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Agreement between periapical radiographs and cone-beam computed tomography for assessment of periapical status of root filled molar teeth

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Abstract

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Aim To assess the agreement between periapical radiograph (PA) and cone-beam computed tomography (CBCT) for periapical assessment of root filled maxillary and mandibular molars.

Methodology Periapical radiograph and CBCT (iCat) images of 60 previously root filled molars (30 maxillary and 30 mandibular) were obtained at a review clinic. Agreement between PA and CBCT assessments of (i) number of canals per tooth, (ii) number of lesions per tooth, (iii) mesial-distal dimension of lesions, (iv) coronal-apical dimension of lesions and (v) presence of 'J'-shaped lesions were determined in comparison analyses and correlation analysis.

Results There were significant differences between PA and CBCT assessment for the mean number of canals ($P < 0.001$) and periapical lesions ($P < 0.001$), mean mesial-distal ($P < 0.001$) and coronal-apical dimension of the lesion (if present; $P < 0.001$) and the mean number of 'J'-shaped lesions ($P < 0.05$). The magnitude of the statistical differences (or bias) was greater for maxillary than mandibular molars regarding the number and size of the lesions identified. Correlation values were weaker between PA and CBCT assessments of maxillary molars than for mandibular molars in all parameters assessed.

Conclusion There were substantial disagreements between PA and CBCT for assessing the periapical status of molar teeth, especially for the maxillary arch. The findings have implications in periapical diagnosis and for evaluating the outcome of endodontic care.

Keywords: CBCT, failure, periapical status, radiographic diagnosis, radiolucency, success, treatment outcome.

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Introduction

Intraoral periapical radiographs have been used for many years as the only means to evaluate the outcome (bony healing) of root canal treatment (Tyndall & Rathore 2008). However, it is widely accepted that periapical lesions may only become visible on radiographs when there is considerable erosion/demineralization of bone from the inner surface of the cortical plate, or when there is actual perforation of the bony cortex (Bender & Seltzer 1961). Radiographic detection of periapical lesions within the alveolus is also affected by the location (tooth type; Shoha *et al.* 1974) and the 3-dimensional shape of the lesion (Gao *et al.* 2010). Absence of discernible radiographic change does not always equate to an absence of periapical inflammation (Brynolf 1967, de Paula-Silva *et al.* 2009a). Compared with periapical films, the CBCT has been reported to be a more sensitive means to detect changes in density of the bony structure

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(Tsai *et al.* 2012) and for the presence of periapical rarefaction (Lofthag-Hansen *et al.* 2007, Liang *et al.* 2011). It also allows 3-dimensional visualization of the location of any lesions (Cotton *et al.* 2007, Patel *et al.* 2007, Tyndall & Rathore 2008). With the use of CBCT, an increased accuracy for the diagnosis of the periapical status has been reported (de Paula-Silva *et al.* 2009b), although a recent meta-analysis concluded that CBCT may not necessarily improve the diagnostic ability compared with intraoral radiographs (Petersson *et al.* 2012). A quick search on the PUBMED using the keywords 'cone-beam' or 'CBCT' and 'periapical' indicated that there were over 150 articles relating the use of CBCT to endodontic dentistry, but very few (Christiansen *et al.* 2009, Liang *et al.* 2011, Patel *et al.* 2012) were reports of the periapical status of root filled teeth assessed by this imaging tool. Others were case reports (Tanomaru-Filho *et al.* 2010) or animal experiments (de Paula-Silva *et al.* 2009b). Generally, these studies indicated that the prevalence of periapical radiolucent lesions for endodontically treated teeth was higher when CBCT was used as the imaging tool, compared with periapical radiography. However, the amount of reports of endodontic treatment outcome based on this method of evaluation is still sparse.

The aim of this study was to compare CBCT and intraoral periapical (PA) radiograph as a means to determine the periapical status of molar teeth after root canal treatment. The null hypothesis was that CBCT and periapical films were equally effective for the detection of periapical rarefaction associated with the tooth root.

