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RESEARCH

Detection of periodontal bone loss using digital intraoral and cone beam computed tomography images: an *in vitro* assessment of bony and/or infrabony defects

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Objectives: To explore the diagnostic values of digital intraoral radiography and cone beam CT (CBCT) in the determination of periodontal bone loss, infrabony craters and furcation involvements.

Methods: Accuracy assessment of the imaging modalities was conducted through bone level measurements, infrabony crater and furcation involvement classifications. For CBCT, images were obtained at 120 kV and 23.87 mAs, and observations were made on a 5.2 mm panoramic reconstruction view and on 0.4 mm thick cross-sectional slices. Intraoral radiographs of a size 2 charge-coupled device (CCD) sensor were obtained using the paralleling technique, at 60 kV (DC) and 0.28 mAs exposure. 71 human cadaver and dry skull bony defects were measured and evaluated by 3 observers. Comparison was made with the gold standard.

Results: The mean error (gold standard deviation) of bone level measurements was 0.56 mm for intraoral radiography and 0.47 mm for the CBCT panoramic 5.2 mm reconstruction view. There were no significant differences ($P = 0.165$) between the two methods. However, on 0.4 mm thick cross-sections, the mean error was 0.29 mm and the Wilcoxon signed-rank test indicated a significant difference when compared with the CCD ($P = 0.006$). The detection of crater and furcation involvements failed in 29% and 44% for the CCD, respectively, in contrast to 100% detectability for both defects with CBCT.

Conclusions: CBCT on the panoramic 5.2 mm reconstruction view allowed comparable measurements of periodontal bone levels and defects as with intraoral radiography. CBCT with 0.4 mm thick cross-sections demonstrated values closer to the gold standard, indicating more accurate assessment of periodontal bone loss. Further research is needed to explore these results *in vivo* and to determine the use of CBCT in periodontal diagnosis.

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Keywords: periodontium, crater, furcation involvement, intraoral radiography, cone beam computed tomography

Introduction

Studies have shown that early detection of periodontal disease is important in the prevention of tooth loss and/or for the patient's general health.[1,2] However, current diagnostic approaches including clinical probing and intraoral radiography have shown several limitations in their reliability.[3–10] Clinical probing is dependent on the probing force, while periapical radiographs or bitewings may over- or underestimate the amount of bone loss due to projection errors. One of the main drawbacks of intraoral radiography is the overlap of anatomical structures and lack of three-dimensional (3D) information. This often hinders a true distinction between the buccal and lingual cortical plate and complicates the evaluation of periodontal bone defects, especially the infrabony lesions, also denoted as craters, and furcation involvements. (For description of bony defects, we will be using the general term "crater" in

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this article, which can refer to 1-walled, 2-walled, 3-walled or 4-walled defects, or any combination of these.)

Several efforts for optimizing these diagnostic tools have been made over the past few years. Unfortunately, electronic probes have not demonstrated more advantages over manual probing.[11,12] Digitalization of intraoral radiographs has considerably reduced radiation dose and made digital subtraction radiography (DSR) possible for lesion follow-up.[9,13,14] However, intraoral radiography remains essentially a two-dimensional (2D) imaging technique with a lack of information on the 3D defect nature of infrabony lesions. Conventional CT solves this problem by providing axial slices throughout the object of interest but has major drawbacks, including high radiation dose, high cost and low resolution.[15–17] In order to enforce this 3D assessment of bone defects, the current diagnostic approach needs further improvement for early diagnosis of periodontal disease.[18–21]

Cone beam CT (CBCT), also called dental CT, is a recently developed imaging modality. When compared with conventional CT, CBCT considerably reduces radiation exposure to patients.[15–17] Although there have been limited publications concerning CBCT for periodontal assessment, the application of this new imaging modality with a combination of existing 2D digital intraoral radiographs may offer new perspectives on periodontal diagnosis and treatment planning.[22–25]

The purpose of this study was to explore the diagnostic value of CBCT in the determination of periodontal bone loss, including the 3D topography of infrabony defects. Since bone loss can be subdivided into linear and non-linear loss, the study was divided into two parts, the first dealing with the assessment of periodontal bone height and the second with the evaluation and classification of 3D topography of periodontal bone craters and furcation involvements. We hypothesized that both imaging techniques would allow accurate assessment of bone loss and that CBCT would allow more accurate evaluation of the non-linear periodontal bone defects than intraoral radiography. This study was a continuation of our previous reports on the potential of CBCT for periodontal diagnosis.[23,25]

Materials and methods

Assessment of bone levels through anatomical marker measurements and the evaluation or classification of non-linear bony defects were implemented on intraoral digital radiographs (Schick CDR®; Schick Technologies, Long Island City, NY) and CBCT images (i-CAT™, 12-bit; Imaging Sciences International, Hatfield, PA).

