Original Article

Localization of Mandibular Canal in Dry Mandibles using Digital Orthopantomography and Cone Beam Computed Tomography: A Pilot Study

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Abstract

Context and Aim: Dental implants are widely used for rehabilitation of edentulous arches. Yet, placement of oral implants in mandible is associated with numerous complications including hemorrhage and neurosensory disturbances. Enumerating precise information concerning the vital structures of the mandible, thus, becomes all the more important before the placement of implants. The aim of the present study was to determine the efficiency and accuracy of digital orthopantomography (OPG) and cone beam CT (CBCT) in determining the location of mandibular canal in pre-operative assessment of mandibles for implant placement. **Materials and Methods:** Ten dry edentulous mandibles of adult humans were selected for this study. The study comprised of two phases, namely, a radiographic phase and a clinical phase. The radiographic phase was based on obtaining digital orthopantomographs and cone-beam computed tomograms. During the clinical phase, all the mandibles were sectioned at an angle of 90 degrees to the inferior border of the mandible and direct clinical measurements were obtained. **Statistical Analysis Used:** Statistical analysis was done using IBM SPSS statistics 20 (Chicago, USA). Paired and Unpaired t-tests were used to do a comparative analysis of the two modalities used. $p<0.05$ was considered to be statistically significant. **Results:** The results of the present study revealed that the measurements of both the vertical (D1 and D2) and the buccolingual distances of the mandible (D3 and D4) obtained by CBCT were in accordance with the ones obtained with the help of direct clinical measurements and there was no statistically significant difference in the said variables (D1, D2, D3, D4) between the two measurements. On the contrary, there was a significant statistical difference between the values obtained with the help of digital orthopantomography (OPG) (D1,D2) as against the same values obtained with the help of direct clinical measurements. **Conclusion:** The findings of the present study implied that CBCT is the most efficient and accurate diagnostic tool available to locate the course of mandibular canal in the selection of potential implant sites. The accuracy of the i-CAT Cone Beam Computed Tomography (CBCT) unit was found to be superior to the digital panoramic images in the present study because of multiplanar 3D reconstructions.

Keywords: Localization; Mandibular Canal; Dry Mandibles; Digital Orthopantomography; Cone Beam Computed Tomography

Introduction

Dental implants are widely used for rehabilitation of edentulous arches. Yet, placement of oral implants in mandible is associated with numerous complications including hemorrhage and neurosensory disturbances. [1-3] Enumerating precise information concerning the vital structures of the mandible, thus, becomes all the more important before the placement of implants. [4] A precise knowledge of the anatomy and their disparities are important to execute suitable surgical procedures and to secure the vital structures of the patient. [5-7] Dentomaxillofacial imaging is based either on conventional or, digital techniques. Digital imaging has many advantages versus conventional including a significant reduction of radiation exposure and feasibility of image manipulation and analysis amongst the many which improves sensitivity and diminishes errors inbuilt in conventional

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imaging. For pre-implant assessment, orthopantomography (OPG) and cone beam computed tomography (CBCT) are the routinely used digital imaging modalities. [8] Measurements obtained through comparison of digital orthopantomography (OPG) and cone beam CT (CBCT) with dry edentulous mandibles can help to supplement the data about the estimation of the efficiency and accuracy of these imaging modalities in identifying the vital structures including the mandibular canal. The aim of the present study was to determine the efficiency and accuracy of digital orthopantomography (OPG) and cone beam CT (CBCT) in determining the location of mandibular canal in pre-operative assessment of mandibles for implant placement.

Methods

Ten dry edentulous mandibles of adult humans were selected for this study. Mandibles with any evidence of fractures, teeth and socket spaces were excluded from the study. The study comprised of two phases, namely, a radiographic phase and a clinical phase. The radiographic phase was based on obtaining digital orthopantomographs and cone-beam computed tomograms. Areas with 5 mm, 15 mm and 25 mm distance from the distal margin of the mental foramen were marked as A, B and C on both the right and left sides of the dry mandibles. Care was taken to maintain symmetry of both the sides of mandible. Radioopaque markers in the form of 2.54 mm steel ball bearings were placed on the above said A, B and C positions with the help of modeling wax to calculate the magnification error. Digital panoramic images were obtained with KODAK 800°C panoramic unit at 60 kVP and 2 mA exposure parameters with an exposure time of 13.63 seconds. Dry mandibles embedded with radioopaque marker were placed in the focal trough of the digital panoramic unit by maintaining the reference lines parallel to the symphysis menti and mesial aspect of the mental foramen with the support of bite plane and insulating tape. Digital images were acquired and stored in the computer. The following distances were measured on the acquired images:

D1: The distance from the Alveolar Crest to Inferior Border of Mandible (mm);

D2: The distance from the Alveolar Crest to Superior Border of Mandibular Canal (mm).

