

RESEARCH

Periapical radiography and cone beam computed tomography for assessment of the periapical bone defect 1 week and 12 months after root-end resection

R Christiansen^{*1}, L-L Kirkevang², E Gotfredsen¹ and A Wenzel¹

¹Department of Oral Radiology, School of Dentistry, Faculty of Health Sciences, Aarhus University, Denmark; ²Department of Dental Pathology, Operative Dentistry and Endodontics, School of Dentistry, Faculty of Health Sciences, Aarhus University, Denmark

Objectives: Our aim was to compare periapical radiography and cone beam CT (CBCT) for assessment of the periapical bone defect 1 week and 12 months after root-end resection.

Methods: 50 patients (58 teeth) with a persisting apical periodontitis in a root-filled tooth (incisor, canine or premolar) were treated with root-end resection. 1 week and 12 months post-operatively, a CBCT scan (NewTom[®] 3G) and a periapical radiograph (Digora) were obtained. Three observers detected and measured the periapical bone defects on periapical radiographs and CBCT images (coronal and sagittal sections).

Results: 1 week post-operatively, a periapical bone defect area was measured in all teeth by all observers. The defect was 10% smaller on periapical radiographs (mean = 12.4 mm², SD = 8.2) than on the CBCT images measured in the coronal plane (mean = 13.0 mm², SD = 7.8), a difference which was not statistically significant ($P = 0.58$). 12 months post-operatively ($n = 52$), there was considerable variation between the observers' detection of a remaining defect on the periapical radiographs and the CBCT images. The average agreement between the periapical radiograph and the CBCT images in the coronal sections was 67%, and more defects were detected on CBCT than on periapical radiographs.

Conclusions: On average, the periapical bone defect measured on periapical radiographs was approximately 10% smaller than on coronally sectioned CBCT images 1 week post-operatively. More remaining defects were detected 1 year after periapical surgery on CBCT images than on periapical radiographs, but it is uncertain how this information is related to success or failure after root-end resection.

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Introduction

A periapical radiograph is the first choice radiographic method for detection of apical periodontitis, treatment planning and follow-up examinations after both orthograde root-filling therapy and periapical surgery. With the recent developments in cone beam CT (CBCT) studies have been conducted to assess the application of a CBCT examination. Recent studies have compared conventional radiography and CT for detection of

periapical pathology. Several studies have found that the prevalence of apical periodontitis was higher when examined with CBCT than with conventional radiography,^{1–4} and it has been suggested that CBCT imaging is indicated for treatment planning of periapical surgery in multirrooted teeth in selected cases.^{2,3,5}

There are obvious disadvantages of CBCT compared with periapical radiography: the technique is expensive, higher radiation dose^{6,7} is involved and it has limited availability, and therefore the diagnostic gain from applying this method compared with intraoral radiography should have clinical relevance for treatment or other advantages for the patient.

*Correspondence to: René Christiansen, School of Dentistry, Department of Oral Radiology, Faculty of Health Sciences, Aarhus University, Vennelyst Boulevard 9, DK-8000 Aarhus C, Denmark; E-mail: RChristiansen@odont.au.dk

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The aim of the present study was to compare periapical radiography and CBCT for assessment of the periapical bone defect 1 week and 12 months after root-end resection.

Materials and methods

50 patients (58 teeth), 26 women and 24 men (average age 55 years, range 30–77), with a persisting apical periodontitis in a root-filled tooth (incisor, canine or premolar) received periapical surgery. In 14 cases, a premolar had 2 canals that received treatment. In 42 patients, 1 tooth was treated, and in 8 patients 2 teeth were treated. Each patient was given written and verbal information about the study, and a consent form was signed before participation. There was no financial inducement to participate, and patients were given the opportunity to withdraw from the study at any time. The project was approved by the regional Committee of Ethics, registered in a public clinical trials register (ClinicalTrials.gov ID no. NCT00228280), and conducted in accordance with the World Medical Association Declaration of Helsinki.