2 carefully selected and processed adult human skulls containing multiple periodontal defects were used for the measurement and observation of 71 selected sites. The first skull, a cadaver head with upper and lower jaws fixed by a 10% formaldehyde aqueous solution (formalin), functioned as a clinical subject. A second human dry skull was covered with a soft tissue substitute, Mix-D, and used for simulation.[26] In order to assess bone levels, the cementoenamel junction (CEJ) could only be used as a reference point for the formalin-fixed jaws. Because of dehydration of the dry skull, standardized fiducials were introduced as a substitute for the faded CEJ. Radiopaque gutta-percha fragments with a small central indentation were glued onto the buccal and lingual surfaces of the respective teeth (see Figure 1).

Intraoral digital images were obtained using the paralleling technique in a standardized exposure set-up with a size 2 charged coupled device (CCD) sensor and a direct current (DC) X-ray unit (Heliodent® DS; Sirona Dental Systems GmbH, Bensheim, Germany). A rectangular (4×3 cm) collimator and film-holding system (Universal Collimator and XCP®; Dentsply RINN, Elgin, IL) with standardized bite blocks were used. The focal–film distance was 30 cm. The exposure setting was 60 kVp with 0.28 mAs (40 ms $\times$ 7 mA). For CBCT scanning, the occlusal plane of the jaw bones was positioned horizontally to the scan plane and the midsagittal plane was centred. The beam height at the surface of the image receptor was adjustable and set to visualize the entire jaws (between approximately 20 mm and 60 mm beam height), giving between 54 and 159 slices of 0.4 mm thickness. A low-dose protocol of 120 kVp and 23.87 mAs (20 s pulsed scanning and a 7 mA current) and a 0.4 mm voxel size were used for image acquisition (see Figure 2).

Three observers (a Medical Imaging Master and PhD student, and two radiology faculty members, Temple University, School of Dentistry, Philadelphia, PA) randomly measured periodontal bone levels and classified the defects while seated at a distance of 60 cm from a 17 inch LCD high-resolution screen (1440×900 pixels) of a Sony Vaio® VGN A417m computer (Sony Corporation, Tokyo, Japan). Intraoral 2D images were displayed with the Emago® software (Emago Advanced v3.5.2; Oral Diagnostic Systems (ACTA), Amsterdam, The Netherlands) in tagged image file format (TIFF). CBCT images were viewed with i-CAT software (Xoran CAT v2.0.21; Xoran® Technologies Inc., Ann Arbor, MI). Measurement tools on both programs were used for assessing bone levels and for furcation classification, if necessary.

The acquired measurement data and periodontal defect classifications were compared with the gold standard. The latter were based on blinded determination of physical measurements and classifications on the skull models by two of the observers. Mesial, central and distal bone levels and bone crater depths on the oral and vestibular sides of each selected tooth were measured. The gold standard of the cadaver jaws was obtained after image acquisition by flap surgery to allow physical measurements using a digital sliding calliper (Mitutoyo, Andover, UK), description and classification. Furcation classification was done using a

Figure 1 Clinical simulation by processing a dry skull. (a) Gutta-percha markers, used as fiducials for bone loss assessment, were glued onto the vestibular and oral sides of every tooth. (b) After measuring the gold standards, the dry skull could be covered with the soft tissue substitute. (c) The intraoral images were obtained using standardized bite blocks containing waxed imprints of the teeth. After *in vitro* pilot-testing of these rigid occlusal keys, a standardized set-up was obtained which allowed correct fiducial visualization and correct projection geometry

furcation probe. For the dry skull, however, gold standards were obtained prior to adding the soft tissue substitute and image acquisition.