For the purpose of getting cone beam computed tomograms, dry mandibles were placed in 12x12x10cm plastic box filled with water. The position of the mandibles in water was maintained at a constant during the procedure for obtaining CBCT images. The plastic box was, then, placed within the focal trough of the i-CAT Cone Beam Computed Tomography (CBCT) unit. i-CAT is a Cone Beam Computed Tomography (CBCT) unit which is an Extended Field of View model (Imaging Sciences International, Hatfield, PA). In the present study, i-CAT Cone Beam Computed Tomography (CBCT) unit was used while images were obtained at 120kVp and 5mA exposure parameters with a rotation time of 26.3seconds by software addition of two different rotational scans using two different fields of view covering the craniofacial complex and maxilla/mandible. In addition to D1 and D2, the following distances were measured on computed tomograms:

D3: Buccolingual (BL) Width 5 mm under Mandibular Crest (mm);

D4: Buccolingual (BL) Width at the Circumference of the Mandibular Canal (mm).

The measurements of D1, D2, D3 and D4 are made with the help of Vernier calipers. During the clinical phase, all the mandibles were sectioned at an angle of 90 degrees to the inferior border of the mandible along the regions of A, B and C using the bone cutter tool. On the sectioned mandibles, measurements of D1, D2, D3 and D4 were, then, made. The following formula was used to calculate the Actual Bone Height from the radiographic measurements obtained using digital orthopantomography (OPG):

$$ABH = ADB \times RBH/RDB;$$

where in; ABH= Actual bone height available for implant placement;

ADB=Actual diameter of the metal ball bearings;

RBH=Radiographic Bone Height available for implant placement as measured from the radiograph; and

RDB=Diameter of the metal ball bearings on radiograph.

Statistical analysis

Statistical analysis was done using IBM SPSS statistics 20 (Chicago, USA). Paired and Unpaired t-tests were used to do a comparative analysis of the two modalities used. $p<0.05$ was considered to be statistically significant.

Results

Table 1 shows the descriptive statistics of dried mandibles with Cone Beam Computed Tomography while Tables 2, 3 and 4 show the same for Digital Orthopantomography (Magnified), Digital Orthopantomography (Calculated) and for Direct Clinical Measurements respectively. Table 5 shows the

Table 1: Descriptive statistics of dried mandibles with cone beam computed tomography.

Cone Beam Computed Tomography		Right Side		Left Side		Mean	SD
		Min.	Max.	Min.	Max.		
D1 Alveolar Crest to Inferior Border of Mandible (mm)	A	10.7	18.5	10.5	18.5	15.70	2.73
	B	10.6	18.3	10.4	18.2	15.51	2.74
	C	10.4	18.3	10.4	18.0	15.35	2.78
	Avg	10.57	18.37	10.43	18.23	15.52	2.75
D2 Alveolar Crest to Superior Border of Mandibular Canal (mm)	A	4.8	10.1	4.8	10.1	7.78	1.81
	B	4.5	9.8	4.5	9.6	7.52	1.78
	C	4.3	9.6	4.4	9.5	7.31	1.75
	Avg	4.53	9.83	4.57	9.73	7.53	1.78
D3 BL Width 5 mm under Mandibular Crest (mm)	A	7.7	14.6	7.7	14.6	11.07	2.34
	B	7.8	14.3	8.1	14.5	11.23	2.10
	C	8.0	14.3	8.1	14.3	11.31	2.01
	Avg	7.83	14.33	7.97	14.43	11.20	2.14
D4 BL Width at the Circumference of the Mandibular Canal (mm)	A	8.0	14.4	8.0	14.3	10.87	2.19
	B	8.0	14.3	8.1	14.1	10.97	2.11
	C	8.4	14.3	8.3	14.3	11.07	2.00
	Avg	8.13	14.27	8.13	14.17	10.97	2.09

