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Comparison of the diagnostic performance of CBCT and intraoral digital periapical radiographs in alveolar bone loss assessment.

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ABSTRACT

Objective: To compare digital Intra Oral Periapical (IOPA) Radiographs with Cone Beam CT (CBCT) images in detecting and localizing alveolar bone loss by comparing linear measurements of height, depth and width of the defects to analyse if use of CBCT is justified for assessing periodontal defects.

Materials and method: 35 CBCT images and digital IOPAs from the secondary database were assessed for horizontal and vertical bone loss using measurement tool and contrast enhancement features of the software.

Result: No significant difference was seen between the two imaging methods in terms of identification of pattern of bone loss, depth and width of defect.. 21of the 35 teeth evaluated had combined bone defects which could be detected only on CBCT.

Conclusion: The two methods were similar in detecting height, depth and width of bone defects. CBCT however allowed analysis of buccal and lingual/palatal surfaces improving visualization of the morphology of the defect. Hence, CBCT should be only advised for advanced periodontitis.

KEYWORDS : Cone beam computed tomography, Digital intraoral radiography, Periodontal bone assessment , digital imaging

INTRODUCTION

Diagnosis and accuracy in determining the exact location, extent and configuration of bony defects of the jaw are of utmost importance to determine prognosis, treatment planning and long-term preservation of teeth. If relatively accurate diagnosis can be established by radiography, proper treatment planning prior to treatment procedures will be possible. Radiographs have been used from time immemorial in planning initial, corrective and supportive phases of therapy, though some decisions may be made on clinical assessments alone.[1]

Among two-dimensional (2D) radiographic methods, bitewing and periapical radiographs are the most suitable because they are easily acquired, cheap and provide high-resolution images.[2,3] Also studies suggest that radiographic assessments on the digitized images came close to the intra surgical gold standard.[4] According to literature, these methods are limited by overlapping anatomical structures, difficulty in standardization[5,6] and by underestimating the size and occurrence of bone defects.[7]

CBCT provides 3 dimensional analysis and rapid volumetric image acquisition taken at different points in time that are similar in geometry and contrast, making it possible to also evaluate differences occurring in the fourth dimension i.e. time. In its various dental applications, images of jaws and teeth can be visualized accurately with excellent resolution, can be restructured three dimensionally, and can be viewed from any angle.[8]

Research comparing the use of three-dimensional (3D) volumetric images and 2D images in artificial bone defects have shown that CBCT has a sensitivity of 80–100% in the detection and classification of bone defects,[6,9,10] on the other hand digital periapical images have also been found to be close to the intrasurgical gold standard.[4] Hence, it was the purpose of this study to assess and compare the linear measurements of the height, depth and width of the periodontal defects in detecting and localizing alveolar bone loss in digital intra oral periapical (IOPA) radiography obtained on phosphor plate system with paralleling technique and CBCT images to determine whether the use of CBCT is justified for diagnosing periodontal defects.

MATERIALS AND METHOD

35 CBCT images and digital IOPAs of patients who underwent the investigations for various clinical conditions were collected from the secondary database of the radiology clinic at Dr D.Y Patil Dental College and Hospital. Areas of bone loss were identified on the images. Horizontal and vertical bone loss was then assessed in both images using various features of the software, including measur ement tool and contrast enhancement.

The CBCT machine used was Kodak 9000 3D system; exposure volume (FOV) of 30 mm in width and 50 mm in height, the voxel size was set at 76 microns. Exposure parameters were set at tube Voltage 80 kV; tube current 2 mA; exposure time 14 seconds. CBCT images were generated using Care Stream CS 3D Imaging Software version 3.1.9 in DICOM format in an Intel ® Core (7M), 93-2120 CPU @3.30 GHz, 1.89 GB RAM, Microsoft XP Professional Service Pack 2.