In the first part of this study, 43 sites including linear defects, 3D craters and furcation involvements were chosen out of 20 randomly selected teeth for assessment on intraoral CCD and CBCT images, and the obtained bone height measurements were subsequently compared with the gold standards. Measurements on the CBCT software were carried out on a panoramic reconstruction view (the same for each observer) with a default slice thickness of 5.2 mm, large enough to visualize the specific fiducials and the bone perpendicular to it (see Figure 2c). Those CBCT measurements were repeated afterwards on cross-sectional slices of 0.4 mm (see Figure 2d). Subjective quality assessment of lamina dura delineation, contrasts, bone quality and defect description was performed using an ordinal scale ranging from 0 to 3 (0 = lack of visibility, 1 = poor visibility, 2 = medium visibility, 3 = good visibility).

In the second part of the study, a group of 11 teeth in the molar region of the upper and lower jaws, containing 28 mesial or distal craters and buccal and lingual (or for maxillary molars, buccal, mesial and distal) furcation involvements, was selected for comparison with the gold standard. Crater and furcation involvement classifications on CCD and CBCT images were given an ordinal scale from 0 to 4 (no defect, 1-, 2-, 3- and 4-walled) and from 0 to 3 (no furcation involvement, class I, class II and class III), respectively.[27–29] Analysis was carried out on both programs and for CBCT using coronal, sagittal and axial slices of 0.4 mm each through the selected infrabony defects (see Figure 2e).

Statistical analysis

43 selected sites were measured by 3 observers on the digital intraoral CCD and CBCT images and compared with the gold standards. Imaging methods and observers were used as independent variables and bone levels measurements as dependent variables. Although these data were not ordinal, we opted for non-parametric tests (Wilcoxon signed-rank test for comparison of absolute differences with gold standard of CCD *vs* CBCT measurements) as no normality could be found in the measurement data, even after transformation.[30,31] For the quality rating on images of both modalities, the ordinal data of the dependent variables were compared using the Wilcoxon signed-rank test, except for crater and furcation visibility on CBCT cross-sectional slices, for which the Mann–Whitney test was applied considering a discrepancy between the 2D and 3D data.

28 craters and furcation involvements were classified by the same observers on both modalities and compared with the gold standards. Imaging method and observers were independent variables, and crater and furcation involvement were dependent variables. Comparison of the ordinal data from the gold standards, CCD and CBCT was carried out using the Kruskall–Wallis test. All statistical analyses were carried out using SPSS® v13.0 statistical software (SPSS Inc., Chicago, IL).

Results

The results of the reliability analyses and the Kruskal–Wallis tests for observer effect evaluation are given in

