Accuracy of Linear Measurements of Ultra-Low Dose Cone Beam Computed Tomography and Digital Panoramic Radiography Performed on Mandibular Anaesthetic Landmarks Versus Real Mandibular Measurements: A Diagnostic Accuracy Study

Hala Wafik El Fayoumy[1], Hoda Abd El Kader Saleh[2], Mohamed Khalifa Zayet[2], Iman Dakhli[3]

[1]Student, [2]Professor, [3]Associate Professor, Oral and Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University

Abstract

Aim: This study was conducted to evaluate the accuracy of linear measurements performed on mandibular anaesthetic landmarks obtained by ultra-low-dose cone beam computed tomography and digital panoramic radiography in comparison with real measurement on dry mandible.

Method: A total number of nine dry human mandibles were selected and mandibular anaesthetic landmarks were marked using gutta-percha. The dry mandibles were submitted for digital panoramic radiography and cone beam computed tomography with mini-dose parameters using the SOREDEX CRANEX™ 3Dx unit, linear measurements were performed on SCANORA Lite image viewer and on Demand 3D viewer. The real linear measurements were measured using digital caliper.

Results: There was a statistically significant difference in all measurements performed on digital panoramic radiographs,reformatted panoramic images underestimate real linear vertical measurements without significant difference, the absolute error for the cross-sectional views of CBCT ranged from 0.0001 to 1.44mm for mandibular foramen linear measurements, using mini-dose parameters did not affect image quality nor measurements accuracy.

Conclusions: Linear measurements driven from CBCT cross-sectional images using On Demand software are accurate and have the lowest error value; therefore it is considered one of the most important imaging modality for preoperative surgical site assessment.

Keywords: *Cone Beam Computed Tomography, Ultra-Low Dose, Reformatted Panoramic Images, Digital Panoramic Radiography.*

Introduction

One of the most important mandibular anatomical landmarks in the mandible is the inferior alveolar nerve and its' branches which can be damaged during surgical procedures. Also, the success of any surgical procedures depends on the proper localization of mandibular foramen to achieve excellent anaesthesia with minimum patient discomfort. Therefore the dentist must be able to localize it prior to any dental procedure.[1]

Panoramic radiography is one of the most commonly used extraoral techniques which provides a view of the maxillo-mandibular area. It provides a view of the surgical site and the adjacent anatomical structures such as the mandibular canal and the mental foramen. Other

Corresponding Author:
Hala Wafik El Fayoumy
Student, Oral & Maxillofacial Radiology Department, Faculty of Dentistry, Cairo University
Address: 8/2 5th Sector Maadi Nerco/Cairo-Egypt
e-mail: hala.wafik@dentistry.cu.edu.eg
Mobile: 002-01007000267

advantages of this technique include a lower radiation dose to the patient and a relatively shorter acquisition time.[2]

However, panoramic radiography has its limitations such as magnification, low image resolution when compared to periapical radiography, it also gives two-dimensional images without any sectional information. Because of a relatively thin focal trough especially in the anterior region, this technique is sensitive to head positions. Mistakes due to the patient's position could increase errors in measurements questioning the accuracy of this technique.[3, 4]

Several authors found that there was no significant difference between real distance measurements and panoramic measurements for different mandibular posterior locations using dry human mandibles. Also, the distances measured by panoramic radiography were closely correlated with those measured by cone beam computed tomography (CBCT). A strong correlations between panoramic radiography and CBCT in measurements of alveolar bone height in the regions of the maxillary sinus, nasal fossa, mandibular canal, and mental foramen was reported. [5]

Cone beam computed tomography is an imaging modality that uses a cone-shaped X-ray beam and allows the acquisition of volumetric data in a single rotation around the object to produce a series of two and three-dimensional images using the cone-beam algorithm. It allows three-dimensional visualization, eliminates the drawbacks of two-dimensional imaging, and produces images of higher resolution.Ultra-low-dose cone beam computed tomography is a recommended option for clinicians due to the decrease in radiation exposure to patients, imaging doses must be kept as low as reasonably achievable.[6,7, 8]

Despite the extended application of both digital panoramic radiography and ultra-low-dose cone beam computed tomography in the various dental fields, little work has been done to assess and compare the role of these imaging modalities in mandibular landmark localization and also to evaluate their diagnostic accuracy in relation to real measurement.