Materials and methods

Data collection

Sample size calculation was based on a hypothesized value of an intraclass correlation of <80% (i.e. not strong agreement) between PA and CBCT assessments of the periapical status of molars, which showed that the minimum number of subjects needed was 30 per group; a total of 60 subjects. Patients who had received root canal treatment of a maxillary or mandibular, first or second permanent molars in a dental teaching hospital between 2001 and 2005 were invited to attend a recall in late 2009 or 2010. The root canal treatments were performed under local anaesthesia and rubber dam isolation by dental undergraduate students under supervision using a standard protocol. Briefly, after access cavity preparation, the canals were prepared either by a step-down technique using stainless steel K-files (K-Flexofile, Dentsply Maillefer, Ballaigues, Switzerland) with a filing motion, or a combination of manual and engine-driven nickel–titanium instruments (ProFile, Dentsply Maillefer) in a rotary fashion. The clinical procedures of the treatment were described previously (Cheung & Liu 2009). A random sample of 60 patients who attended a review clinic were included (30 patients regarding a single maxillary molar and another 30 for a mandibular molar). Randomization was done by lottery from the list of maxillary and mandibular cases returning for review. The study was approved by the local ethics authority (HKU/HA HKW IRB, Ref No. UW09-190).

At the review visit, after routine clinical examination, one intraoral paralleling radiograph (buccal–lingual view) was taken for the tooth concerned using a size 2 dental X-ray film (Ektaspeed Plus; Eastman Kodak, Rochester, NY, USA) with a positioning device (XCP; Rinn, Elgin, IL, USA). All periapical films were exposed with a dental X-ray unit (Oralix DC; Gendex, Hatfield, PA, USA) and developed in an automatic processing machine (Velopex Intra-XE; Medivance Instruments, London, UK). Then, the aim of the study and the procedures involved were explained to the patient whom was invited to take part. After obtaining informed consent from the patient, an in-house CBCT (i-CAT; Imaging Sciences International, Hatfield, PA, USA) scan was performed for the dental arch; all CBCT scans were acquired with the same setting at: 120 kV, 23.87 mA for 20 s, field-of-view = 160 mm diameter × 75 mm height, with a resolution of 0.3 × 0.3 × 0.3 mm voxel size.

All PA radiographs were coded and assessed over a masked light box by two pre-calibrated examiners (an endodontist and an oral radiologist) in a blind sequence independently, according to the periapical index (PAI; Ørstavik *et al.* 1986). That is, presence of periapical radiolucencies was defined as PAI index of 2 or above. The size of the lesion was measured using a stainless steel ruler in two dimensions: mesial-distal (M-D) and coronal-apical (C-A). Presence of any 'J'-shaped lesions, defined as an asymmetrical radiolucent area extending over the radiographic root apex and coronally on one (not to the same extent on both aspects of the) root surface (Torabinejad & Walton 2008), was also noted.

The CBCT digital images were assessed using a computer software (iCAT Vision; Imaging Sciences International) on a supplier-configured workstation and a calibrated flat-panel monitor (Philips 220CW; Royal Philips Electronics, Amsterdam, the Netherlands) in a room with subdued light by the same independent examiners in a blind sequence for the periapical status, according to the CBCT (periapical) index (cPAI) described by Estrela *et al.* (2008). Each CT image was set to be analysed under the MPR mode, which showed a reconstructed image in standardized coronal and axial views. The size of the lesion was measured in three dimensions: coronal-apical (C-A) and buccal-lingual (B-L)/buccal-palatal (B-P) diameter in the coronal view, and mesial-distal (M-D) diameter in the axial view. Presence of any discernible 'J'-shaped lesions was recorded. Patients with any discernible lesions were scheduled to receive further investigation and treatment.

Data analysis

The mean values of assessment by the two observers were obtained for PA and CBCT readings; agreement between the PA and CBCT assessment was examined using several analytic strategies. First, the mean difference in (i) number of canals per tooth, (ii) number of lesions per tooth, (iii) M-D diameter of lesions, (iv) C-A diameter of lesions and (v) number of 'J' shaped lesions was compared. A paired *t*-test was performed to evaluate whether the difference between the PA and CBCT assessments was significantly different from zero, a test for systemic bias. If present, the effect size (ES; an indication of the magnitude of statistical differences) was calculated by dividing the value of the difference by the standard deviation of those differences (Ellis 2010). Secondly, intraclass correlation coefficients (ICCs) between the PA and CBCT assessments using one-way analysis of variance random effects parallel model were conducted. The ICC is a measure of agreement, as it corrects correlation for systematic differences and provides an unbiased estimate of agreement (Vargha 1997).

Concordance of endodontist's and oral radiologist's assessments of PA and CBCT of 10 maxillary molars and 10 mandibular molars by way of investigating interexaminer reliability was conducted using the same method above. Agreement between reassessments and original assessments from both PA and CBCT images of 10 maxillary molars and 10 mandibular molars by both the endodontist and oral radiologist was determined (Table 1).