descriptive statistics for the included measurements viz. D1, D2, D3 and D4 by Groups. When considering direct clinical measurements from dry mandibles as the gold standard, the results of the present study clearly revealed that the mean values of D1, D2, D3 and D4 (15.52 mm, 7.53 mm, 11.20 mm and 10.97 mm) obtained with the help of cone beam CT (CBCT) [Table 1 and Table 5] were very close to the direct gold standard clinical measurement values of 15.47 mm, 7.51 mm, 11.18 mm and 10.97 mm respectively [Table 4 and Table 5]. Similar measurements obtained with the help of digital orthopantomography (OPG) (Magnified) for D1 and D2 (19.10 mm and 9.16 mm) [Table 2, Table 5] and digital orthopantomography (OPG) (Calculated) for D1 and D2 (16.19 mm and 7.77 mm) [Table 3, Table 5] were, on the contrary, found to be much higher than the clinical measurement values (15.47 mm and 7.51 mm) [Table 4 and Table 5]. Table 6 shows the Pearson's Correlation Coefficients for Cone Beam Computed Tomography for all the said variables, D1, D2, D3 and D4. Similarly, Table 7 for Digital Orthopantomography and Table 8 for direct clinical measurements. The Pearson's Correlation Coefficients obtained showed that there was a direct positive linear relationship evident between distance measurements for D1 (r=0.999, p<0.01), D2 (r=0.998, p<0.01), D3 (r=0.993, p<0.01) and D4 (r=0.996, p<0.01) in cone beam CT (CBCT) (Table 6). A similar positive relationship, also, existed between distance measurements for D1 (r=0.998, p<0.01) and D2 (r=0.996, p<0.01) in OPG [Table 7] as well as between distance measurements for D1 (r=0.997, p<0.01), D2 (r=0.998, p<0.01), D3 (r=0.991, p<0.01) and D4 (r=0.992, p<0.01) in case of direct

Table 2: Descriptive statistics of dried mandibles with digital orthopantomography (Magnified).

Digital Orthopantomography (Magnified)		Right Side Min.	Right Side Max.	Left Side Min.	Left Side Max.	Mean	SD
D1 Alveolar Crest to Inferior Border of Mandible (mm)	A	13.0	23.8	12.9	24.1	19.38	3.35
	B	12.9	23.7	12.7	23.7	19.10	3.29
	C	12.7	23.4	12.6	23.5	18.82	3.29
	Avg	12.87	23.63	12.73	23.77	19.10	3.31
D2 Alveolar Crest to Superior Border of Mandibular Canal (mm)	A	5.7	11.9	5.6	11.8	9.40	2.13
	B	5.5	11.7	5.5	11.7	9.17	2.16
	C	5.4	11.4	5.3	11.4	8.90	2.06
	Avg	5.53	11.63	5.47	11.53	9.16	2.11

Table 3: Descriptive statistics of Dried Mandibles with Digital Orthopantomography (Calculated).

Digital Orthopantomography (Calculated)		Right Side Min.	Right Side Max.	Left Side Min.	Left Side Max.	Mean	SD
D1 Alveolar Crest to Inferior Border of Mandible (mm)	A	11.4	19.5	11.3	19.7	16.43	2.91
	B	11.3	19.4	11.1	19.4	16.19	2.85
	C	11.1	19.2	11.0	19.3	15.96	2.88
	Avg	11.27	19.37	11.13	19.47	16.19	2.88
D2 Alveolar Crest to Superior Border of Mandibular Canal (mm)	A	5.0	10.4	4.9	10.3	7.98	1.89
	B	4.7	10.2	4.6	10.2	7.78	1.92
	C	4.6	10.0	4.5	10.0	7.56	1.83
	Avg	4.77	10.17	4.67	10.13	7.77	1.88

Table 4: Descriptive statistics of Dried Mandibles with Direct Clinical Measurements.

Direct Clinical Measurements		Right Side Min.	Right Side Max.	Left Side Min.	Left Side Max.	Mean	SD
D1 Alveolar Crest to Inferior Border of Mandible (mm)	A	10.6	18.6	10.5	18.5	15.67	2.74
	B	10.4	18.4	10.3	18.3	15.43	2.77
	C	10.4	18.3	10.2	18.1	15.32	2.80
	Avg	10.47	18.43	10.33	18.30	15.47	2.77
D2 Alveolar Crest to Superior Border of Mandibular Canal (mm)	A	4.7	10.1	4.7	10.2	7.77	1.84
	B	4.5	9.7	4.5	9.7	7.49	1.81
	C	4.3	9.5	4.3	9.5	7.27	1.74
	Avg	4.50	9.77	4.53	9.80	7.51	1.79
D3 BL Width 5 mm under Mandibular Crest (mm)	A	7.8	14.6	7.7	14.5	11.07	2.33
	B	7.8	14.2	8.0	14.5	11.19	2.08
	C	8.1	14.1	8.2	14.3	11.28	1.98
	Avg	7.90	14.30	7.97	14.43	11.18	2.12
D4 BL Width at the Circumference of the Mandibular Canal (mm)	A	7.9	14.4	8.0	14.4	10.90	2.21
	B	8.1	14.2	8.0	14.2	10.97	2.09
	C	8.4	14.1	8.4	14.2	11.04	1.96
	Avg	8.13	14.23	8.13	14.23	10.97	2.08

Table 5: Descriptive statistics for D1, D2, D3 and D4 by Groups.