Materials and Method:

Inclusion and Exclusion Criteria: A total number of nine dry human mandibles obtained from the Anatomy Department, Faculty of Medicine, Cairo University, were included in the study. The Selection of the human dry mandibles was independent of age, gender and race. They were intact, free from any bony defects, fractures, pathology. Either dentulous or edentulous mandibles. Any fractured mandible or mandibles with pathological lesions were excluded. All the selected eligible mandibles will be included in the study forming Consecutive series. This research was approved by the Research Ethics Committee and Medical Biostatistics Unit, Faculty of Dentistry, Cairo University.

Setting and Location: Procedures of the study including mandibles preparations regarding the anatomical landmarks and measurements of the gold standard were done at Oral and Maxillofacial Radiology department, Faculty of Dentistry, Cairo University. Procedures of imaging process, data acquisition, and software manipulation were performed at Ekram Radio-Diagnostic Centre (El Sheikh Zayed, Giza, Egypt).

Technical Information:

A. The pre-analytical phase: Mandibular anaesthetic landmarks were identified on each dry mandible and were marked using gutta-percha.

B. The analytical phase: The nine human dry mandibles were submitted for:

1. **Digital Panoramic Radiography:** Panoramic radiographs were obtained using the **SOREDEX CRANEX™ 3Dx unit** (Tuusula, Finland). The exposure parameters were 8mA, 63kV, and 16.4 sec exposure time. Panoramic images were imported to **SCANORA Lite, image viewer** (SCANORA software, Soredex Corp, Helsinki, Finland). (Figure 1, 2).
2. **Cone Beam Computed Tomography (CBCT): SOREDEX CRANEX™ 3Dx unit** was used in this study. Images were acquired at a single rotation. SOREDEX® MiniDose parameters were used. The exposure parameters were 3.2mA, 90kV and 2.3 sec exposure time to take the advantage of 3D data in dose sensitive cases like children, or reduce the radiation dose for the patient. Cone beam computed tomography images were imported to **OnDemand 3D viewer** (OnDemand 3D Software, Cyberimed, Korea). (Figure 3, 4, 5).

C. The post analytical phase: The direct measurements with digital caliper have been used widely as a reference standard based on its frequent usage in similar studies assessing the accuracy of

linear measurements obtained by different imaging modalities[9]. The real linear measurements were measured in millimeter on dry mandibles using **digital caliper** (Mitutoyo Corp., Kawasaki, Japan) and were compared with measurements obtained from both techniques. All measurements were taken twice with one week interval and the mean of each measurement was calculated.

Sample Size Calculation: A paired T-test power calculation was used to detect the proper sample size. Mean differences and standard deviations were estimated according to **Patil et al. 2015**[1] based on the difference in distances measured on dry mandibles between different radiographic techniques. The results showed that a total sample size of 9 mandibles was adequate to detect a mean difference (Effect size) between study groups (radiographic techniques) of 1.66 mm (SD=1.56) with a power of 80% and a two-sided significance level of 5%.

Descriptive Analysis: Linear measurements were described in terms of mean, median, standard deviation (SD), and range according to each group.

Comparative Analysis:

Absolute Error was calculated based on the following equation:

$$Technique\ reading - Real\ reading$$

Relative (Percentage) Error in linear measurements was calculated based on:

$$\frac{Absolute\ Error}{Real\ reading} \times 100$$

Correlation Analysis: To assess the correlation between real measurements with linear measurements that are normally distributed, Pearson's Correlation Coefficient was applied. To assess the correlation between real measurements with linear measurements that are not normally distributed, Spearman's Correlation Coefficient was applied.

The significance level: It was verified at $P \leq 0.05$. The results are considered to be statistically significant if the p-value was less than 0.05.

The statistical package used for this study: R statistical package[10], version 3.3.1 (20-12-2018). Copyright (C) 2018. The R Foundation for Statistical Computing (Statistical analysis was performed with R statistical package, version 3.3.1 (20-12-2018) Vienna, Austria).

Results and Discussion

Regarding mandibular foramen linear measurements from the middle of superior border of mandibular foramen till sigmoid notch (line ab):Digital panorama mean measurement showed a statistically significant difference compared to that of real measurement on the left side, while on the right side both digital and reformatted panorama mean measurement showed a statistically significant difference compared to that of real measurement. (Table 1).