Patients' treatment

For the surgical procedure, a mucoperiosteal flap was raised and access to the root apex was obtained through the buccal cortical bone (buccal window). The periapical granuloma was removed, and perpendicular root-end resection was performed. Patients were allocated to one of two treatment procedures: root-end resection with smoothing of the gutta-percha root filling or root-end resection with a root-end filling with mineral trioxide aggregate (MTA) (for further details on the treatment methods, see previous publications^{8,9}).

1 week after the operation the sutures were removed, and a periapical radiograph of the tooth in question was obtained (paralleling technique, Digora storage phosphor plate system with fmx scanner (Soredex, Helsinki, Finland, spatial resolution 466 × 628 pixel), Gendex

1,000 DC dental unit (Gendex, IL) operating at 65 kVp, 10 mA, 32 cm focus–film distance, exposure time adjusted to the individual region and patient, rectangular collimation) using a bite index made in President putty (Coltene/Whaledent, Altstätten, Switzerland). Also, the operated region was examined by CBCT (NewTom[®] 3G (Quantitative Radiology, Verona, Italy), 15 cm field of view, fixed 110 kVp setting, automated adjusted mA and a scan time of 36 s). The operation site was centred in the field of view. A periapical radiograph and CBCT images of the same tooth are shown in Figure 1.

12 months post-operatively an identical periapical radiograph of the tooth was taken, and the region was scanned again with the CBCT system. Five patients (with six teeth) were not included in the 12 month post-operative control owing to root fracture (tooth extraction), re-operation or drop-out (one patient out of contact).

Radiographic measurements

Three experienced observers, obs 1, obs 2, obs 3 (a radiologist, an endodontist and an oral surgeon, respectively), assessed the images from the two radiographic methods. The periapical radiographs were exported from the Digora system as tiff (tagged image file format) files and imported into the PorDiosW software program (Institute of Orthodontic Computer Sciences, Middelfart, Denmark) developed for analysis of monitor-displayed digital images.¹⁰ The radiographs were displayed on a 48 cm monitor (190s, Philips, China, resolution 1280 × 1024 pixel, 32 bit) situated in a room with subdued lighting. Each observer individually assessed and measured the bone defects on the periapical radiographs. The maximum vertical distance was measured from the resection surface at the central point of the root filling to the most apical part of the defect. The horizontal distance was measured at its maximal width perpendicular to the vertical measurement line, which was displayed by the program.

The CBCT images were individually reconstructed by the three observers, who sectioned the images in the coronal and sagittal planes (1 mm sections with 0.5 mm steps). The images were displayed on a 48 cm monitor

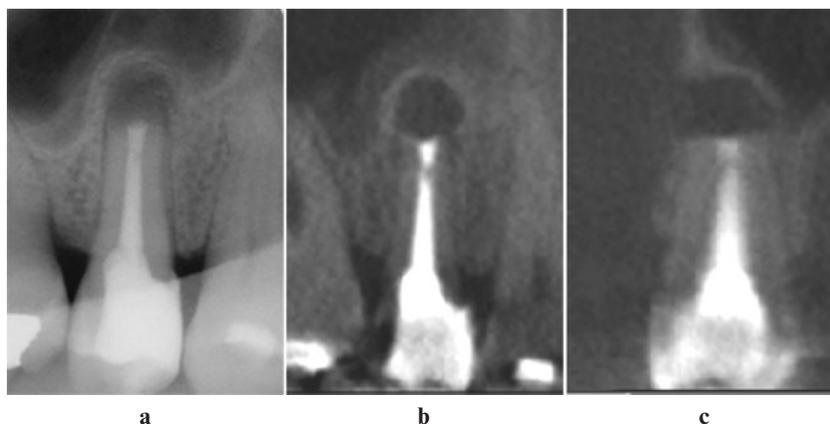


Figure 1 (a) Periapical radiograph 1 week post-operatively; (b) cone beam CT (CBCT) image, coronal section, 1 week post-operatively; (c) CBCT image, sagittal section, 1 week post-operatively