Results

There was no significant difference in the endodontist's and oral radiologist's assessments of PA and CBCT parameters ($P > 0.05$). In addition, ICC values of endodontist's and oral radiologist's assessments were >0.80 on all parameters. There was also no significant difference in repeat assessments, compared with original assessments of PA and CBCT conducted by the endodontist and the oral radiologist ($P > 0.05$) and a high correlation between repeat assessments (ICC > 0.80; Table 1).

Table 1 Reliability of endodontist's and oral radiologist's assessments of molar teeth

	Endodontist	Oral radiologist	Directional difference[a]			
	Mean (SD)	Mean (SD)	Mean (SD)	d[b]	P^*	ICC (95% CI)
Periapical (*n* = 20 repeat measurements)						
Number of canals	2.81 (0.60)	2.86 (0.66)	0.05 (0.22)	0.23	0.329	0.97 (0.93, 0.99)
Number of lesions	1.38 (1.16)	1.14 (1.24)	0.24 (0.54)	0.44	0.056	0.89 (0.74, 0.93)
Size of lesions (M-D):	4.50 (5.55)	4.33 (5.67)	0.17 (0.40)	0.35	0.069	0.92 (0.87, 0.94)
Size of lesions (C-A):	6.43 (8.01)	6.21 (7.98)	0.21 (0.66)	0.32	0.154	0.96 (0.91, 0.98)
Number of 'J' lesions	0.10 (030)	0.14 (0.36)	0.05 (0.22)	023	0.329	0.88 (0.71, 0.95)
CBCT (*n* = 20)						
Number of canals	3.19 (0.68)	3.29 (0.72)	0.10 (0.30)	0.33	0.162	0.95 (0.87, 0.98)
Number of lesions	1.81 (1.21)	1.90 (1.30)	0.09 (0.30)	0.30	0.162	0.96 (0.88, 0.99)
Size of lesions						
Mesial-distal	12.91 (15.05)	12.84 (15.01)	0.07 (0.26)	0.27	0.221	0.96 (0.93, 0.98)
Size of lesions						
Coronal-Apical	12.37 (12.91)	12.45 (13.22)	0.08 (0.71)	0.11	0.601	0.99 (0.98,1.00)
Number of 'J' lesions	0.19 (0.40)	0.14 (.36)	0.05 (0.22)	0.23	0.329	0.91 (078, 0.96)

[a]Directional difference = Difference between endodontist's and radiologist's scores (indicator of bias).
[b]*d* = Standardized difference = mean directional difference/standard deviation of directional difference.
**P* = Probability value obtained from paired *t*-test.

There were significant differences in the mean number of canals identified on PA and CBCT assessments of maxillary molars (3.2 vs. 3.6) and mandibular molars (2.8 vs. 3.3; $P < 0.001$; Table 2). The magnitude of the statistical difference was comparable for maxillary molars (effect size, ES = 0.86) and mandibular molars (ES = 0.88). The ICC values of PA versus CBCT readings in the correlation analysis were 0.36 for all molars, with a value of 0.22 for maxillary and 0.55 for mandibular molars (Table 2). A greater number of 4-canal molars were identified on CBCT scans, compared with periapical films (Table 3).

There were also significant differences in the mean number of lesions identified from PA and CBCT, for both maxillary ($P < 0.001$) and mandibular molars ($P < 0.001$). Effect size value was largest for maxillary molars (ES = 1.07). The ICC value with respect to mean number of lesions was lower for maxillary molars (0.46), compared with mandibular molars (0.73; Table 2). The raw data also indicated a large difference between the two imaging methods for the number of lesions identified (Table 3).

For the size of lesions, there were significant differences in the mean M-D diameter for all molars assessed ($P < 0.001$): maxillary ($P < 0.001$) and mandibular ($P < 0.001$), with a greater effect size in the maxillary arch (ES = 0.68). The ICC value between results of the two imaging methods was lower for maxillary (0.34) than mandibular molars (0.58). Likewise, there were significant differences in the coronal-apical dimension of the lesions identified, maxillary ($P < 0.001$) and mandibular molars ($P < 0.001$). Again the largest effect size of differences was amongst maxillary molars (ES = 0.84). ICC value was lowest for maxillary molars 0.29 (Table 2).

The number of 'J'-shaped lesions was few, but there was significant difference in the mean number of this lesion identified on all molars assessed ($P = 0.007$), both maxillary ($P = 0.043$) and mandibular ($P = 0.014$). The associated effect size was all <0.40. The correlation of the number of 'J'-shaped lesion between assessment on PA and CBCT was highest for mandibular molars (0.81; Table 2).