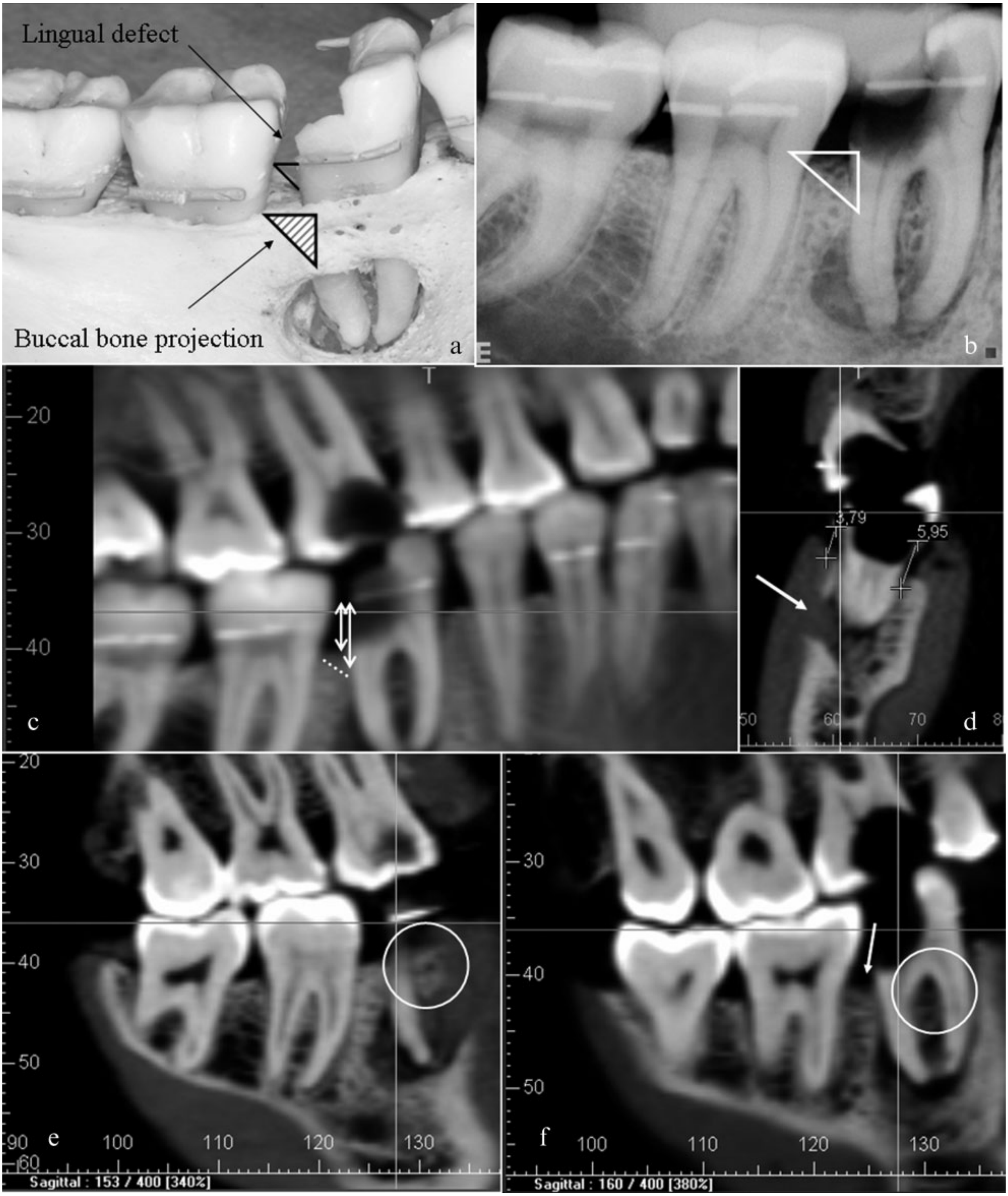

Figure 2 Periodontal assessment of the mandibular right first molar. Before covering the dry skull with soft tissue substitute, the gold standard of bone levels and defect topography were taken. On the distolingual side of the selected tooth, (a) a large defect, which could be difficult to assess on (b) two-dimensional intraoral radiographs due to overlap of the buccal bone plate, was clearly seen. (c) Using a panoramic reconstruction of cone beam CT (CBCT) slices for bone level assessment, measurements are not significantly different from those on charge-coupled device images. However, the same projection overlap is seen (dotted line shows the possible defect border). (d) When measuring on individual coronal or sagittal slices of 0.4 mm, buccal and lingual levels or defects can clearly be separated (also note the buccal plate perforation shown by the arrow). Using these separate CBCT slices, ((e) sagittal slice 153 and (f) sagittal slice 160) a clear three-dimensional effect is obtained, allowing accurate crater topography assessment and furcation involvement evaluation ((e,f) both circles show the bone levels around the bifurcation; the arrow in (f) shows the crater delineation)

Table 1 Overview of intra- and interobserver effects. To test the reliability among observer measurements and classifications on charge-coupled device two-dimensional (2D) and cone beam CT three-dimensional (3D) images, a 15% repeat was done after an interval of 2 weeks. The intraclass correlation coefficients (ICC) and 95% confidence intervals (CI) show high reliability for all observations. The results of the Kruskal–Wallis test show no significant difference ($P > 0.05$) between the observers for all measurements and classifications. Gold standards (GS) of crater and furcation classification did not differ among and between observers

	Observer effect				
	Reliability analysis (intra)		*Kruskal–Wallis test (inter)*		
	ICC	*95% CI*	X^2	*DF*	*Asymptotic significance*
GS measurements	0.934	0.928–0.984	0.283	1	0.595
2D/3D measurements	0.713	0.675–0.914	0.301	2	0.860
2D/3D crater classifications	0.775	0.849–0.951	0.117	2	0.943
2D/3D furcation classifications	0.958	0.976–0.992	0.027	2	0.987

Table 1. No intra- or interobserver effect was found when analysing the gold standard, CCD and CBCT measurements or classifications from the three observers. This made averaging of the observer data possible for further calculations.