The results of the present study showed no statistically significant difference between real linear measurements derived from the digital caliper and linear measurements obtained from reformatted panoramic images except for measurement from the middle of the superior border of the mandibular foramen till sigmoid notch (line ab) on the right side (p-value 0.0234). However, this difference is minimal and generally the reformatted panoramic images underestimate real linear measurements. This comes in accordance with **Lascala et al., 2004** [11], who performed linear measurements on dry human skulls, they concluded that the real distances measured on dry skulls were always larger. However, **Beshtawi et al., 2020**[12], found statistically significant differences in all measurements derived from reformatted panoramic radiographs.

Regarding mandibular foramen linear measurements from middle of anterior border of mandibular foramen till middle of posterior border of mandibular foramen (horizontal diameter): CBCT mean measurement showed a statistically significant difference compared to that of real measurement on the left side, while on the right side, digital panorama mean measurement showed a statistically significant difference compared to that of real measurement.

Linear measurements performed on cross-sectional views showed no statistically significant difference when compared to real linear measurements except for horizontal diameter measurement of the mandibular foramen on the left side (p-value 0.0415). Cross-sectional views showed sometimes overestimation and sometimes underestimation when compared to real linear measurements. **Baumgaertel et al., 2009** [13], **Alamri et al., 2012,**[14] **and Tarazona-Álvarez et al., 2014**[15] have explained the reasons for over and underestimation in

CBCT measurements which might be referred to the software used or the partial volume effect which occurs when a voxel is occupied by two structures with different densities and the voxel reflects an average density.

Regarding linear measurements from middle of midline till middle of anterior border of mental foramen: Left side, digital panorama mean measurement showed a statistically significant difference compared to that of real measurement. Right side, Digital panorama and CBCT mean measurements showed a statistically significant difference compared to that of real measurement. (Table 2).

Measurements that were taken from the midline till mental foramen were severely underestimated on digital panoramic images(with 1:1 magnification), these differences may be attributed to positioning errors, finding in agreement with **Rondon et al 2014**[16]. On the other hand **Langlois et al., 2011**[17], stated that digital panoramic radiographs are reliable for performing linear measurements, as there was no difference among the measurements obtained with the dry specimens.

The current study showed that the absolute and relative error for the cross-sectional views of CBCT ranged from 0.0001 to 1.44mm (0.38% to 1.91%). This comes in agreement with **Lagravère et al., 2008**[18] who evaluated the accuracy of linear measurements in CBCT images and found a mean measurement error less than 1 mm. Reformatted panoramic images showed an absolute error ranging from 0.01 to 0.87 mm. **Lupi et al., 2018,**[19] stated that geometric distortion in reformatted panoramic images can entail a relative error of up to 10%.In contrast, the digital panoramic images showed the highest mean measurement error ranging from 0.08 to 2.11 mm.

In the current study; using ultra-low-dose CBCT (by reducing the milliamperage setting 3.2 mA) did not lower the image quality nor the accuracy of linear measurements. **El Sahili et al., 2018,**[20] found high degrees of concordance between low and high dose images, and images taken at lower milliamperage settings showed good diagnostic quality.

Assessment of intra and inter-observer reliability for linear measurements of mandibular and mental foramina (showed very strong agreement range from 0.91–0.100 by using Intra-class Correlation Coefficient, statistical significance (p-value ≤ 0.05).

