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Cone Beam Computed Tomography versus Intraoral Digital Radiography in Detection and Measurements of Simulated Periodontal Bone Defects Diagnostic Accuracy Study

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Abstract: Detection and accurate assessment of periodontal disease is important to determine the tooth prognosis and treatment. Radiographic assessment provides information about the pattern and extent of the alveolar bone loss. Digital radiography has ability to enhance images and make direct measurements. CBCT provides unique 3D images used for diagnosis and treatment plans, but its use in periodontology not well-reviewed as there is few number of studies searched about the role of CBCT in periodontology. We compare digital radiography with CBCT in the detection and measurements of different bone defects. Dry jaws with simulated bone defects were imaged by CBCT and Digital radiography the data and measurements were compared with the gold standard dry jaws. Our study shows no statistically significant difference between the CBCT and Digital radiography in detecting the presence of the periodontal defects but CBCT more accurate in measuring and detecting the types of periodontal bone defects and furcation involvement; showing non inferiority hypothesis between CBCT and Intraoral Digital Radiography in detecting the presence of the bony defects and superiority of CBCT in the linear measurements and in the detection of the different types of bony defects & furcation involvement.

Keywords: CBCT; digital radiography; bone defects.

1. Introduction

Periodontal diseases are a group of conditions affecting the supporting structures of the dentition. Periodontitis has long been defined as an infection-mediated destruction of the alveolar bone and soft tissue attachments of the tooth. Persistent bacterial colonization on the tooth surface leads to chronic inflammation in periodontal tissues which results in gingival bleeding, pocket formation, destruction of alveolar bone and eventually loss of teeth [1]. The success of periodontal therapy depends on many factors. One of the most important factors is the accurate imaging of the morphology of periodontal bone destruction to establish the treatment plan. Radiographs are necessary to determine the extent and severity of the periodontal lesions [2]. Digital radiography has a lot of advantages as it provides interactive display on a monitor with the ability to enhance image features and make direct measurements [3]. But, the major limitation is their deficiency in assuring available three-dimensional (3D) parameters [4, 5]. On the other hand, 3D CBCT scanning upon comparing to the periodontal probing and 2D intraoral radiography; was found to be more effective in assessing periodontal structures. As it is as accurate as direct measurements using a periodontal probe and as reliable as intraoral radiographs for interproximal areas. Also, since buccal and lingual defects could not be diagnosed with intraoral radiography, CBCT is currently being considered as a superior diagnostic tool for applications in periodontology [2]. Recently, Ashwinirani et al., 2015 compared the efficacy of conventional intraoral periapical and digital radiographs in detecting interdental alveolar bone loss using intrasurgical measurements as the gold standard, and concluded that both techniques underestimated the bone loss measurements when compared to intrasurgical

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measurements, but, bone loss measurements in digital radiography were closer to the intrasurgical measurements than the conventional radiography, moreover, digital radiography was superior to conventional radiography in the detection of interdental bone loss due to reduced time and radiation exposure to obtain the same diagnostic information [6]. In addition, Vasconcelos et al., 2012 Found that while, both CBCT and intraoral digital radiography are useful when diagnosing bone loss in the interproximal surfaces, CBCT offers significant advantages when detecting and locating vertical bone defects, thereby facilitating surgical planning [7]. Furthermore, Indurkar and Verma, 2016 stated that cone- beam CT (CBCT) has emerged as a feasible tool in dentistry, providing a lower cost alternative to conventional CT with high-quality images and lower radiation exposure topatients[8]. Moreover, Aljehani, 2014 found that CBCT has the potential to gather accurate diagnostic and qualitative information regarding a patient's alveolar bone loss (ABL), especially for teeth with intrabony or furcation defects [9]. In addition, Bayat et al., 2016 found that the Perception of the images obtained with the use of CBCT in the assessment of periodontal bone defects could lead to a novel approach in evaluating patients with periodontal disease and could demonstrate to be a great resource for selecting the most appropriate treatment [12]. Based on the fact that, several studies are available on the diagnostic accuracy of CBCT. However, only a few studies have discussed the application of CBCT in periodontology; not many studies have documented the benefits of CBCT. Moreover, A few studies have been published comparing CBCT with digital radiography for the detection and measurements of the periodontal bone defects [10, 11]. Thus, this study aimed to justify the applicability of CBCT in the assessment of periodontal bone defects in comparison with the intraoral digitalradiography.

2. Materials and Methods

Dry mandibles and skulls were selected as reference gold standard method due to its high level of accuracy in the assessment of periodontal bone defects and frequent usage in almost similar studies [13, 17]. Simulated and naturally occurred periodontal bone defects were detected and measured on the dry mandibles and skulls.The naturally occurred bony defects included were: crater, bulbous bone contour and different grades of furcation involvement.The simulated bony defects included were: horizontal bony defects, different types of angular bony defects (one wall, two walls, three walls and combined), dehiscences andfenestrations. Eligibility criteria: Inclusion criteria: The selected dry mandibles and skulls were intact with no mechanical damage (chips, cracks, or fractures in the alveolar process), the teeth were naturally attached to human maxillae and mandibles and the study samples were not identified by age or gender group. Exclusion criteria: teeth with anomalies & fractures and teeth with metallic restorations to avoid artifacts generation on CBCT scanning and.
Participants: The total number of included naturally ataached teeth in this study: 15 teeth.total no. of measurements of bone defects: 120 ; as 30 interproximal linear measurements were done by both technique; (15 by each technique) CBCT and Intraoral Digital Radiography and compared with the real measurements of the Gold Standard & 90 bucco-lingual linear measurements were done by CBCT and compared with the real measurements of the Gold Standard. Detection of the presence of 21 bone defects associated with the naturally attached teeth were done by both techniques CBCT and Intraoral Digital Radiography and compared with the Gold Standard; moreover detection of the types of bony defects were done by CBCT and compared with the Gold Standard.

Test method: Alveolar bone loss measurements and detection of the patterns of bone defects and furcation involvements were done on CBCT and Digital radiography and compared the validity of each technique with the gold standard dry jaws.

- ✓ The Preanalyticalphase:

Size quarter round bur was used for drilling the simulated bony defects. Real

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measurements and bony defects detection were done on the dry mandibles and skulls (maxillae) and recorded into reference datasheet. Cemento-Enamel Junction (CEJ) was used as a reference point of the bone level, but, because of dehydration of the dry skull, guttapurcha was used as standardized marker to substitute forthefadedCEJ,astheradiopaqueguttapurchafragmentsweregluedontoteethsurfacesonthe CEJ [17]. In order to assess bone levels on the gold standard: direct measurements were taken by using periodontal probe (AISI 420, German) and compared to the electronic caliper (Shenhan Measuring Tools Co., LTD, Shanghai) [13, 17]. A graduated Nabers probe (2NC color coded, USA) was used for the classification of the furcation involvements on the gold standard [14, 17]. Soft tissue simulation was made by adapting 8 sheets of pink wax each of 1.5 mm thickness on the dry mandibles and skulls; provided approximately 12 mm thickness which is consistent with what was recommended [25]. The same measurements and detection were after that done by both CBCT and Intraoral Digital Radiography and recorded into datasheet for each technique to be compared with the gold standarddatasheet.

Radiographicscanning:The dry jaws were imaged with CBCT and Digital radiographic techniques. CBCT scanning:Dry jaws were examined radiographically using CBCT(Scanora 3DX**) machine with CMOS flat panel detector and isotropic voxel size of 133 µm using small field of view(8×10cm) and high definition mode with exposure parameters of ; 90 Kvp ,10 m.A ,effective exposure time 6 s, and 0.5mm Focal spot[15]. Then OnDemand software was used for the analysis and measurements. Digital radiography imaging: Semi direct digital radiographs was used; Belmont PHOT-XIIS with the exposure settings which chosen according to the stored protocol for intraoral digital imaging in the x-ray machine (60 kVp, 6 mA and 0.16 seconds exposure time), Durr sensor size 2 was used for image capture, A film holder (XCP®; DentsplyRinn, Elgin, IL) was fixed to the X-ray tube head as the parallel technique was used and Vistascan software; was used for taking the measurements.

- ✓ The Analyticalphase:

I- Detection of bony defects:

A- Detection of the presence of bony defects and furcation involvement:

The detection of infrabony defects and furcation involvement (FI) was done by both techniques; CBCT and Intraoral Digital Radiography. Based on the study done by Bayat et al., 2016; The presence or absence of the defects and FI was recorded as Yes or No in the datasheets and compared with the data from the gold standard [12]. As periodontal bone defects starts when the distance from the cementoenamel junction (CEJ) to the AC is more than 2 mm and presence of FI done when there were radiographic signs as reduced radiodenisty in the furcation area in which bony trabeculae outlines were visible, Presence of triangular radiolucency at the furcation area, and/or alveolar bone level below furcation (Figure 1. a), in CBCT the Presence of FI was demonstrated as loss of trabecular bone at the furcation region on both axial and sagittal view.