Part 1: bone level measurements and quality rating

Table 2 shows that no significant difference was found ($P = 0.165$) when comparing the intraoral CCD bone level measurements with those on the panoramic reconstruction image of the CBCT data with 5.2 mm slice thickness. However, when comparing the absolute differences of the gold standards and the CCD measurements with those of the 0.4 mm cross-sectional CBCT slices, a significant difference was found between both modalities ($P = 0.006$). Although further analysis through the Mann–Whitney test did not reveal a significant difference between the raw data (actual measurements) of the gold standard and the CCD or CBCT data, further investigation of the latter test will indicate the cause of the difference in the nature of the data. The descriptive statistics show a smaller deviation range and mean error for the CBCT measurements on 0.4 mm cross-sectional slices compared with those for CCD images or those on the CBCT panoramic reconstruction image. This is also indicated by the ranks for CBCT measurements on cross-sectional slices of 0.4 mm. 27 negative ranks (CBCT-gold standard (GS) difference < CCD-GS difference), 13 positive ranks (CCD-GS < CBCT-GS differences) and 1 tie reveal that 63% of the measurements were closer to the gold standard using cross-sectional CBCT images and only 33% were closer to the gold standard using CCD images. Figures 3 and 4 are graphic representations of the exact and absolute differences from the gold standards. Table 3 gives an overview of descriptive statistics for the three methods.

Deviations for intraoral radiography ranged from 0.01 mm to 1.65 mm, for CBCT panoramic measurements deviations ranged from 0.03 mm to 1.69 mm and for CBCT cross-sectional measurements they ranged from 0.04 mm to 0.9 mm. The latter are all under 1 mm deviation and 80% of them are under 0.5 mm. For CCD, deviations were over 1 mm in 13% of the cases and less than 0.5 mm in 63% of the sites. Over- and underestimations were both 50% for CCD, with a mean of 0.56 mm for the overestimations and 0.55 mm for the underestimations (see Table 3). Over- and underestimations on the CBCT panoramic image had the same ratio with a mean of 0.47 mm. A tendency to overestimate (63%, with a mean of 0.34 mm) was seen compared with the underestimations (37%, with a mean of 0.24 mm) for cross-sectional measurements.

The quality rating yielded a significantly better outcome for the intraoral radiographic images regarding lamina dura, contrast and bone quality (see Figure 5). Crater and furcation visibility were not scored differently for CCD and the CBCT panoramic image. However, when using the CBCT cross-sectional slices, the morphological descriptions of the periodontal defects were more clearly depicted when using CBCT ($P = 0.014$). Further exploration of these findings was tested in Part 2 of this article.

Part 2: craters and furcations

For both the crater and the furcation variable, a significant difference was found with the Kruskal–Wallis test between the observations on the 2D intraoral

Table 2 Comparison of the gold standards (GS), two-dimensional (2D) charge-coupled device (CCD) and three-dimensional (3D) cone beam CT (CBCT) data. The Wilcoxon signed-rank test was used to compare measurements on intraoral CCD images and those on a 5.2 mm panoramic reconstruction image (CBCT1) or 0.4 mm thin cross-sectional slices (CBCT2) of CBCT images. A highly significant difference was found between both modalities for CBCT2 ($P = 0.006$). However, further exploration through the Mann–Whitney test did not reveal any significant differences of the measurements with the gold standard for both modalities

		Wilcoxon signed-rank test			*Mann–Whitney test*	
		Z	*Exact significance*		*Z*	*Exact significance*
Measurements	CCD *vs* CBCT1	−1.419	0.165	–		
	CCD *vs* CBCT2	−2.455	0.006	GS *vs* CCD	−0.384	0.708
				GS *vs* CBCT	−0.185	0.857