IOPA radiograph were taken using Photostimulable Phosphor (PSP) plates (24 X 40 mm) with paralleling angle technique using Rinn XCP holders with the help of Kodak 2200 Intra Oral X ray System; exposure parameters of tube voltage 70 kV; tube current 7 mA; exposure time ranging from 0.18 seconds to 0.310 seconds. The plates were scanned using Kodak CR 7400 Digital Radiography System and images generated in Trophy DICOM software version 6.2.0.0 and Kodak imaging software version 6.12.26.0.

INCLUSION AND EXCLUSION CRITERIA

Images of good quality defined as medium density and contrast, centralization of region, and those which assessed and visualized CEJ were included in the study; while areas which presented overlap, metallic restorations, producing scatter or compromised CEJ were excluded. These were selected by an oral radiologist with 13 years of professional experience.

IMAGE EVALUATION

The images were analyzed by two examiners who were well trained: Examiner1 was an oral radiologist with 2 years professional experience and Examiner 2 was Masters Student in oral radiology. The interpretation was carried out in a quiet room, using a 17 inch monitor with 1280 X 1024 screen resolution. The images were analyzed at different times, thereby characterizing a blind study of the results. Each examiner assessed whether the pattern of bone loss was horizontal or vertical in both types of image. The sites were measured first on periapical radiographs and later on CBCT images with the help of measurement tool in the Kodak Imaging Software V 6.12.26.0 based on the method proposed by Misch et al.[12] Three measurements were performed for each site: the height (H) of the alveolar crest measured from the CEJ to the AC; the depth(D) of the periodontal defect, measured from the CEJ to the bottom of the defect; and the width(W) of the periodontal defect, measured from the highest point on the AC to the root adjacent to the periodontal defect(Fig.1,2). In IOPA if the level of AC showed more than one image (buccal/lingual superimposition), the deepest point was considered for the measurement. The axial slices in CBCT (Fig.3) were used to verify the presence of combined bone defects, according to the classification of Goldman and Cohen.[11]

FIGURES

Figure 1 : Measurement tool used to measure height, depth and width of the periodontal defect in CBCT image.

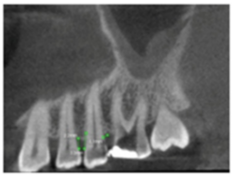
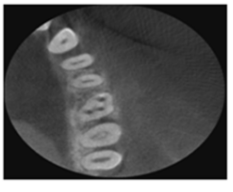


Figure 2 Measurement tool used to measure height, depth and width of the periodontal defect in Digital IOPA.

Figure 3 Cross sectional view on CBCT.



STATISTICAL ANALYSIS

The SPSS software for Windows (version 20.0; IBM SPSS) was used, assuming a significance level of 5% (a=0.05) for all tests. To evaluate the intra and inter examiner concordance, the Kruskal–Wallis test was used; Pearson co relation test was done to further evaluate inter examiner agreement.

RESULTS

In order to classify the presence of alveolar bone loss, a distance of 1.4 mm from the CEJ to the AC was used as the parameter of normality.[12] 35 teeth were imaged and alveolar bone loss was found at 42 sites. There were 6 sites with horizontal bone loss and 16 sites with vertical bone loss and 20 sites with both horizontal and vertical bone loss. The sites of bone loss included were ranging from mild periodontitis(1-2mm) to severe periodontitis(6-7mm).

The result of the Kruskal–Wallis test for comparison between the measurements made by the two examiners showed p-value of> 0.05 for all the measurements indicating that the scores were non-variant for data collected by the examiners. (Table no.1) The results demonstrate a high agreement between the two examiners, revealing good calibration and reliability of the results of the study. There was no statistically significant difference in relation to the identification of the pattern of alveolar bone loss in either imaging modality. Examiners 1 and 2 were in agreement in 100.0% of the cases in identifying horizontal or vertical bone loss.

According to the Pearson's correlation test (Table no.2) carried out at a significance level of 0.01, comparison between the scores obtained by IOPA and CBCT for the height of bone loss (H) and depth of bone loss (D) were highly significant with a high positive co-relation. The height and depth were also highly significant (height range – 0.986- 0.933, depth range- 0.993- 0.925) when compared between the two examiners indicating a good correlation in the findings of IOPA and CBCT and also reproducibility of the findings in both the techniques.