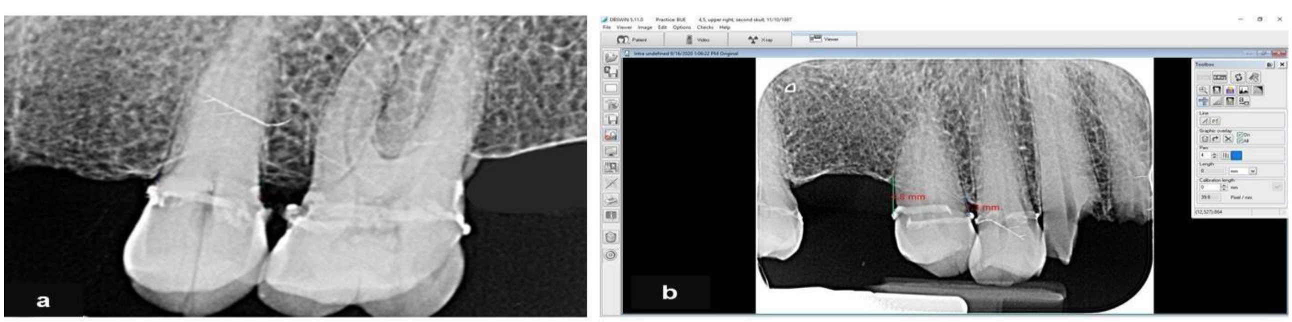

Fig (1): Intraoral digital radiograph a: furcation involvement and horizontal bone loss distal to the upper left first molar, b: alveolar bone loss measurements on digital radiography software.

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B- Detection of the types of bony defects and furcation involvements Grades:

As CBCT provides 3D assessments; so the type of the infrabony defects were determined as in angular bone defects determined according to the number of remaining walls; One-walled, two-walled, three-walled, or combined osseous defect (Figure 2); on four surfaces (mesial, distal, buccal/ labial and palatal/ lingual) and other bone defects detection included too (Figure 3); by choosing the correct answer choice in the datasheet among one-, two-, three-wall or combined angular defect and other bone defects: e.g.; fenestration and dehiscence, crater and bulbous bone contour [5] and compared with the data from the gold standard. Moreover, classification of FI in horizontal bone loss was included according to modified Glickman's classification as **Class I;** incipient or early stage of furcation involvement, bone destruction is less than 2 mm into the furca, **Class II;** horizontal bone destruction extending deeper than 2 mm but less than 6 mm into the furca and **Class III;** horizontal bone destructions communicate between furcae of the tooth, and result in a through-and-through tunnel [26]. The classification was done on CBCT by measuring the depth of FI on axial view where the slice showed the greatest amount of bone loss. On this slice, a line was drawn tangentially to the adjacent root surfaces. The distance from this line to the deepest point of bone loss was designated as the amount of furcation bone loss. In case of trifurcation assessment as in upper molars (Figure 4); buccal, mesio-palatal and disto-palatal furcation bone loss were measured for maxillary molars [26]. The type of furcation involvement was determined by choosing the correct answer choice in the datasheet among class I, II and III and compared with the data from the gold standard as the graduated Nabers probe (2NC color coded, USA) was used for the classification of the furcation involvements on the gold standard (mandibles and skulls).

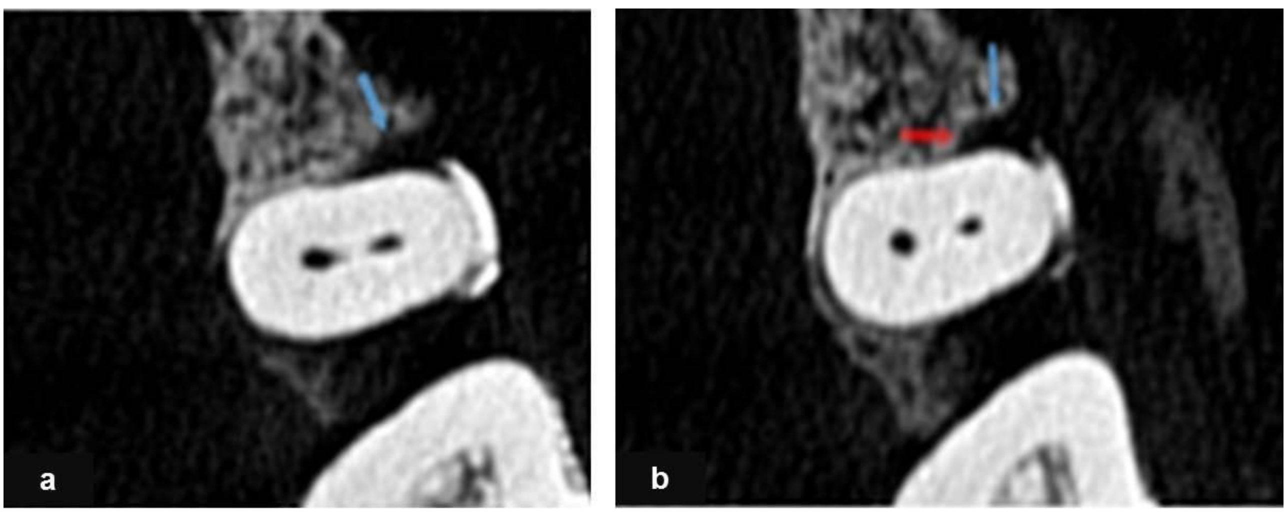

Fig (2): CBCT axial cuts showing Combined angular bone defect mesial to upper left second premolar starts as one wall defect (distal wall) and converted into two walls defect (distal and palatal) when go moreapically

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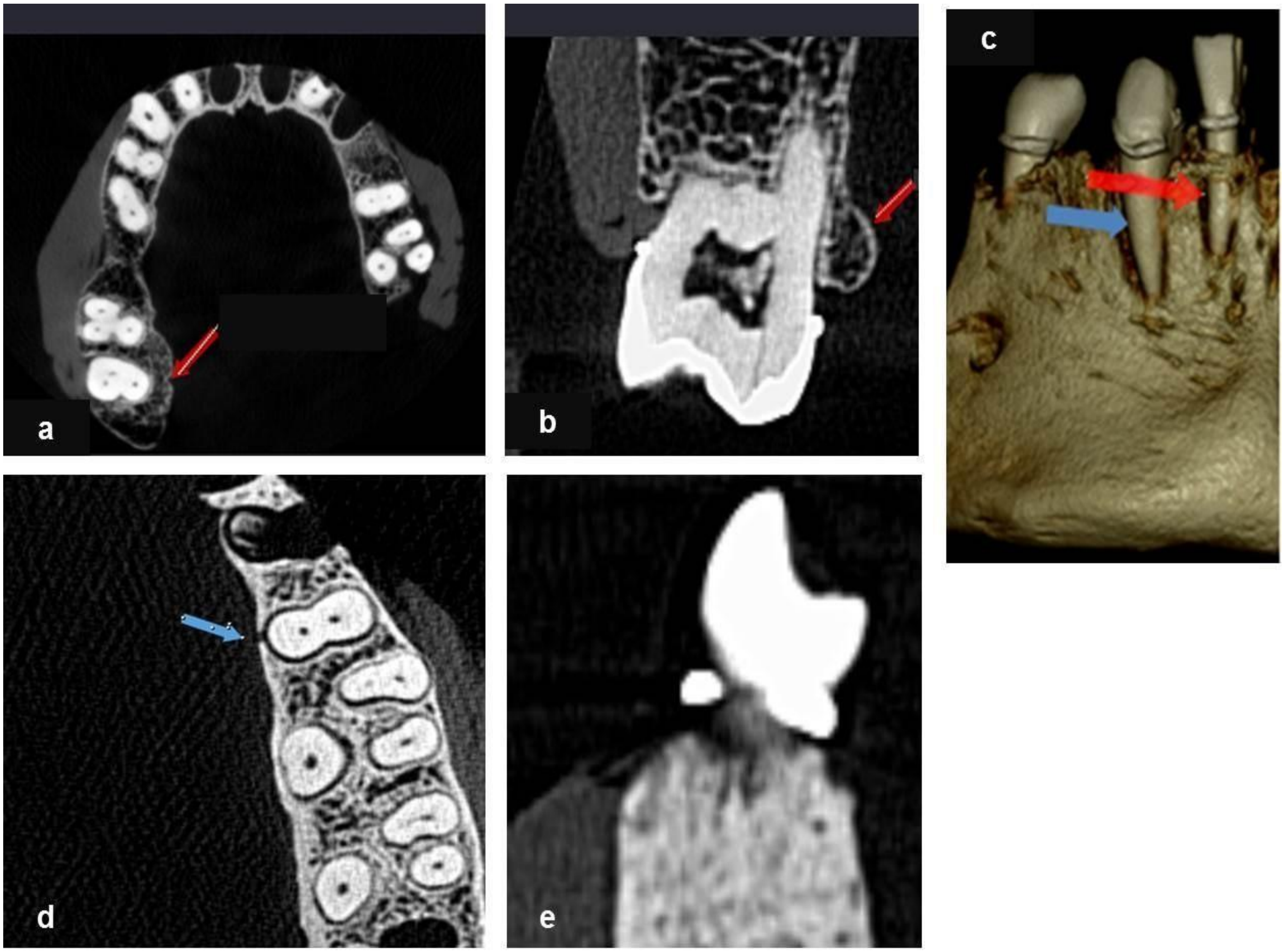