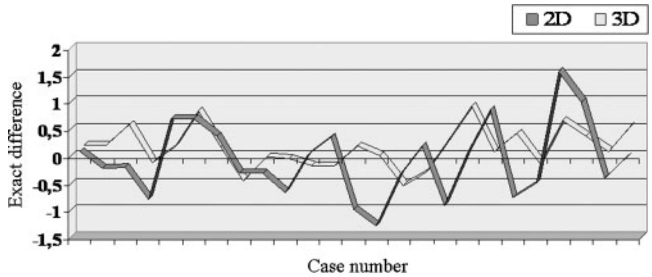

Figure 3 Line chart derived from the measurement data. The lines represent the exact difference from the gold standard of the bone level measurements on both three-dimensional (3D) cross-sectional cone beam CT slices and two-dimensional (2D) charge-coupled device, allowing visualization of over- and underestimations and measurement deviations

images, the CBCT slices and the gold standard (respectively $P = 0.008$ and $P = 0.017$). When using the Mann–Whitney test to determine which one is significantly different from the gold standard we found that for both variables, CCD classifications of infrabony defects are inferior when compared with CBCT assessment ($P = 0.04$ for crater and $P = 0.036$ for furcation involvements). On the intraoral digital images, 29% of the craters and 44% of the furcation defects were not detected and only 29% and 20% of the variables, respectively, were correctly classified. On the CBCT images, however, both defects showed a 100% detectability, while 91% of the craters and 100% of the furcation involvements were correctly classified. Also, on intraoral images, it was not possible to differentiate vestibular from oral furcation involvements.

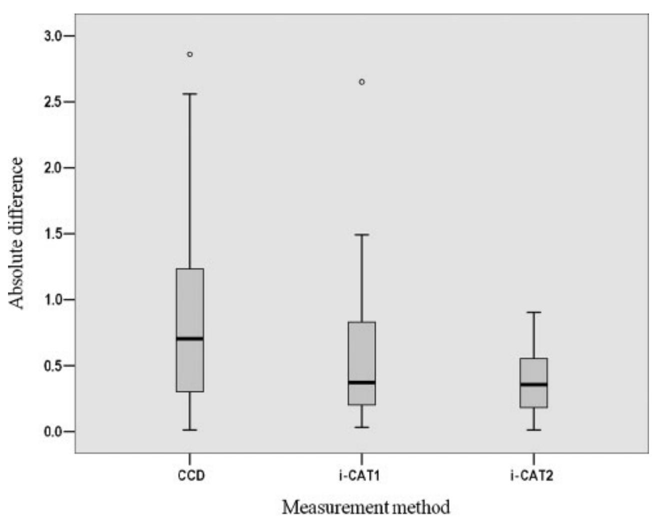

Figure 4 Box plots of absolute differences between the gold standard bone level measurements and the observer measurements on different modalities. The chart shows median (black line), interquartile range (boxes) and extreme values. The values of i-CAT2 clearly show the least deviation. i-CAT1 = CBCT measurements on panoramic reconstruction with 5.2 mm slice thickness. i-CAT2 = CBCT measurements on coronal or sagittal slices of 0.4 mm. CCD, charge-coupled device

Table 3 Descriptive statistics of the measurements for bone level assessment. CBCT1 are the measurements on the panoramic reconstruction CBCT image of 5.2 mm slice thickness. CBCT2 are the measurements on CBCT cross-sectional slices of 0.4 mm. The mean error (compared with the gold standards), minimum and maximum are given. Over- and underestimations tend to be equally dispersed, except for in CBCT2 where a slightly higher overestimation rate is seen. If admitting a clinically acceptable measurement discrepancy of 1 mm, the percentages of the CBCT2 measurements run up to 100%

	CCD	*CBCT1*	*CBCT2*
Mean error	0.56	0.47	0.29
Minimum (in mm)	0.01	0.03	0.04
Maximum (in mm)	1.65	1.69	0.9
% overestimations	50	52	63
% underestimations	50	48	37
% measurements <1 mm	87	90	100
% measurements <0.5 mm	63	67	80

CCD, charge-coupled device; CBCT, cone beam CT

Discussion

Many investigations of the recent CBCT technology have validated its usefulness for several diagnostic purposes, such as implant planning or orthodontics.[24,32] However, limited studies have been reported on the advantages of CBCT for periodontal diagnosis.[22–25] The present results demonstrate an equal accuracy of periodontal bone level measurements using intraoral 2D digital CCD images (mean error of 0.56 mm) or using a panoramic reconstruction image with 5.2 mm slice thickness of 3D CBCT data (mean error of 0.47 mm). This panoramic reconstruction provides the user with an overall view and allows quick assessment of the periodontal bone. The slice thickness was set on the default setting of 5.2 mm, large enough to visualize all teeth with their fiducials on one reconstruction. Quality rating on