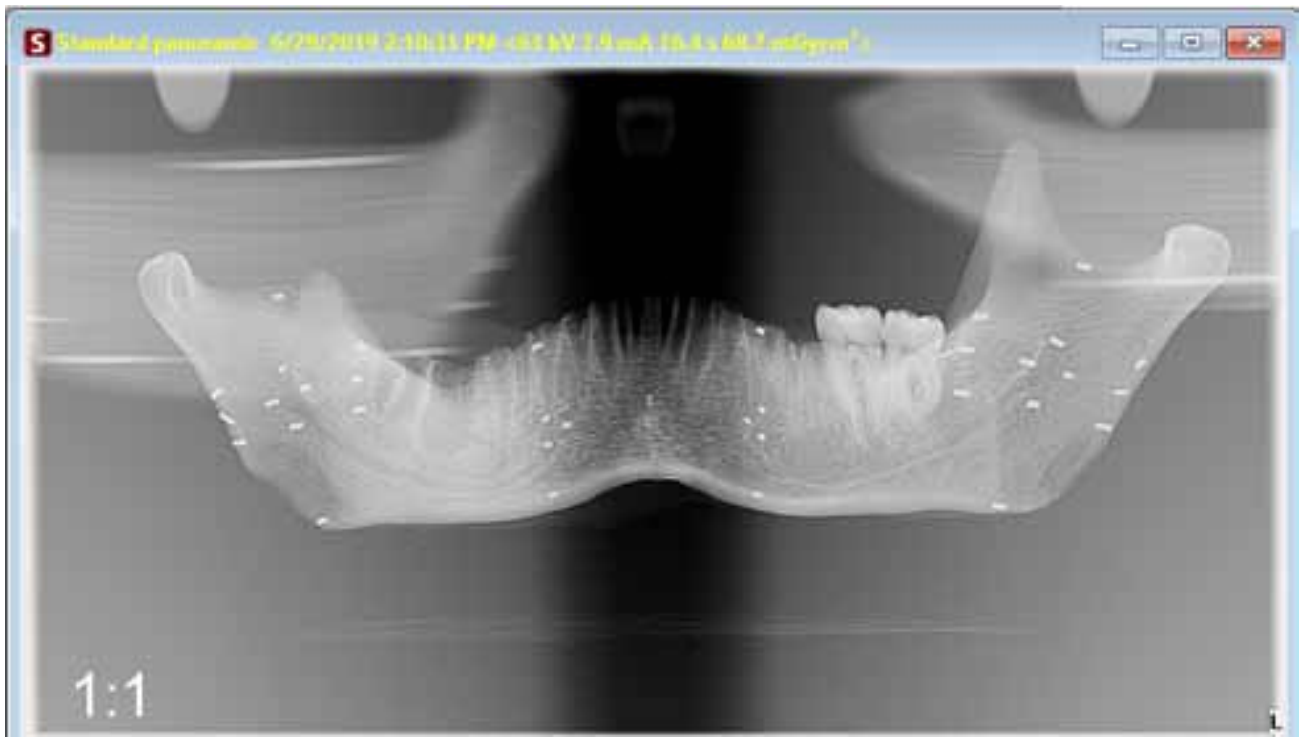

Figure (1): Scanora lite viewer.