Discussion

There was substantial agreement between the endodontist and oral radiologist for all the parameters assessed using both PA and CBCT imaging techniques; correlation analyses indicated good to excellent interexaminer reliability. Furthermore, there was substantial agreement between reassessments conducted by the two examiners for the both imaging methods across all the parameters, as well as good to excellent agreement for intraexaminer reliability. The

Table 2 Agreement between PA and CBCT assessments of molar teeth

	Periapical	CBCT	Directional difference[a]			
	Mean (SD)	Mean (SD)	Mean (SD)	d[b]	*P*[*]	ICC (95% CI)
ALL Molars (*N* = 60)						
Number of canals	2.98 (0.57)	3.45 (0.59)	0.47 (0.54)	0.87	<0.001	0.36 (0.12, 0.56)
Number of lesions	0.95 (1.08)	1.55 (1.18)	0.60 (0.99)	0.60	<0.001	0.51 (0.30, 0.68)
Size of lesions (M-D):	3.22 (8.31)	8.30 (10.36)	4.56 (7.81)	0.58	<0.001	0.38 (014, 0.58)
Size of lesions (C-A):	4.11 (6.77)	8.76 (7.97)	5.43 (6.48)	0.84	<0.001	0.51 (0.29, 0.67)
Number of 'J' lesions	0.08 (0.28)	0.20 (0.40)	0.12 (0.32)	0.38	0.007	0.53 (0.32, 069)
Maxillary molars (*n* = 30)						
Number of canals	3.20 (0.41)	3.63 (0.49)	0.43 (0.50)	0.86	<0.001	0.24 (0.13, 0.46)
Number of lesions	0.73 (1.02)	1.63 (1.16)	0.90 (0.84)	1.07	<0.001	0.46 (0.18, 0.69)
Size of lesions (M-D):	1.72 (2.51)	6.40 (7.16)	4.68 (5.74)	0.68	<0.001	0.34 (0.21, 0.69)
Size of lesions (C-A):	1.92 (7.35)	2.70 (7.97)	5.43 (6.48)	0.84	<0.001	0.29 (0.18, 0.46)
Number of 'J' lesions	0.03 (0.18)	0.17 (.38)	0.13 (0.35)	0.37	0.043	0.43 (−0.18, 0.73)
Mandibular molars (*n* = 30)						
Number of canals	2.77 (0.63)	3.27 (0.64)	0.50 (0.57)	0.88	<0.001	0.55 (0.07, 079)
Number of lesions	1.16 (1.12)	1.47 (1.22)	0.30 (1.05)	0.29	<0.001	0.73 (0.44, 0.87)
Size of lesions (M-D)	4.72 (7.69)	10.20 (14.18)	5.48 (11.07)	0.50	<0.001	0.58 (0.12, 0.80)
Size of lesions (C-A)	6.30 (8.71)	10.00 (12.29)	3.70 (8.97)	0.41	<0.001	0.76 (0.49, 0.88)
Number of 'J' lesions	0.13 (0.35)	0.23 (0.43)	0.10 (0.31)	0.33	0.014	0.81 (0.60,0.91)

[a]Directional difference = Difference between periapical and CBCT scores (indicator of bias).
[b]*d* = Standardized difference = mean directional difference/standard deviation of directional difference.
**P* = Probability value obtained from paired *t*-test.

Table 3 Number of canals and lesions identified by PA and CBCT assessments

	Maxillary (n = 30)		Mandibular (n = 30)	
	First molar	Second molar	First molar	Second molar
No. of teeth	23 (100%)	7 (100%)	20 (100%)	10 (100%)
No. of roots	69	21	42	19
No. with 4 canals identified by				
PA films	4 (17%)	2 (30%)	3 (15%)	0
CBCT	14 (61%)	5 (71%)	10 (50%)	1 (10%)
No. of canals identified by: (both 6's and 7's included)[a]				
PA films	96		83	
CBCT	109		97–98	
No. of lesions identified by:				
PA films	19–21		30–35	
CBCT	48–52		44	

[a]A range in the figure indicated that the two observers did not agree entirely.

authors recognized that the two periapical indices (periapical index by Ørstavik *et al.* versus cPAI by Estrela *et al.*) are not directly comparable. Nor should the two radiological means – as a matter of fact – because they are based on fundamentally different principles for image construction. Nonetheless, the two indices were used to indicate the presence of any periradicular radiolucent area and to allow measurement of the size of lesions that were identified by the two methods of assessing the periapical status.