Fig (3): a: CBCT axial cut showing bulbous bone contour on the palatal aspect of the upper second and third right molars. b: CBCT coronal cut showing bulbous bone contour on the palatal aspect of the upper second right molar. c: CBCT volume rendering view showing Fenestration (red arrow) and dehiscence (blue arrow) on the labial surface of the teeth. d: CBCT axial cut showing dehiscence in the palatal aspect of upper right second premolar. e: CBCT Cross sectional cut viewing crater at distal aspect of lower right second premolar.

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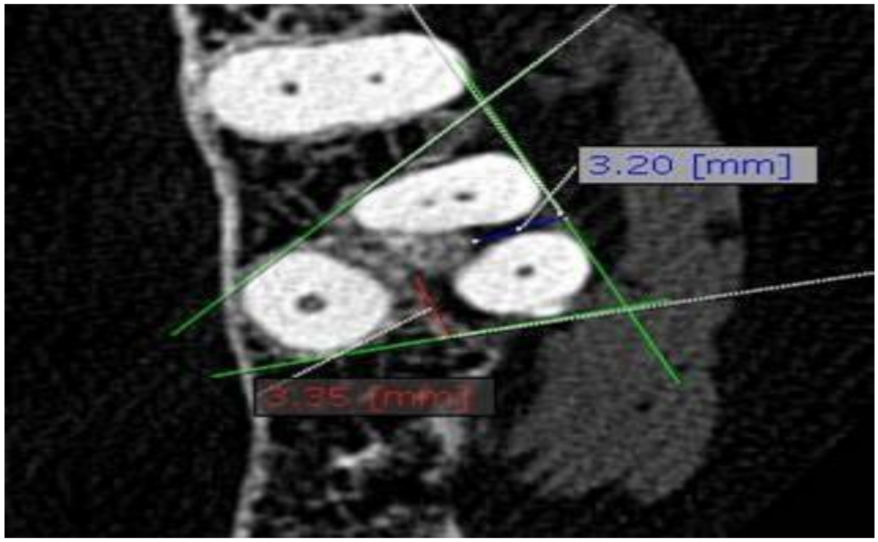

Fig (4): CBCT axial cut showing measurement of trifurcation bone loss: disto palatal class II FI (3.35 mm> 2mm) and mesiodistal class II FI (3.20) mm of upper left first molar as class II horizontal bone destruction extending deeper than 2 mm but less than 6 mm into the furca.

II- Alveolar bone loss linear measurements:

Based on study done by Vasconcelos et al., 2012 ; in order to evaluate periodontitis; the height of the alveolar crest (AC) measured from the CEJ to the AC and the depth of the defect measured from the CEJ to the bottom of the defect [7]. In order to assess bone levels on the gold standard (real measurements on the maxillae and mandibles); direct measurements were taken by using periodontal probe (AISI 420, German) and compared to the electronic caliper (Shenhan Measuring Tools Co., LTD, Shanghai) and used as a standard reference.

A- Linear Interproximal measurements:

Radiographic assessment of alveolar bone loss (the depth of the defect) was done by measuring the distance from the CEJ tothe deepest point of the defect [7,15] and compared with the gold standard. The sites were measured on both techniques; Intraoral Digital periapical radiographs and CBCT, bone heights less than 2 mm were dropped; as periodontal bone loss considred when the distance from CEJ (with guttapurchafiducials) to the deepest point of the defect is more than 2 mm. In Intraoral Digital radiographs: First the images were converted from pixels into millimetres, then with the use of the ruler tool in the software the distance extending from the CEJ to the deepest point of the bony defect was measured (Figure 1.b). In Cone beam computed tomography the bone level was measured on MPR cuts (Sagittal and coronal views) by digital measurement tool of the software (Figure 5) as the distance extending from the CEJ to the deepest part of the bony defect. The interproximal bone defect depth was measured on sagittal slices for the posterior teeth and on coronal slices for the anterior teeth [15]. Measurements from Intraoral Digital radiography and CBCT then compared the gold standard (real measurements on the maxillae and mandibles).

B- Buccal and lingual linear measurements of alveolar bone loss (height of alveolar crest):

As the 3D assessment is the most important feature of the CBCT; buccal and lingual

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bone resorption,evaluation was done and compared with the real measurements on the gold standard, by measuring the distance from CEJ (with guttapurchafiducials) to the alveolar crest AC at 6 points for each tooth; Mesial, central and distal bone levels on the buccal and lingual sides of each selected tooth (mid- buccal, disto-buccal, mesio-buccal, mesio-lingual/ palatal, mid-lingual/palatal, and disto- lingual/palatal) [17] on the **cross sectional cuts** after drawingthepanoramiccurvecorrectlyinrelationtothetoothalignmentontheaxialview (Fig 6). On the gold standard (mandibles and skulls) an electronic digital caliper (Shenhan Measuring Tools Co., LTD, Shanghai) was used for measuring the distance from CEJ to AC; the digital caliper was aligned with the long axis of the tooth during taking measurements at the 6 points on eachtooth.

produce reformatted cross sectional slices that perpendicular on the axial plane. Measuring bone height was done on the cross sectional slices, 3 cross sectional slices were selected for each tooth at mesial aspect for measuring the mesiobuccal and mesiolingual points, in the middle of the tooth for measuring the mid buccal and mid lingual points and at distal aspect of the tooth for measuring the distobuccal and distolingual points (Figure7). Measurments were then compared with the gold standard measurements.

- ✓ Post Analyticalphase:

Intra observer and Inter observer reliability: 2 weeks time interval was set between the two readings for the intra observation of images. For Intra observer reliability: All measurements were done twice.

For inter observer reliability: Assessment of radiographic images was carried out with three expert radiologists (two faculty members of the Cairo University and one faculty member of the British University in Egypt) randomly observed and made the bone height measurements and classification of periodontal defects and furcation involvements on both CBCT and Digital images. The results were compared with the real gold standard on dry jaws.

Research Ethics Commitee: This study was approved by the ethics committee of the faculty of dentistry Cairo University no. 18-10-12. Date: 30/10/2018.