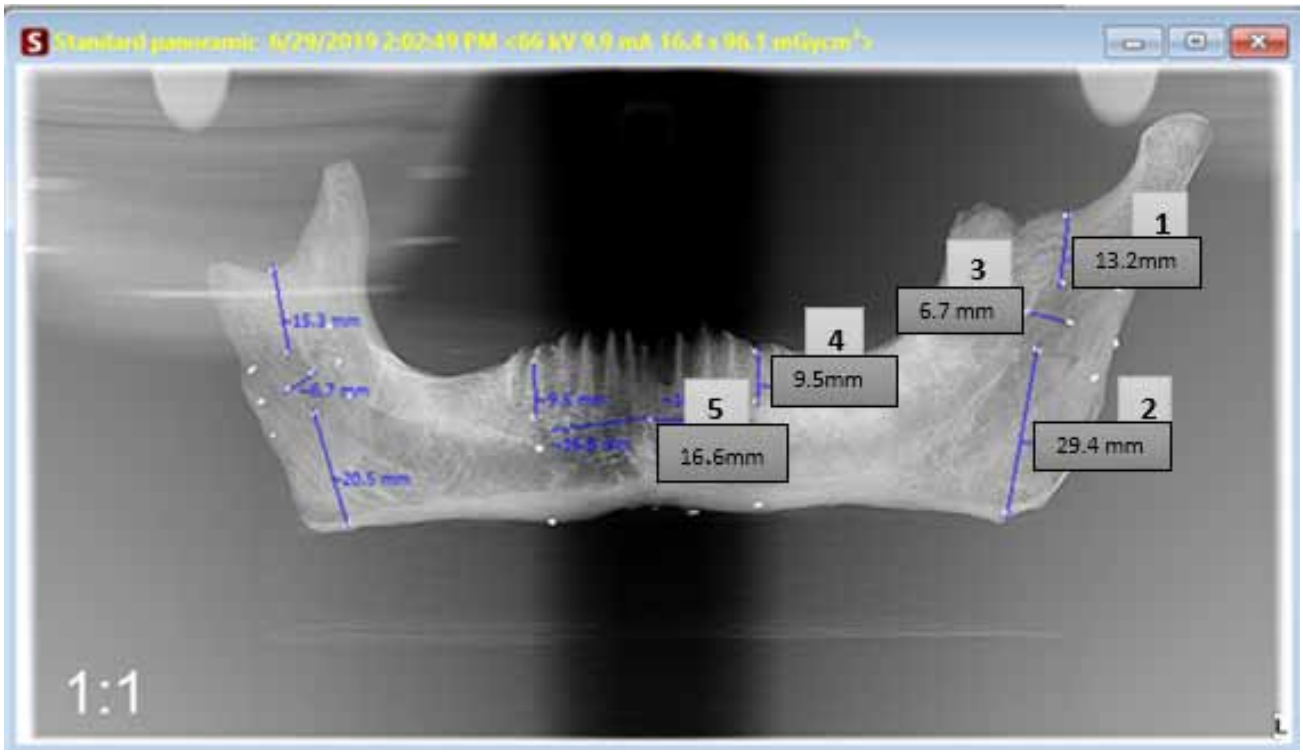

Figure (2): Digital panoramic radiograph with 1:1 magnification showing linear measurements performed on mandibular and mental foramina bilaterally, (1) line ab, (2) line ef, (3) mandibular foramen horizontal diameter, (4) linear measurement from crest of ridge till superior border of mental foramen, (5) measurement from midline till anterior border of mental foramen.