(VistaLine 191D, Olórin, Billdal, Sweden, resolution 1280 × 1024 pixel, 32 bit, digital DICOM 14) in a room with subdued lighting. If a bone defect was detected, the vertical and horizontal distances were measured in the “worst case” CBCT slice (the slice in which the defect appeared to be largest). Each observer decided individually which section appeared to be “worst case”. The maximum vertical distance was measured from the resection surface at the central point of the root filling. If two root fillings were seen (in the sagittal plane), the maximum vertical distance was measured from the midpoint between these two root fillings. The vertical dimension of the buccal window in the “worst case” CBCT slice was measured by placing two measurement points; thereafter, the software program automatically displayed a measurement line (“the buccal window line”). The horizontal distance was measured from the “buccal window line” to the maximal width of the defect perpendicular to the vertical measurement line (already displayed by the program). All measurements were performed by the tools available in the NewTom® 3G software (NNT version 2.11, Verona, Italy), which provides measurements in true millimetres.

Data treatment

The area of the bone defect (vertical dimension × horizontal dimension) was calculated for each observer’s measurements on the periapical radiographs and the CBCT images in the coronal and sagittal plane. The calculated area on the periapical radiographs was converted from pixels to millimetres by the known pixel per millimetre spatial resolution.

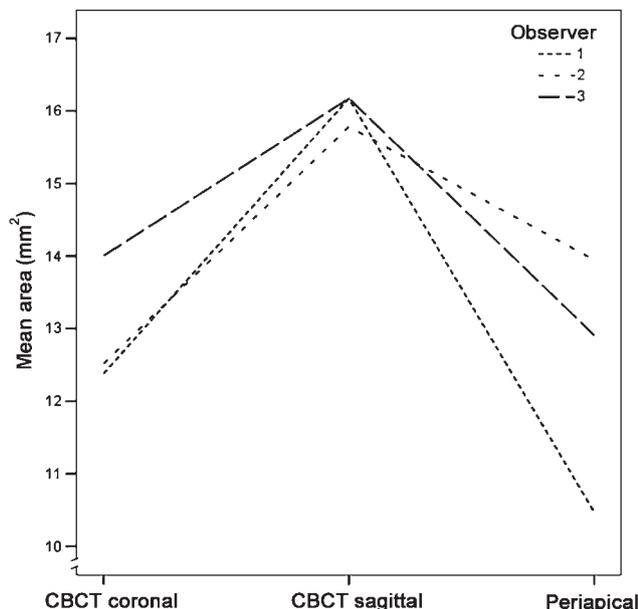


Figure 2 Mean area in millimetres squared of the periapical defects measured on cone beam CT (CBCT) images, coronal and sagittal sections, and on periapical radiographs by three observers 1 week post-operatively

1 week post-operatively, the periapical defect area was analysed by a two-way analysis of variance (ANOVA) with the factors observer and radiographic method. A pair-wise comparison between the areas obtained from the periapical radiographs and CBCT coronal sections was made using *post hoc t*-test. The level of statistical significance was $P < 0.05$. The calculated areas of each observer’s measurements on the periapical radiographs and the CBCT images in the coronal plane were, moreover, presented in a Bland–Altman plot, illustrating the relationship between the difference and the mean between the two radiographic methods.¹¹ The calculated areas were log-transformed because the measurement error was proportional to the size of the defect.

12 months post-operatively, agreement between the radiographic methods on whether or not a periapical defect could be detected was calculated as a percentage for each observer and as the mean between observers.

Results

Area of the periapical bone defect 1 week post-operatively

1 week post-operatively, 58 teeth were examined. All observers had measured a periapical defect on the periapical radiographs and on the CBCT images in both the coronal and sagittal sections, and all observers had measured the buccal window on the CBCT images in the sagittal plane.