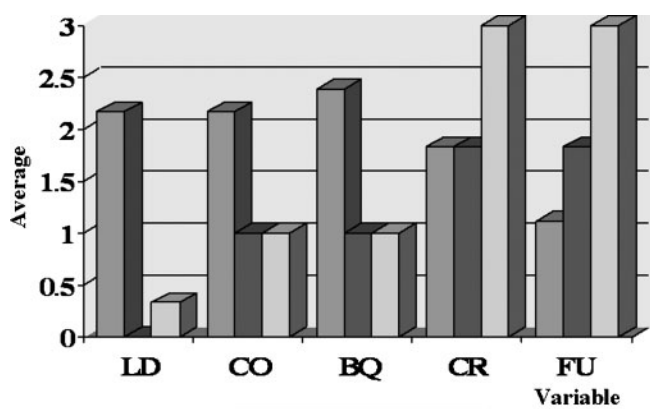

Figure 5 Quality assessment: variable comparison for the charge-coupled device (CCD) ratings and the two cone beam CT (CBCT) ratings. The lamina dura (LD) were well delineated on the CCD images and (almost) not visible on CBCT. CCD also scored better for the variable contrast (CO) and bone quality (BQ), but only periodontal craters (CR) and furcation involvements (FU) were better visualized on CBCT cross-sectional slices (i-CAT2) compared with CCD or CBCT panoramic reconstruction images of 5.2 mm (i-CAT1)

both 2D and 3D images shows a clearly positive outcome for CBCT cross-sectional slices when rating crater and furcation involvement evaluation. The delineation of lamina dura, bone quality and contrast rating remains better for the digital intraoral CCD images, which contain a higher resolution compared with CBCT. These findings are comparable with similar studies.

Misch et al[22] found no significant difference in bone level measurements using periapical F-speed films (mean error of 0.27 mm) or cross-sectional CBCT slices (mean error of 0.41 mm). The present study therefore based the current comparison on digital image datasets in 2D and 3D. While the use of digital intraoral radiography has not been found to be superior to conventional radiography for periodontal linear measures,[33] it cannot be overlooked since it offers at least two essential benefits, such as radiation dose reduction and image analysis for improved bone diagnostics.[9,13,14] A digital CCD system was therefore used for comparison instead of conventional film. With regard to the first benefit, we attempted to reduce the intraoral radiographic dose as much as possible while keeping full diagnostic capabilities. The method and exposure settings used in the present study have been tested and validated in a previous report.[23] The mean error of the measurements on intraoral CCD images in our results differs slightly from the 0.27 mm deviation found by Misch et al[22] on conventional film. This deviation could be related to the different methodology used and the sample size of infrabony defect measurements.

Even though the results in this study showed a similar outcome for bone level assessment using both imaging modalities, a conclusion based on CBCT panoramic reconstruction images of 5.2 mm would not allow complete exploitation of the acquired 3D CBCT data. Therefore, the selected sites were measured again on the 3D CBCT data, but this time on coronal or sagittal images of 0.4 mm through the specific fiducials. This, however, did reveal a better assessment of periodontal bone levels on CBCT cross-sectional slices (mean underestimation of 0.29 mm) than on intraoral CCD images (mean error of 0.56 mm). These findings differ from Misch et al,[22] which could be due to the different CBCT protocol. In contrast to a reconstruction slice of 1 mm thickness used in the latter study, the measurements in the present study were taken on images of 0.4 mm slice thickness. However, more research, including outcome assessment of various exposure and reformatting protocols and evaluation of the diagnostic validity during clinical follow-up, is required for proper justification of various CBCT applications in dentomaxillofacial radiology. Deviations from the gold standard were only between 0.04 mm and 0.9 mm for the cross-sectional slices. When defining accuracy in terms of clinical measurement, a certain discrepancy between actual bone level and estimated bone level on radiographs has to be considered as clinically acceptable. Small or large errors in locating the CEJ and the alveolar crest can respectively lead to over- and underestimation of disease prevalence.[6] Considering that a 0.5 mm discrepancy can be seen clinically,[6,7] 2D CCD is accurate enough in 63% of the measures and 3D CBCT in 80%. A 1 mm discrepancy even leads to 100% accuracy for CBCT in contrast to 87% for CCD.