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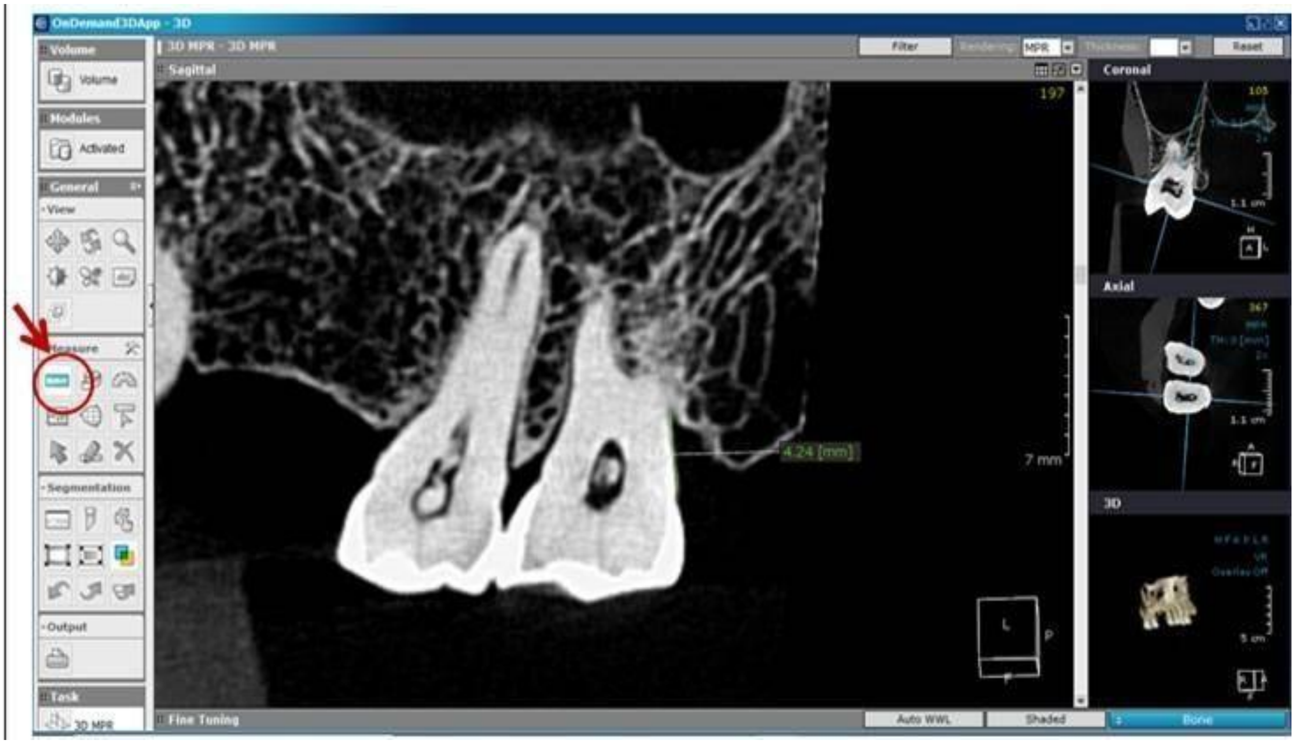

Fig (5): CBCT view showing ruler tool measuring the depth of the angular defect distal to the upper right third molar from the CEJ till the deepest point in the defect on the sagittal cut after the adaptation of the axial plane to be aligned with the level of CEJ and the coronal plane to be aligned with the long axis of the tooth on the other orthogonal planes.

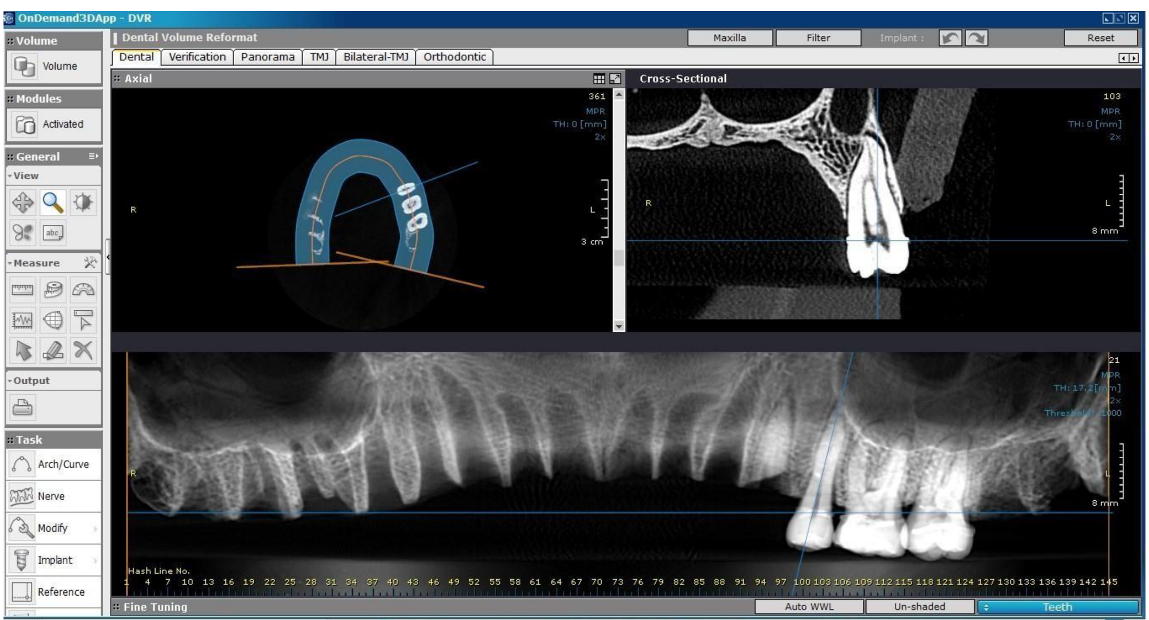

Fig 6: reach midbuccal and midlingual points on the upper left second premolar on the cross sectional cut after drawing panoramic curve correctly on the axial cut and adapting the coordinates on the panoramic view and cross sectional cut as the cross sectional plane aligned in the middle of the tooth and parallel to the long axis of the tooth while the axial plane aligned at the level of the CEJ.

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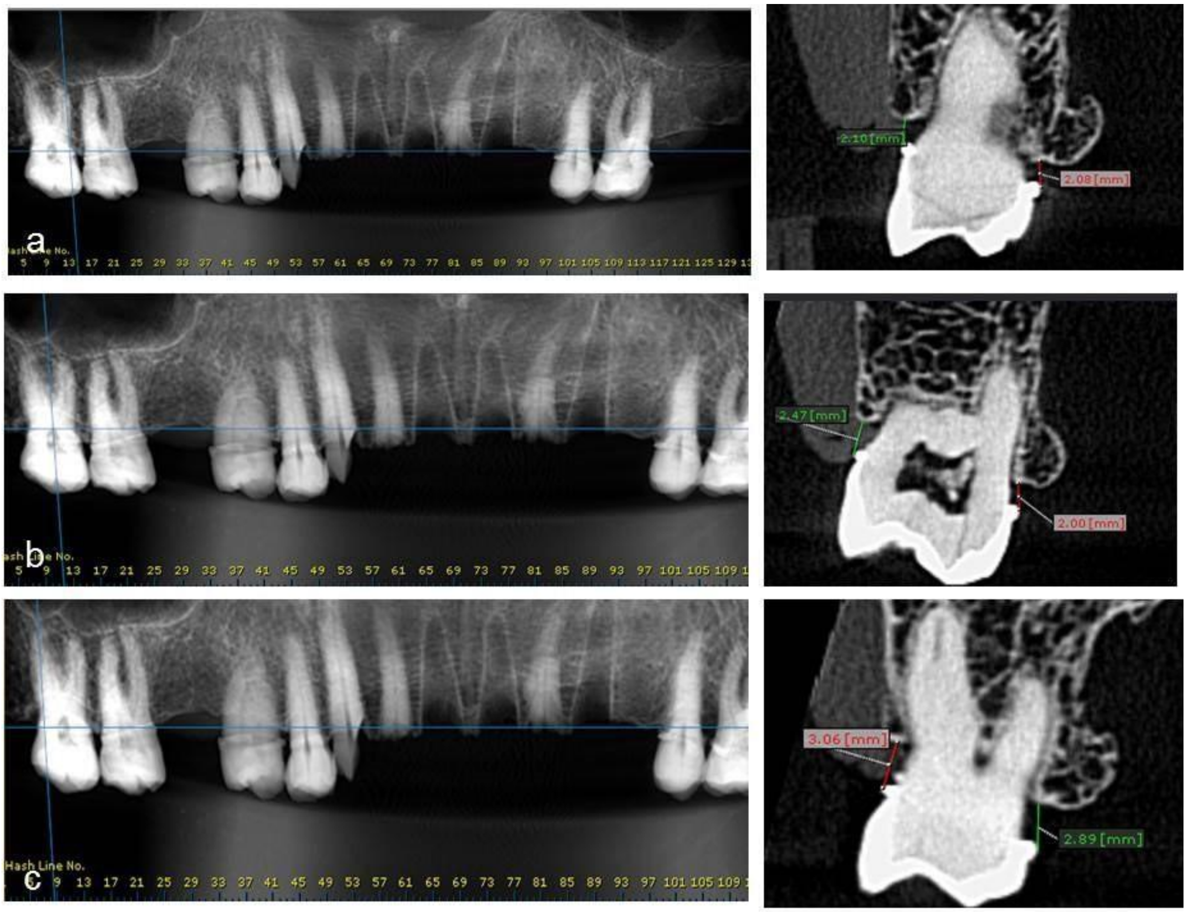

Fig (7): CBCT Reconstructed panorama and cross sectional cuts showing linear measurements; a: at mesiobuccal and mesiopalatal points at the mesial aspect, b:atmidbuccal and midpalatal points in the middle and c: at distobuccal and distopalatal points at the distal aspect of upper right third molar.