Mean and standard deviation of the bone defect area (mm²) on the periapical radiographs and CBCT images and the vertical distance of the buccal window (mm) can be seen in Table 1. The results of the ANOVA are illustrated in Figure 2. The average bone defect area 1 week post-operatively was approximately 10% smaller on the periapical radiographs (mean = 12.4 mm², SD = 8.2) than on the coronal CBCT images (mean = 13.0 mm², SD = 7.8) (Table 1, Figure 2), a difference which was not statistically significant ($P = 0.58$). The differences in areas between the two methods were illustrated by plotting the difference between the two methods against their mean, both for each observer separately and for the mean between observers (Figure 3). Obs 1 measured the bone defect area as being, on average, 20% smaller on the periapical radiographs than on the coronal CBCT images, whereas obs 2 and 3 measured the defect area as being 3% and 6%, respectively, smaller on the periapical radiographs than on the coronal CBCT images.

Detection of a remaining periapical bone defect 12 months post-operatively

12 months post-operatively, 52 teeth were examined. The agreement between the two by two methods on the presence/absence of a bone defect for each observer and the mean between observers is displayed in Table 2.

Table 1 Mean and standard deviation (SD) of the bone defect area (mm²) on periapical radiographs and cone beam CT images and the vertical distance of the buccal window (mm) 1 week post-operatively (*n* = 58)

	Periapical radiograph		CBCT					
			Coronal section		Sagittal section		Buccal window	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Obs 1	10.5	6.8	12.4	7.0	16.2	8.3	5.1	1.2
Obs 2	13.9	11.1	12.5	5.8	15.8	8.1	5.2	1.2
Obs 3	12.9	10.1	14.0	12.5	15.8	8.6	5.3	1.2
Mean	12.4	8.2	13.0	7.8	15.9	8.0	5.2	1.2

In 50% (average between observers) of the cases, a defect was detected both on the periapical radiograph and on the CBCT images in the coronal sections, and in 17% no defect was detected with either of these methods; thus an average agreement of 67% between these two methods was found. More defects were detected on CBCT images in the coronal section than on the periapical radiographs (average 28%), whereas in 5% of the cases a periapical defect was detected on the periapical radiograph but not on the CBCT images. The defects that were detected on the CBCT images in the coronal sections but not on the periapical radiograph were as follows: one-third of the defects were 0.3–1.8 mm²; one-third were 1.8–4.7 mm²; and one-third were 5.1–20.1 mm².

In 69% (average between observers) of the cases, a defect was detected on both the coronal and the sagittal CBCT images, and in 15% no defect was detected; thus an average agreement of 84% between the coronal and sagittal sections was found. In 9% of cases a defect was detected in the coronal sections but not in the sagittal sections, and in 7% a defect was detected in the sagittal sections but not in the coronal sections.

Discussion

1 week post-operatively, all observers detected and measured a periapical bone defect with both image modalities. This could be expected since the observers knew that root-end resection had been performed

Table 2 Agreement between the two by two methods of the presence of a defect 12 months post-operatively (*n* = 52): periapical radiographs vs CBCT images in the coronal plane, and CBCT images in the coronal plane vs the sagittal plane for each observer and mean (rounded off) between observers

Periapical	CT coronal	Obs 1	Obs 2	Obs 3	Observer mean (%)
+	+	27	23	28	26.0 (50)
+	–	4	3	1	2.6 (5)
–	+	10	18	16	14.7 (28)
–	–	11	8	7	8.7 (17)
CT coronal	CT sagittal	Obs 1	Obs 2	Obs 3	Observer mean (%)
+	+	34	34	40	36.0 (69)
+	–	3	7	4	4.7 (9)
–	+	2	6	3	3.6 (7)
–	–	13	5	5	7.7 (15)