Groups	Distances	Min.	Max.	Mean	SD
Cone Beam Computed Tomography	D1	10.43	18.37	15.52	2.75
	D2	4.53	9.83	7.53	1.78
	D3	7.83	14.43	11.20	2.14
	D4	8.13	14.27	10.97	2.09
Digital Orthopantomography (Calculated)	D1	11.15	19.47	16.19	2.88
	D2	4.67	10.19	7.77	1.88
Direct Clinical Measurements	D1	10.33	18.43	15.47	2.77
	D2	4.50	9.80	7.51	1.79
	D3	7.90	14.43	11.18	2.12
	D4	8.13	14.23	10.97	2.08

Table 6: Pearson's Correlation Coefficients for Cone Beam Computed Tomography.

		A	B	C
D1- Alveolar Crest to Inferior Border of Mandible (mm)				
A	r-value	1	.999	.998
	p-value		.000**	.000**
B	r-value	.999	1	.999
	p-value	.000**		.000**
C	r-value	.998	.999	1
	p-value	.000**	.000**	
D2- Alveolar Crest to Superior Border of Mandibular Canal (mm)				
A	r-value	1	.998	.998
	p-value		.000**	.000**
B	r-value	.998	1	.999
	p-value	.000**		.000**
C	r-value	.998	.999	1
	p-value	.000**	.000**	
D3- BL Width 5 mm under Mandibular Crest (mm)				
A	r-value	1	.993	.980
	p-value		.000**	.000**
B	r-value	.993	1	.994
	p-value	.000**		.000**
C	r-value	.980	.994	1
	p-value	.000**	.000**	
D4- BL Width at the Circumference of the Mandibular Canal (mm)				
A	r-value	1	.996	.987
	p-value		.000**	.000**
B	r-value	.996	1	.996
	p-value	.000**		.000**
C	r-value	.987	.996	1
	p-value	.000**	.000**	

Correlation is significant at 0.01 level (2-tailed)

Table 7: Pearson's Correlation Coefficients for Digital Orthopantomography.

		A	B	C
D1- Alveolar Crest to Inferior Border of Mandible (mm)				
A	r-value	1	.998	.995
	p-value		.000**	.000**
B	r-value	.998	1	.999
	p-value	.000**		.000**
C	r-value	.995	.999	1
	p-value	.000**	.000**	
D2- Alveolar Crest to Superior Border of Mandibular Canal (mm)				
A	r-value	1	.996	.995
	p-value		.000**	.000**
B	r-value	.996	1	.998
	p-value	.000**		.000**
C	r-value	.995	.998	1
	p-value	.000**	.000**	

Correlation is significant at 0.01 level (2-tailed)

Table 8: Pearson's Correlation Coefficients for Direct Clinical Measurements.

		A	B	C
D1- Alveolar Crest to Inferior Border of Mandible (mm)				
A	r-value	1	.997	.995
	p-value		.000**	.000**
B	r-value	.997	1	.999
	p-value	.000**		.000**
C	r-value	.995	.999	1
	p-value	.000**	.000**	
D2- Alveolar Crest to Superior Border of Mandibular Canal (mm)				
A	r-value	1	.998	.998
	p-value		.000**	.000**
B	r-value	.998	1	.998
	p-value	.000**		.000**
C	r-value	.998	.998	1
	p-value	.000**	.000**	
D3- BL Width 5 mm under Mandibular Crest (mm)				
A	r-value	1	.991	.980
	p-value		.000**	.000**
B	r-value	.991	1	.995
	p-value	.000**		.000**
C	r-value	.980	.995	1
	p-value	.000**	.000**	
D4- BL Width at the Circumference of the Mandibular Canal (mm)				
A	r-value	1	.992	.986
	p-value		.000**	.000**
B	r-value	.992	1	.998
	p-value	.000**		.000**
C	r-value	.986	.998	1
	p-value	.000**	.000**	

Correlation is significant at 0.01 level (2-tailed)

clinical measurements [Table 8]. The Pearson's Correlation Coefficient values for cone beam CT (CBCT) ranged from 0.980 to 1 indicating an excellent correlation amongst all the measurements made with cone beam CT (CBCT) [Table 6]. Likewise, for digital orthopantomography (OPG) [Table 7] and direct clinical measurements [Table 8], r-values ranged from 0.995 to 1 and 0.980 to 1 respectively indicating an excellent correlation amongst all the measurements made with digital orthopantomography (OPG) and direct clinical measurements implying a significant positive correlation amongst them. Table 9 and Table 10 show Duncan's t-test for Clinical and Digital

Table 9: Duncan's t-test for all Clinical and Digital Orthopantomography (Magnified) Measurements by Distance.