Statistical methods: All Data were collected, tabulated and subjected to statistical analysis. Statistical analysis is performed by SPSS in general (version 20), also Microsoft office Excel is used for data handling and graphicalpresentation. Quantitative variables are described by the Mean, Standard Deviation (SD), the Range (Minimum – Maximum), Standard Error (SE) and 95% confidence interval of themean, Qualitative categorical variables are described by proportions andPercentages. For assessment of the agreement between measurements methods with reference method Dahlberg error and Relative Dahlberg Error (RDE) are used together with Concordance Correlation Coefficients (CCC) including the 95% confidence limits. To measure and quantify the size of the differences, Bland and Altman 95% confidence Limits of Agreements (LOA) are applied. All these methods are also applied for both inter and intra observer reliability analysis. For comparing the mean Dahlberg Error (DE) of inter observer reliability independent samples t test is used .For diagnostic testing , sensitivity, specificity, positive predictive values , negative predictive values and test diagnostic accuracy are calculated with the 95% confidencelimits. Significance level is set at $P < 0.05$ and two tailed test assumption is applied

3. Results:

I- Detection of bonydefects:

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A- Detection the presence of bony defects and furcation involvement:

Including comparing the detection the presence of Infrabony defects and Furcation involvement with the gold standard.

All observers results were:

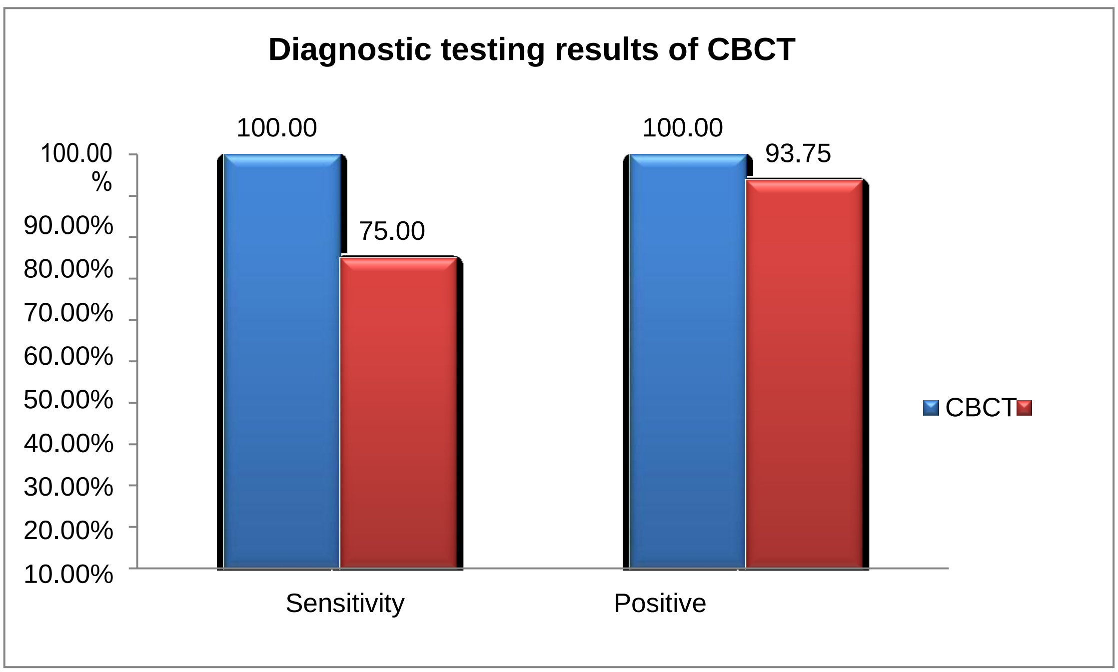
Cone Beam Computed Tomography: CBCT was 100 % exactly matching the Gold standard in the detection of the presence of bone defects with Sensitivity = 100% and Positive predictive value = 100%; showed excellent test accuracy.

Intraoral Digital Radiography: Sensitivity = 75%, Positive predictive value = 93.75%; showed good test accuracy.

The results showed no statistically significant difference between CBCT and Digital radiography both techniques are accurate in detecting the presence of infrabony defects and furcation involvements (Scheme I).

B- Detection of the types of bony defects and furcation involvements grades:

Cone Beam Computed Tomography:The detection of the types of the bony defects and the grading of furcation involvements carried out by CBCT and compared with the gold standard. All observers results were: 100% identically the same match between CBCT and the Gold standard jaws. The results showed no statistically significant difference between CBCT and gold standard dry jaws in detection types of bony defects and furcation involvements (Table1).



Scheme I. Comparison between sensitivity and positive predictive value of CBCT and Intraoral Digital radiography in the detection of the presence of bone defects and furcation involvement

Table 1. Different types of bony defects and furcation involvement detected on Dry jaws and CBCT

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tooth	Dry jaws and CBCT												
	furcation			angular					other				
	I	II	III	1Wall	2Walls	3Walls	combined	crater	Bulbous Bone contour	dehisence		fenestration	
										Buccal	Lingual	Buccal	Lingual
Lower right second premolar								√		√			
Lower right canine										√			
Lower right lateral incisor						√						√	
Lower left central incisor											√		
Lower left lateral incisor											√		
Lower left canine				√						√	√		
Upper left second premolar					√								
Upper left first molar		√								√			
Upper right third molar	√			√					√	√			
Upper right second molar									√	√			
Upper left second premolar											√		
Upper left second molar							√						

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II- Alveolar bone loss linearmeasurements:

A- Linear Interproximalmeasurements:

Measuring the distance from the CEJ to the deepest point of the defect on CBCT and Digital radiography and compared the results with the gold standard.

All observers results were:

Cone Beam Computed Tomography: Relative Dahlberg Error from all observers ranging from 2.3%: 4.2% (< 5 %), with Concordance Correlation Coefficient about 0.9; strength of agreement of CBCT in linear interproximal measurements was Excellent; perfectly matching the gold standard with very small error value less than 5 %.

Intraoral Digital Radiography: Relative Dahlberg Error from all observers ranging from 15.4 %: 22.2 % (about 20%) with Concordance Correlation Coefficient ranging from 0.5: 0.7 (about 0.5); strength of agreement of the digital radiography with the gold standard dry jaws in linear interproximal measurements was Poor with error value about20%.

The results showed there was statistically significant difference between CBCT and IntraoralDigital radiography as CBCT is an accurate technique in linear interproximal alveolar bone loss measurements while digital radiography not accurate technique (SchemeII).

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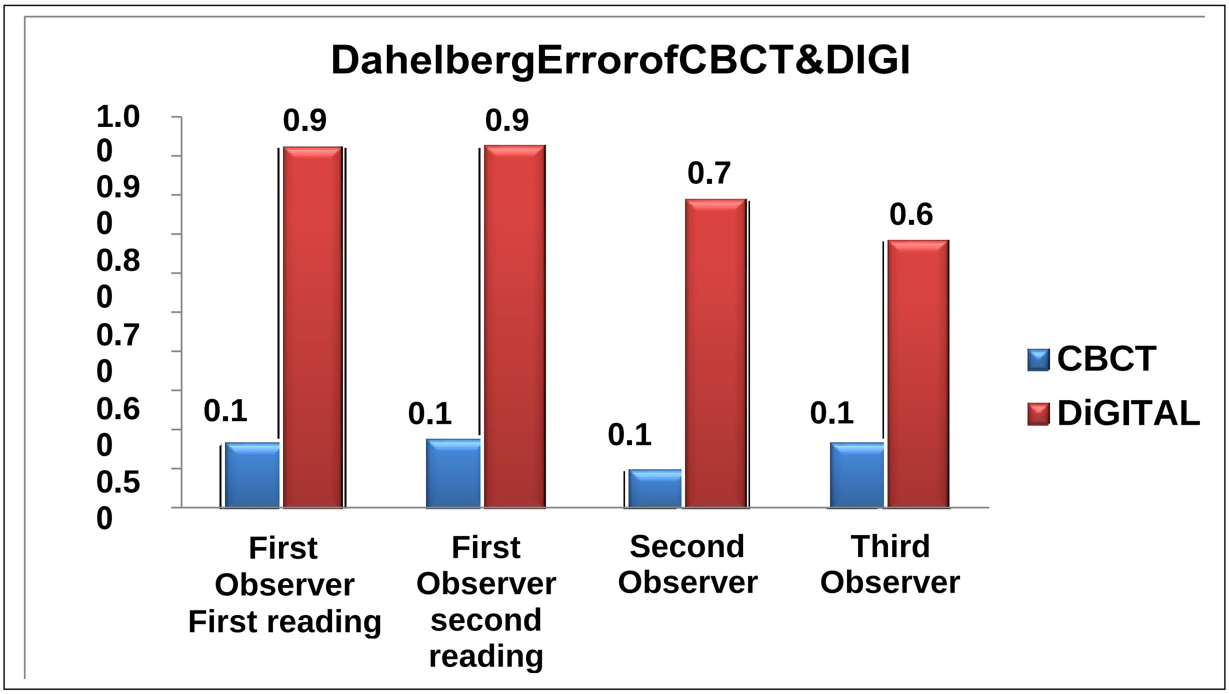

Scheme II. Comparison between Dahlberg error of CBCT and Intraoral Digital Radiography in the linear interproximal alveolar bone loss measurements

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Intraobserver reliability in interproximal alveolar bone loss linear measurements:

Cone Beam Computed Tomography: Relative Dahlberg Error was 2.5% With Concordance Correlation Coefficient about 0.99 (Table 2). CBCT intraobserver reliability strength of agreement wasExcellent.