Only molar teeth were included in this study, as they probably are the most problematic in terms of radiographic interpretation. The apical region of maxillary molars is often overlapped with the image of the radio-dense zygomatic process. Likewise, the thick cortical plate of the mandible can make the identification of small, developing lesion rather unpredictable on a periapical radiograph (Gao *et al.* 2010). The iCAT machine was used in this study, as it was the only machine that was available in-house at that time. The scan volume was 160 mm diameter × 75 mm height, which was always directed to cover both dental arches, with the base of the skull excluded. A rapid scanning time (20 s) was chosen, which would produce an acceptable resolution for the purpose (0.3 mm isometric voxel size), to limit the radiation dose. Newer machines with a limited field-of-view should further reduce the effective dose for the patient.

A greater number of root canals were observed in CBCT of maxillary and mandibular molars than in PA radiographs. The magnitude of the statistical difference for both maxillary and mandibular molars (ES > 0.80) could be interpreted as large. It is common knowledge that there may be more than one canal in a root of oval or oblonged cross-sectional configuration, and that the two canals could appear as one radiographically due to overlap of their images. The MB2 canal is a well-known example, and CBCT technology has helped in the diagnosis of its presence (Matherne *et al.* 2008). The findings of this study suggest that missed canals in mandibular molars from PA radiograph may also be common, stressing the importance for a good working knowledge of pulp canal anatomy for the clinicians. Use of magnification would also aid in locating all root canals that may be present.

CBCT has been reported as a more sensitive tool to detect periapical rarefaction than intraoral radiographs (Tsai *et al.* 2012). The results indicated the same. For all molars evaluated, the mean number of lesions found was 0.95 with PA films versus 1.55 with CBCT. That was a 63% increase in the amount of periapical lesions detected. Interestingly, although, the effect size of this difference between the mean number of lesions observed from the two imaging methods is relatively small (~0.20) for mandibular molars, as opposed to a much larger difference (ES > 0.80) for maxillary molars. Moreover, the intraclass correlation values (ICC) between PA and CBCT assessment were higher in mandibular than maxillary molars. In other words, there is a greater discrepancy between the two radiological means for the detection of periradicular lesions in the maxilla than in the mandible. It is plausible that the presence of anatomical features, such as the maxillary sinuses (which appear radiolucent) around maxillary tooth roots and/or the zygomatic process that can overlap with maxillary molar roots on periapical films, is a factor for the difference.

The PA radiographs in the present study were examined by a radiologist and an endodontist, both being skilled in reading dental structures radiographically. It is possible that the amount of discrepancy between the two radiological means might be greater, if a less experienced assessor (say, perhaps, a general practitioner) had been looking at those images. Another limitation of this study is the recruitment of one person each from radiology and endodontic specialties to assess the radiographs and CBCT scans. One may argue that multiple assessors from each specialty may provide a more objective evaluation, but that practice could also lead to greater number of disagreements, especially when intraoral radiographs were concerned. A radiologist who has absolutely no knowledge about the quality of endodontic treatment was included, for an objective assessment of the radiographic appearance. The practice of having one radiologist and an endodontist was adopted in a recent meta-analysis of the diagnostic effectiveness of various radiographic methods (Petersson *et al.* 2012).

There were marked differences in the size of lesions, both in terms of mesial-distal and coronal-apical dimensions, between PA and CBCT assessments. Viewing of CBCT images on a computer screen had an obvious advantage and was likely to be more accurate than using a stainless steel ruler on the periapical film. However, the substantial difference in the size of lesions as revealed by CBCT versus PA is unlikely to be due to the different measurement method alone. Previous studies have also identified large differences in lesion size (in all directions/sections) between the two radiological assessments (Estrela *et al.* 2008, de Paula-Silva *et al.* 2009a). The projection geometry and the masking effect due to the cortical plate or the zygomatic process are likely to be the major factors for the misrepresentation of the lesion size on a periapical radiograph. Of note, a greater effect size and weaker correlation values were observed, suggesting that incongruence in lesion size may be particularly apparent for maxillary molars. The findings would have implications in periapical diagnosis and for evaluating the outcome of endodontic care.

Conclusion

There were substantial disagreements between PA and CBCT assessments of the number of canals, number and size of lesions (if any) and the number of 'J'-shaped lesion (if any) amongst molar teeth. The discrepancy was more pronounced for maxillary molars, in terms of both the presence and the size of lesions, than for the mandible. The findings suggested that there is a high chance of underestimating the amount of lesions associated with root filled teeth (say, in treatment outcome studies), especially for the maxillary posterior segment, when periapical radiographs only are used for evaluating the outcome of endodontic treatment.

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