Clinical and Digital Orthopantomography (Magnified) Measurements		Mean Difference	Std. Error Mean	p-value	95% Confidence Interval Of The Difference	
					Lower	Upper
D1	A	-3.70500	.85930	.000**	-4.1072	-3.3028
	B	-3.67500	.80058	.000**	-4.0497	-3.3003
	C	-3.50500	.81465	.000**	-3.8863	-3.1237
	Avg	-3.62833	.81271	.000**	-4.0087	-3.2480
D2	A	-1.63500	.41457	.000**	-1.8290	-1.4410
	B	-1.67500	.40377	.000**	-1.8640	-1.4860
	C	-1.63500	.39507	.000**	-1.8199	-1.4501
	Avg	-1.64833	.38760	.000**	-1.8297	-1.4669

p<<0.001- Highly Significant**

Table 10: Duncan's t-test for all Clinical and Digital Orthopantomography (Calculated) Measurements by Distance.

Clinical and Digital Orthopantomography (Calculated) Measurements		Mean Difference	Std. Error Mean	p-value	95% Confidence Interval Of The Difference	
					Lower	Upper
D1	A	-.75500	.08255	.000**	-.9278	-.5822
	B	-.76000	.06000	.000**	-.8856	-.6344
	C	-.64500	.07451	.000**	-.8009	-.4891
	Avg_D1	-.72000	.06651	.000**	-.8592	-.5808
D2	A	-.21000	.04525	.000**	-.3047	-.1153
	B	-.28500	.05041	.000**	-.3905	-.1795
	C	-.29000	.05125	.000**	-.3973	-.1827
	Avg_D1	-.26167	.04328	.000**	-.3522	-.1711

p<<0.001- Highly Significant**

Table 11: Duncan's t-test for all Cone Beam Computed Tomography and Digital Orthopantomography Measurements by Distance.

Cone Beam Computed Tomography and Digital Orthopantomography Measurements		Mean Difference	Std. Error Mean	p-value	95% Confidence Interval Of The Difference	
					Lower	Upper
D1	A	-.72500	.08139	.000**	-.8954	-.5546
	B	-.68000	.07420	.000**	-.8353	-.5247
	C	-.61000	.07810	.000**	-.7735	-.4465
	Avg_D1	-.67167	.07142	.000**	-.8212	-.5222
D2	A	-.20000	.04413	.000**	-.2924	-.1076
	B	-.26000	.06341	.000**	-.3927	-.1273
	C	-.25000	.05735	.000**	-.3700	-.1300
	Avg_D1	-.23667	.04896	.000**	-.3391	-.1342

p<<0.001- Highly Significant**

Orthopantomography (Magnified) and Clinical and Digital Orthopantomography (Calculated) measurements by distance respectively. Likewise, Table 11 and Table 12 show Duncan's t-test for Cone Beam Computed Tomography and Digital Orthopantomography and Clinical and Cone Beam Computed Tomography measurements by distance. The results of the present study revealed that the measurements of both the vertical (D1 and D2) and the buccolingual distances of the mandible (D3 and D4) obtained by CBCT were in accordance with the ones obtained with the help of direct clinical measurements and there was no statistically significant difference in the said variables (D1, D2, D3, D4) between the two measurements. On the contrary, there was a significant statistical difference between the values obtained with the help of digital orthopantomography

Table 12: Duncan's t-test for all Clinical and Cone Beam Computed Tomography Measurements by Distance.

Clinical and Cone Beam Computed Tomography Measurements		Mean Difference	Std. Error Mean	p-value	95% Confidence Interval Of The Difference	
					Lower	Upper
D1	A	-.03000	.03914	.453	-.1119	.0519
	B	-.08000	.02128	.078	-.1245	-.0355
	C	-.03500	.01957	.090	-.0760	.0060
	Avg	-.04833	.01752	.067	-.0850	-.0117
D2	A	-.01000	.01235	.428	-.0359	.0159
	B	-.02500	.02280	.287	-.0727	.0227
	C	-.04000	.01522	.083	-.0719	-.0081
	Avg	-.02500	.01182	.048	-.0497	-.0003
D3	A	-.00500	.01698	.772	-.0405	.0305
	B	-.04500	.02112	.046	-.0892	-.0008
	C	-.03500	.01957	.090	-.0760	.0060
	Avg	-.02833	.01089	.079	-.0511	-.0055
D4	A	.02500	.01758	.171	-.0118	.0618
	B	.00000	.02406	1.000	-.0504	.0504
	C	-.03500	.01957	.090	-.0760	.0060
	Avg	-.00333	.01231	.789	-.0291	.0224

Table 13: Descriptive statistics for average magnification with Digital Orthopantomography (Magnified) Vs. Digital Orthopantomography (Calculated).