Intraoral Digital Radiography: Relative Dahlberg Error was 2.8% with Concordance Correlation Coefficient about 0.99(Table3). Digital Radiography intraobserver reliability strength of agreement wasExcellent.

Table 2. Intraobserver reliability of CBCT in linear interproximal measurements.

								Bland &Altman		**Concordance**		
		mean	**SD**	**DehlbergErrorr**	**Relative DehlbergErrod**	**Mean of difference**	**SD of difference**	**95% confidence**			**95% confidence**	
								lower	**upper**	**CCC**	**LOWER**	**UPPER**
First observer	**1st reading**	**4.06**	**1.57**	**0.10**	**2.5%**	**-0.0261**	**0.15**	**-0.31**	**0.26**	**0.996**	**0.991**	**0.998**
	2nd reading	**4.03**	**1.58**									

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Table 3. Intraobserver reliability of Intraoral Digital radiography in linear interproximal measurements.

								Bland &Altman		Concordance	
		mean	SD	DehlbergErrorr	Relative DehlbergErrod	Mean of difference	SD of difference	95% confidence		95% confidence	
								lower	upper	LOWER	UPPER
First observer	**1st reading**	**3.58**	**1.25**	**0.10**	**2.8%**	**-0.0267**	**0.16**	**-0.35**	**0.16**	**-0.35**	**0.29**
	2nd reading	**3.55**	**1.30**								

Interobserver reliability in interproximal alveolar bone loss linear measurements:

Cone Beam Computed Tomography: Relative Dahlberg Error was ranging from 2.8%: 5.4% (about 4.1) with Concordance Correlation Coefficient ranging from 0.97: 0.99 (about 0.98) (Table 4). CBCT interobserver reliability strength of agreement wasExcellent.

Intraoral Digital Radiography: Relative Dahlberg Error was ranging from 6.2%: 14.9% (about 10.5) with Concordance Correlation Coefficient ranging from 0.74: 0.95 (about 0.84) (Table 5). Digital Radiography interobserver reliability strength of agreement was Fair toGood.

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Table 4. Interobserver reliability of CBCT in linear interproximal measurements.

								Bland &Altman		Concordance		
		mean	SD	DehlbergErrorr	Relative DehlbergErrod	Mean of difference	SD of difference	95% confidence lower	upper	95% confidence CCC	LOWER	UPPER
First observer& second	First observer	4.12	1.57	0.11	2.8%	-0.0578	0.36	-0.37	0.25	0.994	0.987	0.997
	Second observer	4.06	1.57									
First observer& third	First observer	4.17	1.62	0.22	5.4%	-0.1128	0.31	-0.72	0.49	0.979	0.959	0.989
	Third observer	4.06	1.57									

Table 5. Interobserver reliability of Digital Radiography in linear interproximal measurements.

								Bland &Altman		Concordance		
		mean	SD	DehlbergErrorr	Relative DehlbergErrod	Mean of difference	SD of difference	95% confidence lower	upper	95% confidence CCC	LOWER	UPPER
First observer& second	First observer	3.65	1.21	0.22	6.2%	-0.0733	0.36	-0.77	0.63	0.956	0.895	0.982
	Second observer	4.06	1.57									
First observer& third	First observer	3.73	1.19	0.53	14.9%	-0.1467	0.86	-1.84	1.55	0.743	0.467	0.887
	Third observer	3.58	1.25									

B- Buccal and lingual linear measurements of alveolar bone loss:

Cone Beam Computed Tomography: Measured from CEJ, to the AC at 6 points on (mid-buccal, disto-buccal, mesio-buccal, mesio- lingual/ palatal, mid-lingual/palatal, and disto-lingual/palatal) were done on CBCT and compared with the real measurements on the gold standard.

All observers: Relative Dahlberg Error was 5 % small error value with Concordance Correlation Coefficient about, 0.9. Strength of agreement of CBCT Buccal and lingual linear measurements of alveolar bone loss with the real gold standard (dry jaws) measurements was Excellent (Scheme III).The results showed no statistically significant difference between CBCT and gold standard, which means that CBCT is an accurate radiographictechnique in buccal and lingual alveolar bone loss linear measurements.

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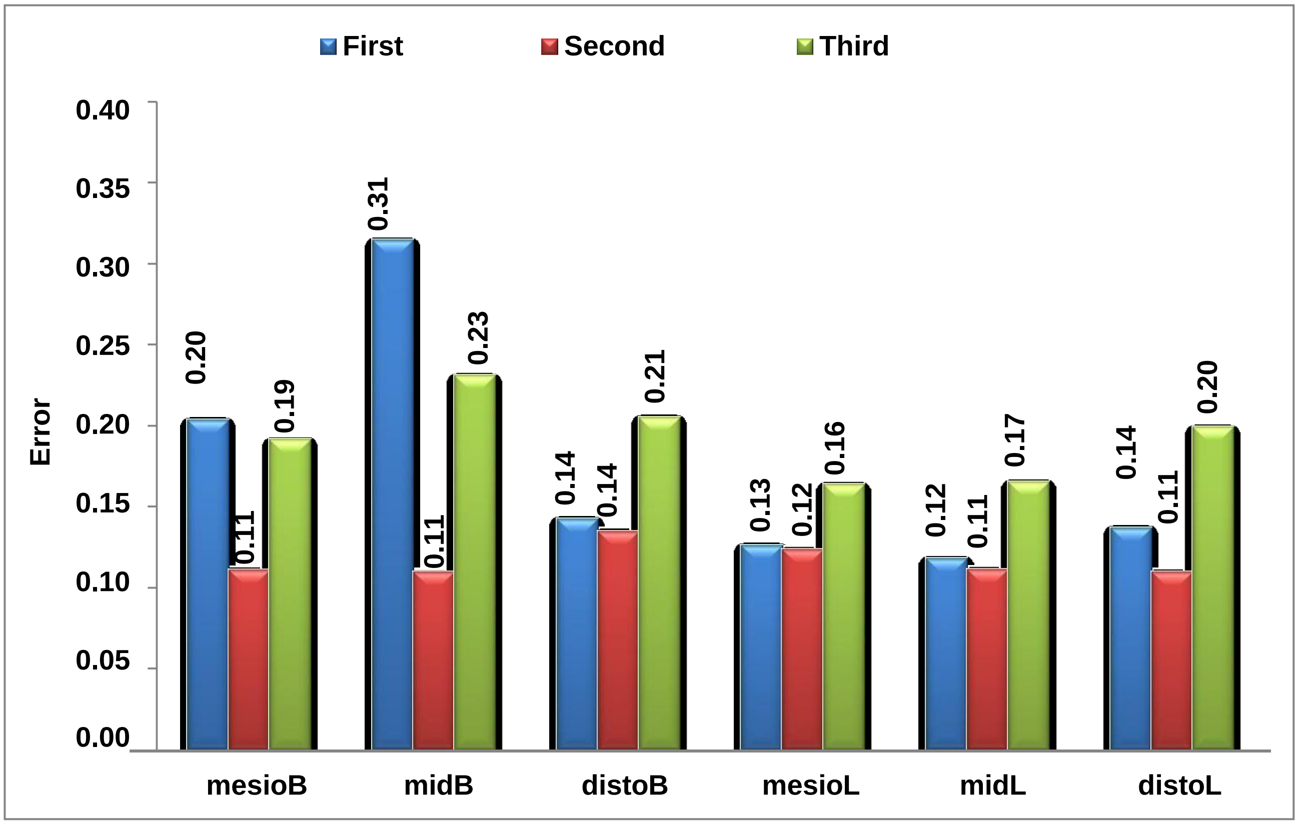

Scheme III. Dahlberg error of the CBCT Buccal and lingual linear measurements of the three observers.