On comparing the width of bone loss (W) between IOPA and CBCT values and between the two examiners, the findings were again statistically significant (width range- 0.798 – 0.407) but not as highly correlated as the height and depth.

In addition, the descriptive statistics also show that the mean values of the scores of IOPA and CBCT in terms of height, depth and width by both the examiners correlate closely indicating a good reproducibility of the findings.

Measurements of the buccal and palatal/lingual surfaces in axial sections were not compared with the periapical images owing to the limitations of the latter. So, we evaluated the agreement of the absolute measurements made between the two examiners, finding p-values of<0.05 which shows that the cross-sectional slices allow for the assessment of bone loss in both buccal and lingual/palatal surfaces reliably. According to the classification proposed by Goldman and Cohen,[11] 21 teeth (60%) presented combined defects with, 1 wall defect in 14 (40%) teeth; 2 wall defect in 4 (11.42%) teeth; 3 wall defect in 1 (2.86%) tooth and craters in 5 (14.28%) teeth. Examiners 1 and 2 were in agreement in 100.0% of the cases.

Table No. 1 : Kruskal Wallis Test Hypothesis Summary (H=Height, D= Depth, W= Width. And 1= Examiner 1, 2= Examiner 2 and V1 is sample size)

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of IOPA H1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.197	Retain the null hypothesis.
2	The distribution of IOPA H2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.270	Retain the null hypothesis.
3	The distribution of CBCT H1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.151	Retain the null hypothesis.
4	The distribution of IOPA D1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.616	Retain the null hypothesis.
5	The distribution of CBCT D1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.568	Retain the null hypothesis.
6	The distribution of IOPA W1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.271	Retain the null hypothesis.
7	The distribution of CBCT W1 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.405	Retain the null hypothesis.
8	The distribution of CBCT H2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.163	Retain the null hypothesis.
9	The distribution of IOPA D2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.416	Retain the null hypothesis.
10	The distribution of CBCT D2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.542	Retain the null hypothesis.
11	The distribution of IOPA W2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.114	Retain the null hypothesis.
12	The distribution of CBCT W2 is the same across categories of V1.	Independent-Samples Kruskal-Wallis Test	.200	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table No.2 : Pearson Co Relation shown in tabular format.
(H=Height, D=Depth, W=Width. And 1=Examiner 1, 2=Examiner 2)