+, Defect present; –, no defect present

1 week earlier. Observers' measurements differed to some extent within and between the image modalities. The variation between observers was smaller for CBCT images than for periapical radiographs, as seen in Figure 2. This finding may not be surprising since CBCT images are 1 mm tissue sections, and periapical radiography displays a summation of a 2- to 3-cm-thick tissue area. There was still some observer variation on CBCT images, more in the coronal than in the sagittal plane. A previous study on the accuracy of measurements on CBCT images found that interobserver variation was greater for less well-defined anatomical structures than for easily recognized foreign bodies, for example orthodontic wires.¹² In the present study, when measuring the periapical defect, three out of four measurement points were placed in cancellous bone with relatively poorly defined borders, which may explain the observer variation seen even on the CBCT images. Besides the tissue thickness imaged, the secondary reconstruction and sectioning were performed by each observer individually, which may further explain some of the observer variation. The measurement points placed by the observers were used when calculating the area of the bone defect on the periapical radiographs and on the CBCT images in the coronal and sagittal planes. The area was calculated as a rectangle, but in most cases the defects were more oval in shape; thus, the calculated areas are most likely an overestimation of the actual defect size. However, when comparing periapical radiographs and CBCT images, the defect areas were calculated using the same algorithm. The periapical radiographs were recorded using a bite index and the paralleling technique, which display structures with a small magnification, on average approximately 5%.¹³ No attempt was made to correct for this probable magnification, which also may explain part of the variation in measurements between the two modalities since the magnification may not be identical in every periapical image.

The bone defect area, expressed as the average measurement between observers, was approximately 10% smaller on the periapical radiographs than on the CBCT images in the coronal sections, and the difference was not statistically significant. The similarity between the two methods was an unexpected finding considering the differences in nature between the methods. No other studies have measured known periapical defects and compared CBCT with periapical radiography.