Intraobserver reliability in buccal and lingual alveolar bone loss linear measurements: Cone Beam Computed Tomography: Relative Dahlberg Error was 4.6%; very small value with Concordance Correlation Coefficient about 0.9
CBCT intraobserver reliability strength of agreement wasExcellent.

Inter observer reliability in buccal and lingual alveolar bone loss linear measurements: Cone Beam Computed Tomography: Relative Dahlberg Error was about 5 % with Concordance Correlation Coefficient was 0.9. Strength of agreement of CBCT interobserver reliability was Excellent. The results showed interobservation agreement between the three observer was reliable and matching each other (SchemeVI).

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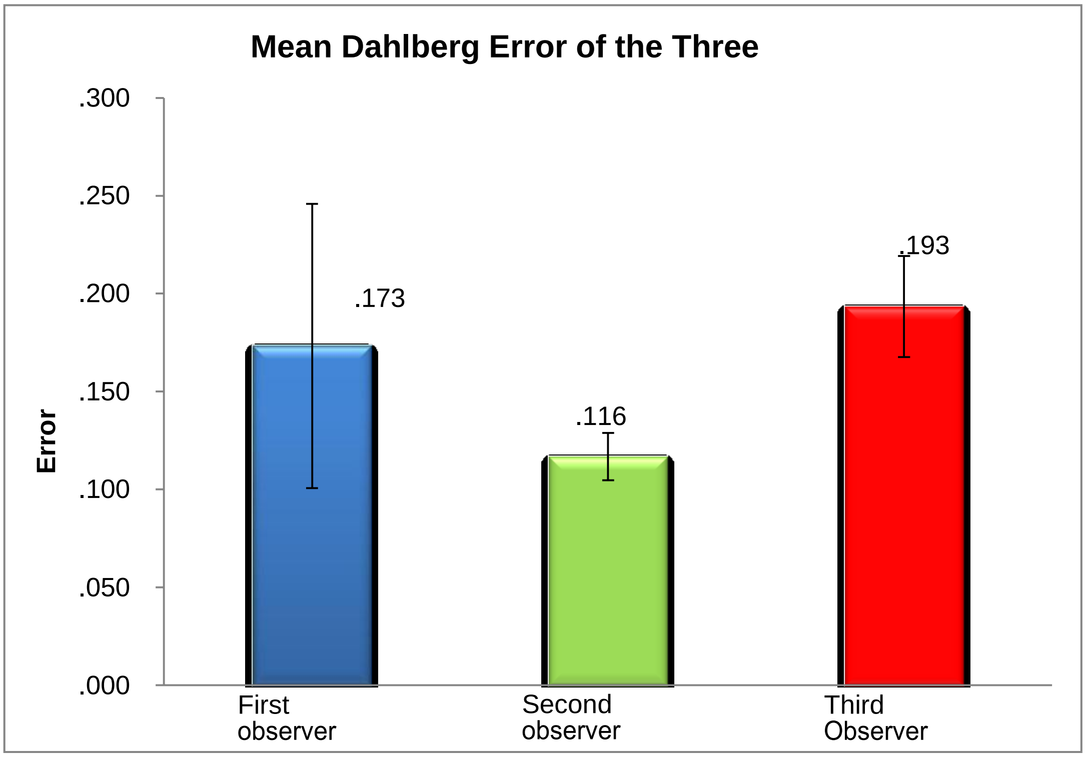

Scheme IV. Mean dehlberg error of CBCT buccal and lingual alveolar bone loss linear measurements of the three observers.

4. Discussion:

It is very important to have access to accurate diagnostic tools that can aid clinicians in cultivating an appropriate treatment choice [16]. Although, Clinical probing and intraoral radiography are the basic diagnostic tools in periodontology, studies have proved the limitations of both techniques in the determination of bone loss patterns. As regards, 2D technologies do not allow for measurement of the bucco-lingual (B-L) width of the defect, but it allows measuring the vertical height and the mesio-distal (M-D) width of the bony defect [5]. Few studies have compared the accuracy of 2D and 3D radiographic techniques for the diagnosis of periodontal diseases, while using CBCT for periodontal assessment may offer new perspectives on periodontal diagnosis and treatment planning, therefore we thought it is worthwhile to explore the use of CBCT in comparison with digital radiography in the assessment of periodontal defects; as the aim of this study was comparing digital radiography with CBCT in the detection and measurements of different simulated bone defects. The radiographic assessment of periodontal defects in current study, included detecting presence of the bony defect, identification of its type, measuring the interproximal depth of the periodontal defect from CEJ to the deepest point in the bony defect and measuring the alveolar crest (AC) height by measuring the distance from CEJ till the AC on the buccal and lingual aspects of the teeth [7, 12, 15, 17]. On one hand, Digital radiography was used in this study in detection and measurements of the periodontal defects, as it has a lot of advantages over conventional radiography including higher Spatial resolution, , no dark-room nor developing process, moreover it provides interactive display on a monitor with the ability to enhance image (contrast, brightness, sharpness and reducing noise) making the original radiograph visually more appealing, and image analysis to reveal diagnostic relevant information from the radiograph ranging from simple linear measurements to totally automated diagnosis [3]. Therefore, in the current study, digital

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radiography was used for detection of the periodontal defects and taking linear interproximal measurements of the alveolar bone loss with the use of digital rulers. As regards, the most accurate intraoral radiographic technique is the paralleling technique to obtain standardized periapical radiographs, so in the current study film holder (XCP®; DentsplyRinn, Elgin, IL) was fixed to the X-ray tube head during exposure as the parallel technique was used. But, the major limitation of the intraoral radiography is their deficiency in assuring available three-dimensional (3D) parameters; can't define the classification of alveolar bone destruction, especially the evaluation of complex defect structures such as combined intrabony defects, craters, and furcation involvement, So, in general, the accurate diagnosis of bone defects was possible only by direct observation during a surgical procedure. However, evaluation of the type and depth of the defect during surgery gives little time to the surgeon to plan out the type of procedure for periodontal regeneration. Hence comes the role of CBCT as its most important advantage is providing unique 3D images demonstrating features [4, 5]. As, CBCT offers many advantages compared with conventional CT; CBCT provides images with high resolution at a lower cost, shorter examination time and less radiation dose, and used for multiple diagnosis and treatment plan. CBCT provides superior image quality, allows easy description of different bone defects [3, 4, 13, 17]. Thanks to the 3D assessment in CBCT, imaging becoming available for periodontal treatment planning. As, one of the most deterministic factors to evaluate treatment procedures is the making of a definite diagnosis of the defect morphology and classification, Cone-beam computed tomography (CBCT) provides high contrast 3D images of periodontal structures that help to determine a definite diagnosis and treatment options for successful periodontal therapy [5]. Accordingly, so on the other hand, CBCT was used in this study for detecting presence of the bony defects, identification of its type, taking both interproximal defect depth measurements and buccal and lingual alveolar crest height needed for the radiographic evaluation. Owing to the ability to collimate the x-ray different dimensions of FOV in CBCT units permits exposure of the specific area of interest, and restricts irradiation of adjacent tissues. This option provides images with high resolution and minimal radiation dose [3]. CBCT different platforms provides images with sub- millimeter isotropic voxel resolution (ranging from 0.4mm to as low as 0.076mm) which means that all the sides are the same dimension with uniform resolution in all directions. This is considered an advantage of the CBCT because if a certain structure needs to be measured, the measurement will be exact in all the three orthogonal planes. Moreover, images acquired in smaller voxel sizes "prettier" and sharper. As, In order to view periodontal structures such as the periodontal ligament space, cortical bone, alveolar crest and alveolar cortical plate, higher image quality and smaller voxel size are required in CBCT technique [13]. Accordingly, small field of view (8×10cm) and high resolution mode with

0.15 voxel size and exposure parameters of [15]; 90 Kvp ,10 m.A ,effective exposure time 6 s, and 0.5mm Focal spot were used in this study. In this study Image analysis was performed using OnDemand software facilitated image restoration, enhancement, and applying measurements. Storage of Dicom images, data access from anywhere with internet, make a diagnosis and treatment planning easier [15]. Human dry mandibles and skulls were used as a gold standard for the detection and measurement of the periodontal defects in the current study; as reference gold standard method has high level of

accuracy in assessment of periodontal bone defects and frequent used in almost similar studies. And because of the dehydration of the dry jaws, guttapurcha was used as standardized fiducials to substitute for the faded CEJ, AS CEJ was used as a reference point to assess bone levels [12, 13, 17]. The results of current study demonstrated the potential value of both Digital radiography and CBCT in the detection and measurements of the periodontal bone defects. Regarding comparing detection of the periodontal bone defects between the two techniques, there was no statistically significant difference between CBCT and Digital radiography as both techniques are reliable in detecting the presence of