The above measurements of bone levels included crater depth and furcation measurements from the CEJ or specific fiducials. These data do not provide enough information on the 3D defect nature, which can be crucial to prognosis and treatment planning of periodontally affected teeth. Infrabony defects are the main cause of tooth loosening and loss and are not often addressed in research regarding the validation of radiographic modalities for periodontal diagnosis.[18–25] For these reasons and because of the favourable results for evaluation of infrabony defects on CBCT images seen in the quality rating, a further exploration of this research was conducted to evaluate the classification of those defects using both 2D and 3D modalities. After comparing defect classifications with the gold standards, the results show a better depiction of crater and furcation involvements on CBCT than on intraoral digital images. Also, vestibular and oral bone defects as well as maxillary trifurcations were easily assessed by CBCT images in contrast to a problematic or even impossible evaluation on CCD images. Craters and furcation involvements were all detectable (100%) on CBCT data, while only 71% of the crater defects and 56% of the furcation involvements were identified on the intraoral CCD images. Misch et al[22] found similar results, showing 100% detection of the artificially created infrabony defects with CBCT and only 67% on intraoral film. Fuhrmann et al[20] found that only 21% of the artificial furcation involvements were identified on dental radiographs and 100% through high resolution CT.

In the present study, we were able to confirm our hypothesis that CBCT would allow accurate assessment of bone levels and a better description of infrabony defects than intraoral CCD images. The results show a more precise measurement deviation from the gold standard using CBCT cross-sectional slices. This finding indicated that the current CBCT system may become more influential in the diagnosis of periodontal diseases. When compared with CBCT, digital intraoral radiography remains a high-resolution but 2D imaging technique, thus preventing visualization of the entire periodontal defect. For instance, our observers were not able to distinguish vestibular from oral bony defects. The maxillary trifurcations could hardly be detected or interpreted. However, because of the higher resolution of intraoral radiography, some diagnostic parameters such as bone quality evaluation remain inferior for CBCT. Also, since the radiation dose of CBCT has been reported up to 15 times less than conventional CT,[17] only 4 to 15 times the dose of a standard panoramic image[16] or only the dose of a film-based full-mouth radiographic examination (FMX),[17] there is growing concern about the over-consumption of CBCT and its radiation safety. Furthermore, Ludlow et al[16] reported dose reduction when using smaller FOV examinations. In our opinion, the use of CBCT should still be carefully justified (diagnostic benefit and risk are balanced), if optimized exposure protocols (following the ALARA (As Low As Reasonably Achievable) principle) are considered. This can be guaranteed if the image acquisition and further interpretation are performed by specialists in this field. In the current study, a low-dose protocol of CBCT (only 23.87 mAs and 0.4 mm voxel size) was used. More studies in the future with a large sample size will determine ideal exposure settings that optimize the image quality and lower the radiation exposure further.

Considering the several advantages, limitations and risks of both modalities, we would like to suggest that the currently tested model of CBCT should only be used for relatively more complex periodontal treatment planning such as prognostic planning and surgery for complex periodontal defects, and potential use of dental implants. Given the limited number of publications on this subject, more research using a large sample-size for periodontal bone level assessment and clinical studies with perioperative check-up as a gold standard for the bone defects should be conducted. This could further expand the applicability of CBCT in periodontal diagnosis.

In conclusion, CBCT images allowed measurements of periodontal linear and non-linear bone levels on panoramic reconstruction images of 5.2 mm slice thickness that were comparable with intraoral digital radiography. Measurements on cross-sectional slices of 0.4 mm demonstrated a more accurate assessment, which is due to the inherent 3D character of the CBCT data and absence of overlapping structures. CBCT showed more potential in the morphological description of periodontal bone crater and furcation involvements. However, because of the lower resolution compared with intraoral digital images, details like trabecular pattern were better visualized using intraoral radiography.

CBCT allowed more accurate assessment of bone craters and furcation involvements than digital intraoral radiography. These findings may offer perspectives for further studies in balancing radiation dose and gather information in order to help establishing selection criteria for assessment of periodontal bone loss. These findings may also be used for further research on accurate periodontal diagnosis and treatment planning, especially when surgery is involved.

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