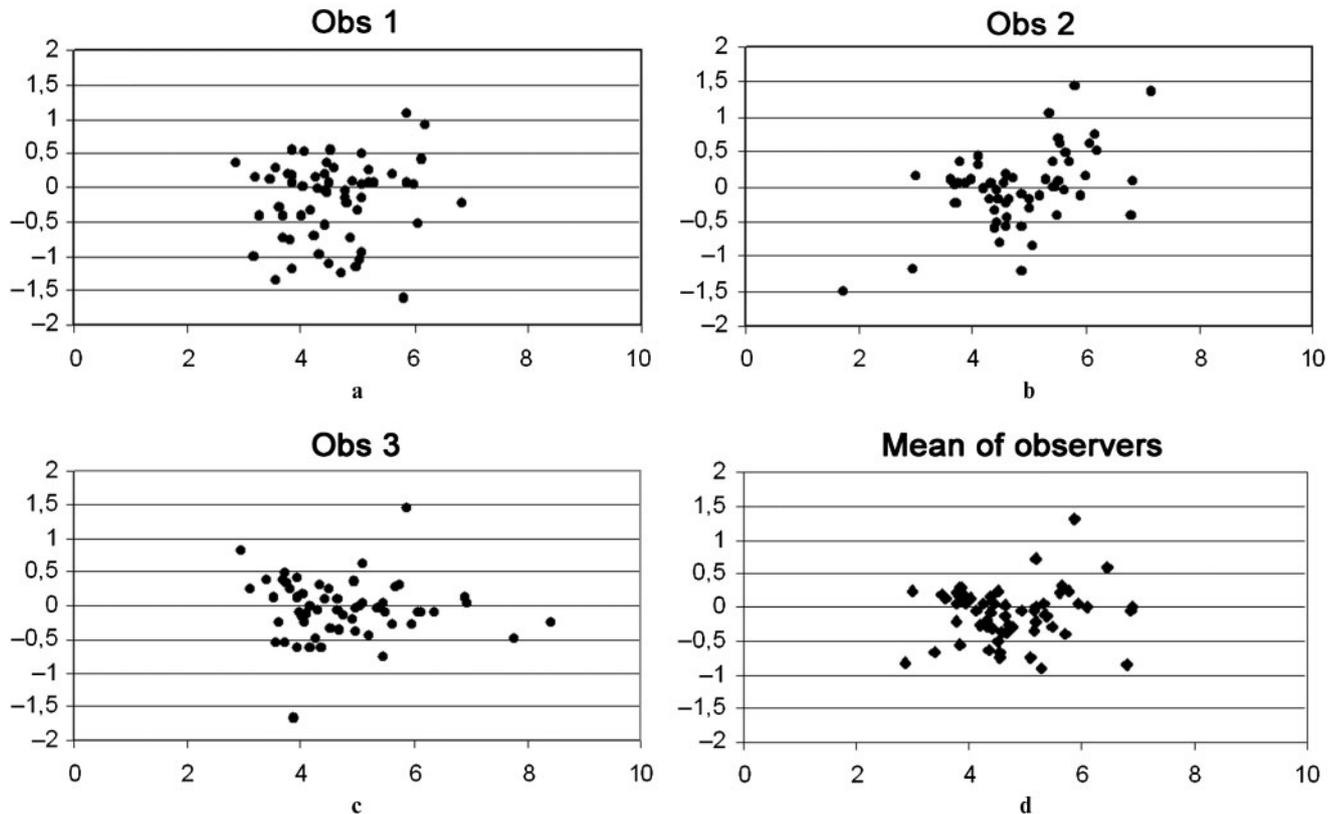


Figure 3 The variation between the calculated area on periapical radiographs and coronal CBCT images for each observer (a–c) and for the mean among observers (d): y-axis, log-transformed difference between the calculated areas; x-axis, log-transformed mean of the calculated areas

Previous studies, however, have compared CBCT images with periapical radiographs in relation to detection of apical periodontitis in patients and repeatedly demonstrated that more periapical lesions were detected using CBCT images.^{1–4} In these clinical studies, between one and three observers analysed the CBCT images, but no data for observer variation have been reported. One *in vitro* study in pig jaws found that artificially made defects were detected with higher accuracy and interobserver agreement on CBCT images than on periapical radiographs.¹⁴

12 months post-operatively, the observers were asked to detect a possible remaining periapical defect. There was considerable variation between the observers' detection of a remaining defect on periapical radiographs compared with CBCT images, and also among observers within the same radiographic method. Part of the variation between the methods may be due to the small size of most of the defects that were detected on the CBCT images but were not visible on the periapical radiographs. The agreement between periapical radiographs and CBCT coronal sections on the presence/absence of a defect was, on average, 67%, and in 28% of the cases a defect was detected on the CBCT images but not on the periapical radiographs.

A classification system has previously been described by which healing of the periapical bone can be

interpreted and categorized from periapical radiographs 1 year after root-end resection.^{15,16} The scoring system is based on histological examination of defects detected on periapical radiographs 1–14 years after surgery.^{17,18} Furthermore, studies with up to 15 years of follow-up have shown that the classification of healing success or failure 12 months after surgery has a high long-term predictive validity.^{17,18} Hence, by conventional periapical radiography, no further radiographic monitoring may be necessary in cases determined to be successful after 12 months.^{19,20} In the present study, there were several remaining defects detected after 1 year on the CBCT images but not on the periapical radiographs, which appeared to show that most defects had healed. Because it is not known how the periapical bone radiolucency observed on the CBCT images corresponds with histology of the tissue and with the prognosis for the tooth, the terms success/failure or healing/no healing were avoided in our study. Until further longitudinal studies have provided evidence for its effectiveness, it may be premature to apply CBCT imaging to assess healing after root-end resection because this may lead to overestimation of failures and unnecessary retreatments. Similarly, CBCT cannot be recommended as a screening method for detection of apical periodontitis because the same problem will apply.

Conclusions

On average, the periapical bone defect measured on periapical radiographs was approximately 10% smaller than on coronally sectioned CBCT images 1 week post-operatively. More remaining defects were detected 1 year after periapical surgery on CBCT images than

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