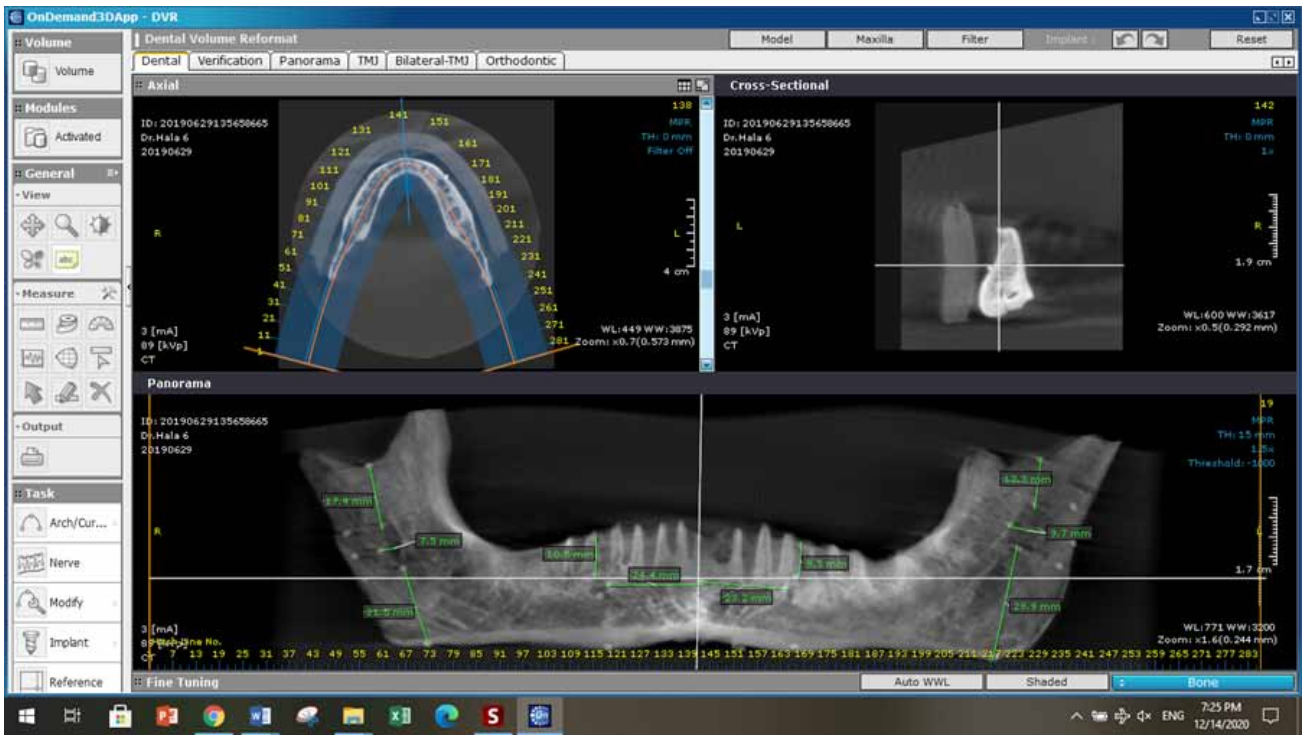

Figure (3): OnDemand 3D viewer.

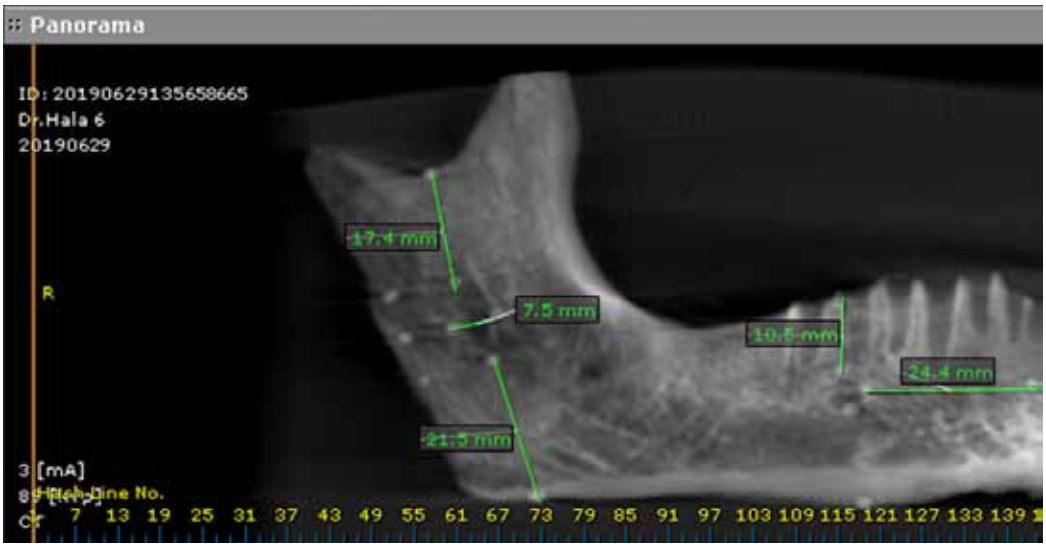

Figure (4): Cropped reformatted panoramic radiograph showing linear measurements performed on mandibular and mental foramina.

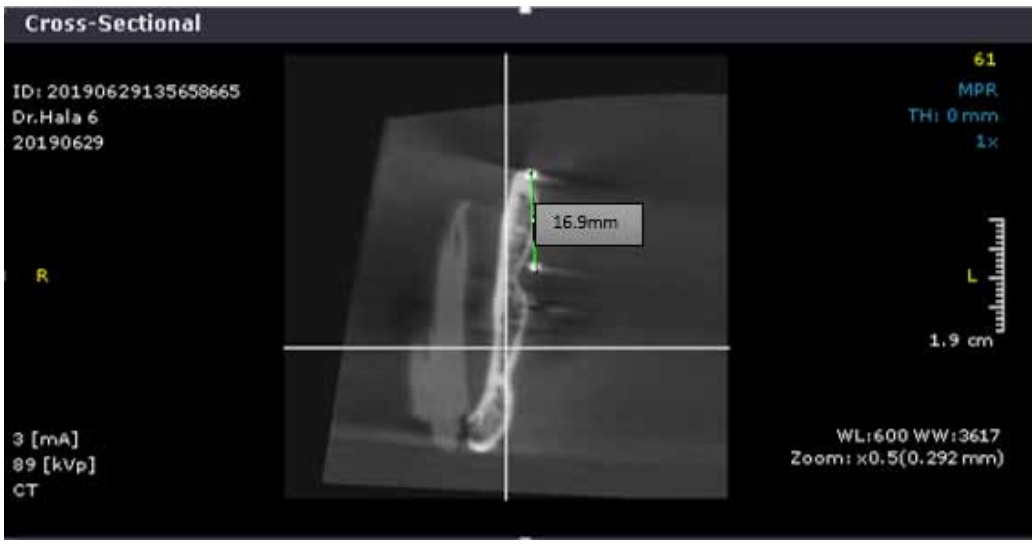

Figure (5): ab linear measurement performed on cross sectional image of cone beam computed tomography.