Correlations

		IOPA H1	CBCT H1	IOPA D1	CBCT D1	IOPA W1	CBCT W1	IOPA H2	CBCT H2	IOPA D2	CBCT D2	IOPA W2	CBCT W2
IOPA H1	Pearson Correlation	1	.986**	.551**	.563**	-.029	-.089	.946**	.951**	.545**	.529**	-.065	-.093
	Sig. (2-tailed)		.000	.000	.000	.812	.463	.000	.000	.000	.000	.592	.442
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT H1	Pearson Correlation	.986**	1	.539**	.552**	-.023	-.089	.933**	.949**	.535**	.533**	-.063	-.097
	Sig. (2-tailed)	.000		.000	.000	.847	.465	.000	.000	.000	.000	.606	.424
	N	70	70	70	70	70	70	70	70	70	70	70	70
IOPA D1	Pearson Correlation	.551**	.539**	1	.993**	.101	-.005	.514**	.525**	.933**	.925**	.059	.084
	Sig. (2-tailed)	.000	.000		.000	.404	.966	.000	.000	.000	.000	.627	.491
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT D1	Pearson Correlation	.563**	.552**	.993**	1	.119	.010	.527**	.537**	.940**	.932**	.075	.097
	Sig. (2-tailed)	.000	.000	.000		.326	.937	.000	.000	.000	.000	.536	.423
	N	70	70	70	70	70	70	70	70	70	70	70	70
IOPA W1	Pearson Correlation	-.029	-.023	.101	.119	1	.689**	-.069	-.006	.154	.173	.798**	.574**
	Sig. (2-tailed)	.812	.847	.404	.326		.000	.571	.960	.205	.153	.000	.000
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT W1	Pearson Correlation	-.089	-.089	-.005	.010	.689**	1	-.092	-.076	.049	.065	.541**	.407**
	Sig. (2-tailed)	.463	.465	.966	.937	.000		.450	.533	.686	.592	.000	.000
	N	70	70	70	70	70	70	70	70	70	70	70	70
IOPA H2	Pearson Correlation	.946**	.933**	.514**	.527**	-.069	-.092	1	.941**	.518**	.488**	-.071	-.088
	Sig. (2-tailed)	.000	.000	.000	.000	.571	.450		.000	.000	.000	.558	.470
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT H2	Pearson Correlation	.951**	.949**	.525**	.537**	-.006	-.076	.941**	1	.534**	.532**	-.048	-.086
	Sig. (2-tailed)	.000	.000	.000	.000	.960	.533	.000		.000	.000	.693	.477
	N	70	70	70	70	70	70	70	70	70	70	70	70
IOPA D2	Pearson Correlation	.545**	.535**	.933**	.940**	.154	.049	.518**	.534**	1	.978**	.084	.151
	Sig. (2-tailed)	.000	.000	.000	.000	.205	.686	.000	.000		.000	.487	.212
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT D2	Pearson Correlation	.529**	.533**	.925**	.932**	.173	.065	.488**	.532**	.978**	1	.131	.195
	Sig. (2-tailed)	.000	.000	.000	.000	.153	.592	.000	.000	.000		.280	.106
	N	70	70	70	70	70	70	70	70	70	70	70	70
IOPA W2	Pearson Correlation	-.065	-.063	.059	.075	.798**	.541**	-.071	-.048	.084	.131	1	.760**
	Sig. (2-tailed)	.592	.606	.627	.536	.000	.000	.558	.693	.487	.280		.000
	N	70	70	70	70	70	70	70	70	70	70	70	70
CBCT W2	Pearson Correlation	-.093	-.097	.084	.097	.574**	.407**	-.088	-.086	.151	.195	.760**	1
	Sig. (2-tailed)	.442	.424	.491	.423	.000	.000	.470	.477	.212	.106	.000	
	N	70	70	70	70	70	70	70	70	70	70	70	70

**. Correlation is significant at the 0.01 level (2-tailed).

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DISCUSSION

The purpose of this study was to assess the usefulness of CBCT in the assessment of alveolar bone loss and compare its diagnostic performance with digital periapical radiographs taken with paralleling technique. This study was carefully conducted according to a previously described methodology, beginning with the criteria for sample selection. The two calibrated examiners identified the periodontal defects on the same computer, using the same software and in the same lighting conditions. Thus, they may not be considered a source of error in the study.

Two basic elements of a periodontal diagnosis are the severity of the problem and whether the condition is localized or generalized. In literature, in young adults, the mean alveolar bone height in relation to the CEJ is 1.4 mm (0.7) and for people over 45 years this average is extended to 3 mm (1.5).[13,14] As this study was carried out in vivo and had a mean age of 35 years, a measurement greater than 1.4 mm between the CEJ and the AC was adopted to indicate the presence of periodontal bone loss. Several studies have however adopted a distance of 3mm and more for evaluating periodontal bone defects[5,12,15]. Hence this study was designed to detect even early bone loss anything more than 1.4mm from the CEJ.

The quality of images obtained by CBCT depends on acquisition parameters, such as milliamperage, kilovoltage and voxel size.[16,17,18] In order to view the periodontal structures such as the periodontal ligament space, cortical bone, AC and alveolar cortical plate, images with better definition are needed as well as a smaller voxel size,[16,18] consequently raising milliamperage and kilovoltage values. The voxel size used in this study was 0.076 mm as compared to 0.2 mm used by K de Faria Vasconcelos et al[12] and Grimard et al,[15] and 0.4mm used by Misch et al[6] and Vandenberghe et al[10] which allowed us a better image definition. The selection of the technical parameters for imaging should be a balance between the need for image resolution and the use of a minimum amount of radiation. It is also known that perception errors are inherent to human observations and decisions; however, the magnitude of the error in visual perception is modulated by image clarity. The small exposure volume used in this study reduces the amount of radiation to the patient as well gives a higher resolution to the images.