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infrabony defects and furcation involvements as the CBCT was 100 % exactly the same as the Gold standard Jaws in the detecting presence of bone defects with 100% sensitivity and positive predictive value showed excellent test accuracy, while the Digital showed 75% sensitivity with positive predictive value of 93.75% Showed highly accurate test method.But regarding comparing the linear measurements between the two techniques there was statistically significant difference, as strength of agreement of the digital radiography with the gold standard dry jaws in linear interproximal measurements was Poor. While, the strength of agreement of CBCT in linear interproximal measurements was Excellent perfectly matching the gold standard.Due to the ability of CBCT in doing 3D assessment, there were extra data and results extracted from CBCT and compared with the gold standard dry jaws;As, detection of the types of the bony defects and the grading of furcation involvements carried out by CBCT showed 100% identical matching to the Gold standard jaws; as CBCT detected different angular bony defect (1 wall, 2 walls, 3 walls and combined), furcation involvement with different grades and different other bony defects (bulbous bony contour, dehiscence, fenestration and crater). Moreover, on CBCT Buccal and lingual linear measurements of alveolar bone loss were measured from CEJ, to the AC at 6 points on (mid-buccal, disto-buccal, mesio-buccal, mesio-lingual/ palatal, mid- lingual/palatal, and disto-lingual/palatal) and compared with the real measurements on the gold standard, the results showed strength of agreement with the real gold standard measurements was Excellent and concluded that CBCT is a accurate radiographic techniques for buccal and lingual measurements. It has an important clinical value as, CBCT noninvasive technique to measure the distance from CEJ to AC at 6 points at each tooth buccally and lingually, while to take these measurements clinically may cause patient discomfort and pain [18]. In the current study, intra observer reliability and inter observer reliability were done and the strength of agreement was Excellent. So, it is an accurate diagnostic study. The results of the current study were in line with a study done by Molon et al., 2014 who evaluated the Detection of Simulated Periodontal Bone defects using digital images and found that the digital radiography is a useful tool for the detection of the periodontal bone defects [24].

Concerning, the measurements of the alveolar bone loss, our results were in concord with Vasconcelos et al., 2012 who compared digitized intraoral radiography and CBCT in detection of periodontal bone loss and the results have revealed difference between the two methods when detecting the height of the alveolar bone crest [7]. As the digital radiography has proven to be highly sensitive and accurate technique. However, intraoral radiography provides only a 2-dimensional (2D) view of 3- dimensional (3D) structures which can lead to underestimation of bone loss and errors [15]. Regarding the measurements done by Digital radiography, our study matched the results of a study done by De Molon et al., 2012 who compared the inverted digital images and film-based images in measuring simulated periodontal bone defect depth of dry pig mandibles and found that the periodontal bone defect measurements in the digital images were inferior to film-based radiographs, underestimating the amount of bone loss [19]. As regards, CBCT measurements accuracy results, in our study were in line with a study done by Pour et al., 2015 who measured the Accuracy of Cone Beam Computed Tomography for detection of bone Loss by measuring the distance from the cemento- enamel junction to the alveolar crest in the buccal, lingual/palatal, mesial and distal surfaces and compared them with the intrasurgical probing measurements and found that CBCT enables accurate measurement of bone loss comparable to surgical exploration and can be used for diagnosis of bone defects in periodontal diseases in clinical settings [13]. Moreover, Vasconcelos et al., 2012 detected periodontal bone loss by measuring distance between CEJ and AC using cone beam CT and intraoral radiography in relation to the gold standard periodontal evaluation database and the results was that the two techniques statistically different from each other, with an average of

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3.8 mm for measurements taken in periapical radiography and 4.1 mm for the CBCT images.and concluded that CBCT is the only method that allowed for an analysis of the buccal and lingual/palatal surfaces and an improved visualization of the morphology of the defect [7]. In addition, Kim and Bassir, 2017 found that use of 3D volumetric images and 2D images in artificial bone defects have shown that CBCT has a sensitivity of 80% to 100% in detection and classification of bone defects, while intraoral radiographs present a sensitivity of 63% to 67% and when compared with periapical and panoramic images, has shown an absence of distortion and overlapping, and the dimensions of the images that it presents were compatible with the actual size of the individual [20]. Another study that matching with the current study results; a study done by Warda et al., 2019 determined the accuracy of cone beam computed tomography (CBCT) in the assessment of mandibular molar furcation defects when compared to intra-surgical assessment and found that CBCT is an accurate technique for furcation assessment [14]. Moreover, the superiority of CBCT over clinical assessment was confirmed through several studies where Walter et al., 2010 showed that CBCT provides more detailed information about the degree of FI compared to the clinical findings and periapical radiographs [21]. Also recently Cimbaljevic ., 2015 concluded that the number of FI detected by means of CBCT was larger than by means of periodontal probing and suggested that CBCT may be used as an adjunct tool for FI assessment [22]. Regarding FI our study was limited in the comparison between the Digital radiography and CBCT as all furcation involvement included here were trifurcations of upper molars and the assessment and grading of the FI were carried out only by CBCT because of the 2D superimposition in digital radiography; the comparison between the 2 techniques carried out only in the detection of the presence FI no grading involved in the comparison. As well as, the results of the current study also were in line with a study done by Bayat et al., 2016 who assessed the diagnostic value of CBCT and digital intraoral radiography for the detection of periodontal defects in the sheep mandible where periodontal defects including Grades I, II and III furcation involvements, one-, two-, three-wall, fenestration and dehiscence were artificially created and concluded that CBCT is superior to digital intraoral radiography for the detection different types of bone defects [12]. Also Regarding, the detection and identification of different types of bone defects our results were matching a study done by Ozcan and Sekerci 2017 who classified the alveolar bone destruction patterns by using cone-beam computed tomography and found that CBCT can provide comprehensive information about the remaining alveolar bone structures [5]. Concerning, our results about buccal and lingual linear measurementsat 6 points in each tooth, our study were in concord with a study done by el Zoheiry et al., 2011 who assessed the periodontal defects using cone beam computed tomography and compared the results with the gold standard dry jaws and found that CBCT images allowed accurate measurements of periodontal defects on cross-sectional slices because of the absence of the overlapping structures [17]. Also regarding the buccal and lingual measurements, there was an interesting study done by Yang et al., 2019 who evaluate the performance of cone-beam computed tomography (CBCT) in assessing periodontal bone loss at 6 points in each tooth and compared it with the clinical measurements and the results were not matching ours as they concluded that CBCT do not agree with results of intra-surgical measurement [18]. But their study was clinical in vivo study; where factors such as force, angulation, and position that may influence the accuracy of probing and they used voxel size of 0.4 while the measurements from the smaller voxel size, high resolution images will be significantly more accurate in case of periodontal assessment [23].

5. Conclusions:

Non inferiority hypothesis between CBCT and Intraoral Digital Radiography in detecting the presence of the bony defects.And superiority of CBCT in the linear measurements and in the detection of the different types of bony defects and furcation involvemen.

Author Contributions:

Marwa Mohamed Ali Responsibility: Collected data, simulating different types of periodontal bone defects on the dry skulls and mandibles, performed CBCT scanning and intraoral digital radiography scanning, recorded the first detection of the different bone defects and linear measurements by the two radiographic technique and compared them with the gold standard dry jaws and ensured the integrity and safeguarding of the scientific data. wrote the manuscript. HossamKandil, responsibility: Assisted in the full research plan, discussed the work through meetings and exchanging email, performed the second examination of the CBCT scans and intraoral digital radiography in detection and linear measurements and was the major contributor in writing and editing the manuscript. Iman Ismail Dakhli., Monitored the progress of the research through regular formal supervisory meetings, gave detailed advice on the necessary completion dates of successive stages of the work, performed the third examination of the CBCT scans and intraoral digital radiography in detection and linear measurements and wrote the primary manuscript. All authors read and approved the final manuscript.

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Institutional Review Board Statement:

This study was conducted according to the guidelines of the Declaration of Cairo University, and approved by the ethics committee of the faculty of dentistry Cairo University no. 18-10-12. At 30/10/2018., due to this study included dry mandibles and skulls were selected as reference gold standard method due to its high level of accuracy in the assessment of periodontal bone defects and frequent usage in almost similar studies [13, 17].

Acknowledgments:

Not applicable.

Conflicts of Interest:

The authors declare that they have no competing interests.

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