Table (1): Descriptive analysis of ab linear measurements in mm regarding each group and between-group comparisons

			Mean	SD	Median	Min	Max	Absolute Error		Relative (Percentage) Error		Comparison with Real measurements Paired t test	
								Mean	SD	Mean	SD	p-value*	Interpretation
ab	Left	Real	15.02	1.61	15.17	12.2	18.01	-	-	-	-	-	-
		DP	14.13	1.24	14.02	12.65	16.55	-0.88	0.84	-5.56	5.58	0.0132	Significant difference
		RP	14.74	1.41	14.7	12.65	17.55	-0.27	0.70	-1.59	4.71	0.2759	Insignificant difference
		CBCT	15.27	1.33	15.55	12.95	17.4	0.26	0.69	1.98	4.69	0.296	Insignificant difference
	Right	Real	15.98	1.54	15.85	13.75	18.83	-	-	-	-	-	-
		DP	14.12	1.54	14.4	11.4	16.45	-1.86	0.66	-11.66	4.14	<0.0001	Significant difference
		RP	15.42	1.62	15.45	12.95	17.5	-0.56	0.60	-3.55	3.90	0.0234	Significant difference
		CBCT	15.92	1.34	16	13.35	17.5	-0.06	0.55	-0.23	3.15	0.7619	Insignificant difference

*Significance level at p-value ≤0.05. N.B.: DP-Digital Panorama, RP-Reformatted Panorama, CBCT-Cone Beam Computed Tomography/Cross-sectional,MD-Mean Difference, SD-Standard Deviation.

Table (2): Descriptive analysis of linear measurements from middle of midline till middle of anterior border of mental foramen in mm regarding each group and between-group comparisons

			Mean	SD	Median	Min	Max	Absolute Error		Relative (Percentage) Error		Comparison with Real measurements Paired t test	
								Mean	SD	Mean	SD	p-value*	Interpretation
Midline till Mental foramen	Left	Real	25.26	2.83	26.17	20.28	28.23	-	-	-	-	-	-
		DP	15	3.06	15.40	8.80	18.35	-10.26	1.88	-40.92	8.39	<0.0001	Significant difference
		RP	25.05	2.88	26	20.10	28.10	-0.21	0.53	-0.85	2.25	0.2638	Insignificant difference
		CBCT	25.49	2.97	26.75	20.55	28.70	0.23	0.63	0.86	2.55	0.3177	Insignificant difference
	Right	Real	25.42	1.98	25.77	22.45	27.64	-	-	-	-	-	-
		DP	15.01	3.13	16.05	8.25	18.35	-10.41	1.81	-41.40	9.46	<0.0001	Significant difference
		RP	25.12	2.27	25.25	21.25	27.80	- 0.3	0.48	-1.26	2.00	0.096	Insignificant difference
		CBCT	25.04	1.91	25.25	21.75	27.65	-0.38	0.47	-1.48	1.88	0.0416	Significant difference

*Significance level at p-value ≤0.05. N.B.: DP-Digital Panorama, RP-Reformatted Panorama, CBCT-Cone Beam Computed Tomography/Axial, MD-Mean Difference, SD-Standard Deviation

Conclusion

From the present work, the following conclusions could be reached:

- Linear measurements obtained from CBCT reformatted panoramic images are more reliable than digital panoramic radiographic measurements.
- Linear measurements driven from CBCT cross-sectional images using On Demand software are accurate and have the lowest error value.

Source of Funding: Self-Funding

Conflict of Interest: None

Acknowledgment: I would like to thank Ekram Radio diagnostic Centre, for their technical help, also Dr. Attera Nazeer, who helped with the statistical analysis in the current study.