Digital Orthopantomography (Magnified) Vs. Digital Orthopantomography (Calculated)	Min.	Max.	Mean	Range
Average Magnification Percentage- D1	12%	18%	15%	14%-17%
Average Magnification Percentage- D2	12%	18%	15%	14%-17%
Average Magnification Factors- D1	1.14	1.22	1.18	1.06-1.30
Average Magnification Factors- D2	1.14	1.22	1.18	1.06-1.30

Table 14: Descriptive statistics for average magnification with Digital Orthopantomography (Magnified) Vs. Direct Clinical Measurements.

Digital Orthopantomography (Magnified) Vs Direct Clinical Measurements	Min.	Max.	Mean	Range
Average Magnification Percentage- D1	14%	23%	19%	17.1%-20.9%
Average Magnification Percentage- D2	15%	22%	18%	16.2%-19.8%
Average Magnification Factors- D1	1.16	1.30	1.24	1.12-1.36
Average Magnification Factors- D2	1.17	1.28	1.22	1.10-1.34

(OPG) (D1,D2) as against the same values obtained with the help of direct clinical measurements. Table 13 and Table 14 show the descriptive statistics for average magnification with Digital Orthopantomography (Magnified) vs. Digital Orthopantomography (Calculated) and average magnification with Digital Orthopantomography (Magnified) Vs. Direct Clinical Measurements.

Discussion

Pre-surgical implant area assessment is an important aspect in any successful implant procedure. A great deal of risk is involved in placement of dental implants because of inaccurate determination of the bone length and the subsequent use of implants that exceed the extent of the bone available. Such risks have their consequences in the form of temporary or, permanent neurosensory disturbances due to inferior alveolar nerve impingement. [9-11] On properly assessing the mandibular canal location in the mandible before dental implant procedures, the chances of occurrence of such nerve injuries are significantly reduced. Although conventional computed tomography (CT) imaging can accurately assess the cortical bone thickness of the remaining alveolar bone, it requires high dose of radiation. Cone beam computed tomography (dental CBCT) which requires a lower radiation dose is frequently used in diagnosis and treatment planning in such cases. In addition to lower doses of radiation, dental CBCT provides greater spatial resolution than CT making it an ideal pre-surgical assessment tool for dental implant surgeries. [12] The aim of the present study was to determine the efficiency and accuracy of digital orthopantomography (OPG) and cone beam CT (CBCT) in determining the location of mandibular canal in pre-operative assessment of mandibles for implant placement. When considering direct clinical measurements from dry mandibles as the gold standard, the results of the present study clearly revealed that the mean values of D1, D2, D3 and D4 (15.52 mm, 7.53 mm, 11.20 mm and 10.97 mm) obtained with the help of cone beam CT (CBCT) were very close to the direct gold standard clinical measurement values of 15.47 mm, 7.51 mm, 11.18 mm and 10.97 mm respectively. Similar measurements obtained with the help of digital orthopantomography (OPG) for D1 and D2 (19.10 mm and 9.16 mm) were, on the contrary, found to be much higher than the clinical measurement values (15.47 mm and 7.51 mm). Furthermore, the Pearson's Correlation Coefficients showed that there was a direct positive linear relationship evident between distance measurements for D1 ($r=0.999$, $p<0.01$), D2 ($r=0.998$, $p<0.01$), D3 ($r=0.993$, $p<0.01$) and D4 ($r=0.996$, $p<0.01$) in cone beam CT (CBCT). A similar positive relationship, also, existed between distance measurements for D1 ($r=0.998$, $p<0.01$) and D2 ($r=0.996$, $p<0.01$) in OPG as well as between distance measurements for D1 ($r=0.997$, $p<0.01$), D2 ($r=0.998$, $p<0.01$), D3 ($r=0.991$, $p<0.01$) and D4 ($r=0.992$, $p<0.01$) in case of direct clinical measurements. The Pearson's Correlation Coefficient values for cone beam CT (CBCT) ranged from 0.980 to 1 indicating an excellent correlation amongst all the measurements made with cone beam CT (CBCT). Likewise, for digital orthopantomography (OPG) and direct clinical measurements, r-values ranged from 0.995 to 1 and 0.980 to 1 respectively indicating an excellent correlation amongst all the measurements made with digital orthopantomography (OPG) and direct clinical measurements implying a significant positive correlation amongst them. Furthermore, the results of the present study revealed that the measurements of both the vertical (D1 and D2) and the buccolingual distances of the mandible (D3 and D4) obtained by CBCT were in accordance with the ones obtained with the help of direct clinical measurements and there was no statistically significant difference in the said variables (D1, D2, D3, D4) between the two measurements. On the contrary, there was a significant statistical difference between the values obtained with the help of digital orthopantomography (OPG) (D1,D2) as against the same values obtained with the help of direct clinical measurements. The results of the present study were found to be in accordance with the study conducted by Angelopoulos C et al. [13] who compared CBCT reformatted panoramic images (i-CAT; Imaging Sciences, Hatfield, PA), direct (charge-coupled device-based) panoramic radiographs (DIMAX; Planmeca, Helsinki, Finland) and digital panoramic radiographs based on a storage phosphor system (DENOPTIX;