Another factor which may affect the quality of images obtained by CBCT is the presence of metal streaks which hampers interpretation of images. In this study however such images were excluded to avoid any error occurring due to streak artifacts.

Studies have shown a high correlation (90-98%) between clinical and indirect digital periapical radiographic measurements in determining periodontal defect depth, width and angle.[4]

The results of this study show when comparing the diagnostic performance of CBCT and intraoral digital periapical radiographs with paralleling technique, the measurements of the distance between the CEJ and the AC, were statistically not different from each other, as compared to the study by K de Faria Vasconcelos et al[12] which showed statistically different results for measurements taken in periapical radiography and for the CBCT images. When measurements of the distance from the CEJ to the deepest point and the width of the defect were compared, this study showed p-values of >0.05, indicating that there were no statistically significant differences between the two methods. A similar result was reported by Misch et al,[6] who saw no significant difference between measurements taken with a digital caliper in artificial bone defects and CBCT radiographic and periapical images. These authors found an average error of 0.27 mm for periapical and 0.41 mm for cross-sectional slices. Vandenberghe et al[10] observed that the cross sectional slices allowed for a better assessment of periodontal bone levels with an average underestimation of 0.29 mm compared with 0.56 mm in periapical digital radiographs.

In this study we found that the measurements of height, depth and width of bone loss obtained by the two techniques were very close and the difference in the measurements were not significant. This close correlation could probably be due to the different protocols followed in this study for CBCT and the use of paralleling technique for intraoral radiography.

Axial slices parallel to the occlusal plane allow for better visualization of the buccal and lingual morphology of periodontal bone defects. Knowledge of the morphological component in this dimension is of fundamental importance for the treatment and prognosis of periodontally compromised teeth because a larger number of remaining walls favor the prognosis of regenerative therapy.[15] The results of this study show that of the 35 teeth evaluated by axial slices, 21(60%) presented combined bone defects. This result is more than that found in K de Faria Vasconcelos et al[12] which was 30.8% and than that of Grimard et al,[15] who found combination bony defects present in 54% of the total defects analyzed in their study. Inclusion of buccal and lingual sites in the study definitely tips the result in favor of CBCT as this dimension cannot be studied with 2D intraoral radiography. But, however, we found that when there was a buccal/ lingual defect, the alveolar crest in the region showed diffuse radiolucency or showed for two levels of alveolar crest on close examination, which could be quite diagnostic of a buccal / lingual defect in a routine intraoral radiograph.

The authors however reinforce the fact that while both imaging modalities are useful when diagnosing bone loss in inter proximal surfaces, CBCT offers significant advantages only when detecting and locating bone defects in the bucco-lingual sites.[5,6,10]

The results show that a request for CBCT may be justified only in cases of severe or advanced periodontitis where mucogingival surgical planning is required. The clinician should still consider the amount of radiation exposure to the patient with CBCT scans. However, in cases of mild to moderate periodontitis, the findings on a digital periapical radiograph are significantly reliable which can be further made more accurate with proper clinical examination. Furthermore, a proper clinical examination can be of vital importance when the clinician has to choose the appropriate imaging method.

Because determination of the depth and to some extent, the width of bony defects is an important parameter in the prognosis of treatment, it is important to accurately measure these two parameters on radiographs to develop a correct and appropriate treatment plan.

In conclusion, the study shows that the diagnostic performance of both the techniques is similar when measuring the height, depth and width of periodontal bone defects but CBCT allowed for identification of combined bone defects through a 3D evaluation of the alveolar bone crest. With the introduction of digital images in radiology, both clinicians and investigators should ensure that these imaging modalities are used to the best of their abilities. The results of this study can be further potentiated with clinical correlation of the periodontal defects using the same parameters for radiographic evaluation.

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