References

1. Patil K, Guledgud MV, Bhattacharya PT. Reliability of Panoramic Radiographs in the Localization of Mandibular Foramen. J Clin Diagn Res. 2015 May; 9(5):ZC35-8.
2. Peker I, Alkurt MT, Michcioglu T. The use of 3 different imaging method for the localization of the mandibular canal in dental implant planning. Int J Oral Maxillofac Implants. 2008 May-Jun; 23(3):463-70.
3. Stramotas S, Geenty JP, Petocz P, Darendeliler MA. Accuracy of linear and angular measurements on panoramic radiographs taken at various positions in vitro. Eur J Orthod. 2002 Feb;24(1):43-52.
4. Rondon RH, Pereira YC, do Nascimento GC. Common positioning errors in panoramic radiography: A review. Imaging Sci Dent. 2014 Mar;44(1):1-6.
5. Tang Z, Liu X, Chen K. Comparison of digital panoramic radiography versus cone beam computerized tomography for measuring alveolar bone. Head Face Med. 2017 Feb 22;13(1):2.
6. Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG. Endodontic applications of cone-beam volumetric tomography. J Endod. 2007 Sep;33(9):1121-32.
7. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2009 Jun;38(6):609-25.
8. Tomasi C, Bressan E, Corazza B, Mazzoleni S, Stellini E, Lith A. Reliability and reproducibility of linear mandible measurements with the use of a cone-beam computed tomography and two object inclinations. DentomaxillofacRadiol. 2011 May;40(4):244-50.
9. Kositbowornchai S, Siritapetawee M, Damrongrungruang T, Khongkankong W,

Chatrchaiwiwatana S, Khamanarong K, Chanthaooplee T. Shape of the lingula and its localization by panoramic radiograph versus dry mandibular measurement. Surg Radiol Anat. 2007 Dec; 29(8):689-94.

10. R Core Team (2018): R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
11. Lascala CA, Panella J, Marques MM. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofac Radiol. 2004 Sep; 33(5):291-4.
12. Beshtawi K, Qirresh E, Parker M, Shaik S. Custom Focal Trough in Cone-Beam Computed Tomography Reformatted Panoramic Versus Digital Panoramic for Mental Foramen Position to Aid Implant Planning. J Clin Imaging Sci. 2020 Jun 8; 10:34.
13. Baumgaertel S, Palomo JM, Palomo L, Hans MG. Reliability and accuracy of cone-beam computed tomography dental measurements. Am J Orthod Dentofacial Orthop. 2009 Jul; 136(1):19-25; discussion 25-8.
14. Alamri HM, Sadrameli M, Alshalhoob MA, Sadrameli M, Alshehri MA. Applications of CBCT in dental practice: a review of the literature. Gen Dent. 2012 Sep-Oct; 60(5):390-400; quiz 401-2. PMID: 23032226.
15. Tarazona-Álvarez P, Romero-Millán J, Peñarrocha-Oltra D, Fuster-Torres MÁ, Tarazona B, Peñarrocha-Diago M. Comparative study of mandibular linear measurements obtained by cone beam computed tomography and digital calipers. J Clin Exp Dent. 2014 Jul 1; 6(3):e271-4.
16. Rondon RH, Pereira YC, do Nascimento GC. Common positioning errors in panoramic radiography: A review. Imaging Sci Dent. 2014 Mar; 44(1):1-6.
17. Langlois Cde O, Sampaio MC, Silva AE, Costa NP, Rockenbach MI. Accuracy of linear measurements before and after digitizing periapical and panoramic radiography images. Braz Dent J. 2011; 22(5):404-9.
18. Lagravère MO, Carey J, Toogood RW, Major PW. Three-dimensional accuracy of measurements made with software on cone-beam computed tomography images. Am J Orthod Dentofacial Orthop. 2008 Jul; 134(1):112-6.
19. Lupi SM, Galinetto P, Cislaghi M, Rodriguez Y Baena A, Scribante A, Rodriguez Y Baena R. Geometric distortion of panoramic reconstruction in third molar tilting assessments: a comprehensive evaluation. Dentomaxillofac Radiol. 2018 Oct; 47(7):20170467.
20. El Sahili N, Nasseh I, Berberi A, David-Tchouda S, Thoret S, Fortin T. Impact of Cone Beam Computed Tomography Dose in Pre-Surgical Implant Analysis. Open Dent J. 2018 Jan 31;12:94-103.