Gendex, Chicago, IL) for the identification of the mandibular canal as part of the pre-implant assessment. The said study, also, concluded CBCT to be the most reliable method for pre-surgical implant assessment and also, to have added advantages in the form of reduced radiation exposure simultaneously. The images acquired with the help of cone beam CT (CBCT) were, also, free from any magnification errors and superimpositions of the neighboring structures. This was, also, in accordance with the results of the study conducted by Yim JH et al [14] which reported that no magnification of images was found in the images acquired by cone beam CT (Panoramic CT) when compared with the digital orthopantomography (OPG) (Planmeca panoramic images). The results of the present study were, also, found to be in accordance with the study conducted by Kamburoglu K et al. [15] which compared CBCT of skull with direct digital caliper measurements and observed that all CBCT measurements were highly accurate to caliper measurements. Similar results were obtained in the study conducted by Tantanapornkul W et al. [16] which concluded CBCT to be an accurate method of assessment in such situations observing that the level of accuracy for determining the sensitivity and specificity was 93% and 77% for cone beam CT and 70% and 63% for digital panoramic images respectively. Georgescu CE et al, [17] also, demonstrated that CBCT is more efficient and accurate compared to digital orthopantomography (OPG) with added advantages in the form of easier and faster transformation of data, allowing direct volumetric reconstructions and a high level of accuracy and reproducibility. Similar results were, also, obtained by Yun-long Z et al. [18] who analyzed the application of cone beam CT (CBCT) and digital orthopantomography (OPG) in pre-surgical implant assessment and concluded that CBCT can evaluate the bone volume of pre-surgical alveolar bone more accurately and can, also, indicate the peri-implant bone volume and quality clearly. In the present study, CBCT images were taken with the soft tissue equivalent (water) to avoid soft tissue burn-out. Hence, overestimation of vertical distances was excluded. The said methodology was adopted in accordance with the study conducted by Suomalainen A et al. [19] which used sucrose solutions to minimize the chances of soft tissue burn-out. According to the said study, the error of linear measurements with CBCT was found to be even smaller than that obtained with the multi-slice CT (MSCT) during pre-surgical implant planning and thus, they concluded cone beam CT (CBCT) to be a reliable tool for implant planning measurements when compared with the MSCT. The said findings were though not in accordance with the study conducted by Potter BJ et al. [12] which showed overestimation in the measurement of distance between the inferior alveolar canal and alveolar crest wherein the tomograms overestimated 3.06% of the distances. Also, the said findings were, again, in contrast with the findings of the study conducted by Peltola JS and Mattila M [20] where an underestimation of the measured distance was found due to burn-out of the soft tissues in the mandible crest area leading to difficulty in identification and errors in the tracing.

Conclusion

The present study determined the efficiency and accuracy of digital orthopantomography (OPG) and cone beam CT (CBCT) in determining the location of mandibular canal in pre-operative assessment of mandibles for implant placement. The findings of the present study implied that CBCT is the most efficient and accurate diagnostic tool available to locate the course of mandibular canal in the selection of potential implant sites. The accuracy of the i CAT was found to be superior to the digital panoramic images in the present study because of multiplanar 3D reconstructions which is not possible with 2D panoramic images. Two dimensional panoramic images do not provide information on bone thickness or, location of vital structures in a buccolingual direction wherein the three dimensional images accurately display the size and buccolingual direction of the mandibular canals and density of the remaining alveolar ridges. The efficiency of digital panoramic image is, further, reduced due to the possibility of magnification errors. However, panoramic radiographs are still valuable in daily practice with the skill and knowledge of the experienced surgeons.

Limitations of the Present Study

The present study does have certain limitations, though, in the form of smaller sample size and with the study being on dry mandibles which are certainly different from that of a patient. Furthermore, the collected sample could not be correlated with information associated with age and gender parameters that might lead to potential bias. Further studies are, therefore, warranted to validate the accuracy of the results obtained in the present study by using larger sample size. The present study was, also, limited only to the posterior mandible, thus, studies pertaining to other areas of mandible might, also, be considered to assess the efficiency of the said modalities in the accurate assessment of different parameters on dry or, otherwise, *in-vivo* studies on mandibles.

