petronas University of Technology, Seri Iskandar, Malaysia

Maya Genisa

YARSI University, Central Jakarta, Indonesia

1. Direct measurement is not comparable technically to the slicing measurement method of landmark point.
2. Definition of statistical significance needs to be explained in more detail from statistical data.
3. Dose/exposure is not a variable of this work. Needs additional work by varying the dose/exposure to support the conclusion.

Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I have a good background in physics and experienced in medical physic and medical imaging work

We confirm that we have read this submission and believe that we have an appropriate level of expertise to state that we do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 02 Mar 2020

Nora Al Abbady, faculty of dentistry cairo university, Cairo, Egypt

1 - The direct and the cbct measurements were taken at the same points
2 - Didn't get what explanation you need more for statistical significance ...would pls clarify more
3 - We used different exposure one normal and the other low dose and we have another paper with ultra low dose
Could you pls explain to me what results u need more to support conclusion
Thanks in advance

Competing Interests: No competing interests were disclosed.

Reviewer Report 15 February 2019

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Plauto Christopher Aranha Watanabe

Department of Stomatology, Public Health and Forensic Dentistry, University of São Paulo, Ribeirão Preto, Brazil

The study "aimed to compare the accuracy of linear measurements conducted using a low dose CBCT protocol in comparison with direct skull linear measurements". I have seious doubts if "CBCT protocol operated at 90 kVp, 7.1 mA, for 9 sec" is really low dose CBCT. The authors cite Hidalgo *et al.*¹³ that used 80 kV and 3 mA and Vasconcelos *et al.*¹⁴ that used 2, 4, 6.3, 8, 10, 12, 15 mA and 60 kV, 10.8 seconds. Another problem, it was that the skulls not were placed in a polystyrene box filled with water before the CBCT examination to simulate soft tissue attenuation. This situation would cause more artifacts on the tomographic images. So, the conclusion is not fully real.

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Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

No

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Dental radiology area

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Comments on this article

Version 1

Reader Comment 30 May 2021

Menna Attia, Alexandria University, Faculty of medicine, Egypt

Dear authors,

I recommend publishing a further work on this article in a forensic journal and change the title of "low dose CBCT". Imitation of soft tissue is a good idea. You may employ the suggestions of the

second reviewer or use clay for example. This type of research is important and lacking in forensic medicine.

The high dose vs low dose CT is not an issue in autopsy cases albeit the image quality and precision of measurements are paramount. Nevertheless, the relatively elevated dose due to the high kV and mAs settings when combined with a large FOV attains a dose range which is comparable with low-dose MSCT protocols (Pauwels et al. 2011; Loubele et al., 2006).

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Competing Interests: None

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