Conflict of Interest

The authors disclose that they have no conflicts of interest.

References

1. American Dental Association and US Department of Health and Human Services. The Selection of Patients for X-ray Examinations: Dental Radiographic Examinations, 2004.
2. White SC, Heslop EW, Hollender LG, Mosier KM, Ruprecht A, Shrout MK. American Academy of Oral and Maxillofacial Radiology. Parameters of radiologic care: An official report of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:498-511.
3. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: Preliminary results. Eur Radiol 1998;8:1558-1564.
4. Baba R, Ueda K, Okabe M. Using a flat-panel detector in high resolution cone beam CT for dental imaging. Dentomaxillofac Radiol 2004;33:285-290.
5. Baba R, Konno Y, Ueda K, Ikeda S. Comparison of flat-panel detector and image-intensifier detector for cone-beam CT. Comput Med Imaging Graph 2002;26:153-158.
6. Sukovic P, Brooks S, Perez L, Clinthorne NH. DentoCAT: A novel design of a cone beam CT scanner for dento-maxillofacial imaging: Introduction and preliminary results. In: Lemke HU, Vannier MW, Inamura K, Farman AG, Doi K, editors. Computer Assisted Radiology and Surgery. Amsterdam: Elsevier Science; 2001; 659-664.
7. Sukovic P. Cone beam computed tomography in craniofacial imaging. Orthod Craniofac Res 2003;6:31-36.

8. El-Khateeb SM, Arnout EA, Hifnawy T. Radiographic assessment of impacted teeth and associated pathosis prevalence: Pattern of occurrence at different ages in Saudi male in Western Saudi Arabia. Saudi Med J 2015;36:973-979.

9. Bartling R, Freeman K, Kraut RA. The incidence of altered sensation of the mental nerve after mandibular implant placement. J Oral Maxillofac Surg 1999;57:1408-1412.

10. Kubilius R, Sabalys G, Juodzbalys G, Gedrimas V. Traumatic damage to the inferior alveolar nerve sustained in course of dental implantation: Possibility of prevention. Stomatologija Baltic Dent Maxillofac J 2004;6:106-110.

11. Wismeijer D, van Waas MA, Vermeeren JI, Kalk W. Patients' perception of sensory disturbances of the mental nerve before and after implant surgery: A prospective study of 110 patients. Br J Oral Maxillofac Surg 1997;35:254-259.

12. Potter BJ, Shrout MK, Russell CM, Sharawy M. Implant site assessment using panoramic cross-sectional tomographic imaging. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;84:436-442.

13. Angelopoulos C, Thomas SL, Hechler S, Parissis N, Hlavacek M. Comparison between digital panoramic radiography and cone-beam computed tomography for the identification of the mandibular canal as part of pre-surgical dental implant assessment. J of Oral Maxillofac Surg 2008;66:2130-2135.

14. Yim JH, Ryu DM, Lee BS, Kwon YD. Analysis of digitalized panorama and cone beam computed tomographic image distortion for the diagnosis of dental implant Surgery. J Craniofac Surg 2011;22:669-673.

15. Kamburoglu K, Kursun S, Akarslan ZZ. Dental students' knowledge and attitudes towards cone beam computed tomography in Turkey. Dentomaxillofac Radiol 2011;40:439-443.

16. Tantanapornkul W, Okouchi K, Fujiwara Y, Yamashiro M, Maruoka Y, Ohbayashi N. A comparative study of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:253-259.

17. Georgescu CE, Mihai A, Didilescu AC, Moraru R, Nimigean V, Nimigean VR, et al.. Cone beam computed tomography as a method of quantitative and qualitative analysis of alveolar crest in the frontal mandibular area. Revue Roumaine de Morphologie et Embryologie Rom J Morphol Embryol 2010;51:713-717.

18. Yun-long Z, Chang-fu L. Application of orthopantomography and cone beam computed tomography in dental implant: A comparative study. Chinese J Tissue Engineering Res 2012;16:2332-2335.

19. Suomalainen A, Vehmas T, Kortesniemi M, Robinson S, Peltola J. Accuracy of linear measurements using dental cone beam and conventional multislice computed tomography. Dentomaxillofac Radiol 2008;37:10-17.

20. Peltola JS, Mattila M. Cross-sectional tomograms obtained with four panoramic radiographic units in the assessment of implant site measurements. Dentomaxillofac Radiol 2004;33:295-300.