International Endodontic Journal

doi:10.1111/j.1365-2591.2010.01802.x

A comparative study between cone-beam computed tomography and periapical radiographs in the diagnosis of simulated endodontic complications

P. S. S. D'Addazio[1], C. N. Campos[1], M. Özcan[2], H. G. C. Teixeira[1], R. M. Passoni[1] & A. C. P. Carvalho[1]

[1]Department of Dental Clinic, Dental School, Juiz de Fora Federal University, Bairro Martelos S/N, Juiz de Fora, Brazil; [2]University of Zurich, Dental Materials Unit, Center for Dental and Oral Medicine, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Zurich, Switzerland

Abstract

D'Addazio PSS, Campos CN, Özcan M, Teixeira HGC, Passoni RM, Carvalho ACP. A comparative study between cone-beam computed tomography and periapical radiographs in the diagnosis of simulated endodontic complications. *International Endodontic Journal*, **44**, 218–224, 2011.

Aim To compare cone-beam computed tomography (CBCT) with periapical radiography for the identification of simulated endodontic complications.

Methodology Sixteen human teeth, in three mandibles, were submitted to the following simulated endodontic complications: G1) fractured endodontic file; G2) root perforation; G3) cast post with deviation; G4) external root resorption. Periapical radiographs were taken of each tooth at three different angles, and CBCT scan was taken. One calibrated examiner who was specialized in dental radiology interpreted the images. The results were analysed using the following scoring system: 0 – unidentified alteration; 1 – alteration identified with inaccurate diagnosis; and 2 – alteration identified with accurate diagnosis. Data were analysed using McNemar and Wilcoxon tests (alfa = 0.05).

Results In the overall assessment, CBCT was superior when compared with periapical radiographs ($P < 0.05$). When individual results on each complication were evaluated, CBCT was superior only in the identification of external root resorption (100% Score 2) ($P < 0.05$).

Conclusion Cone-beam computed tomography could be an alternative to periapical radiographs especially in the detection and assessment of external root resorption.

Keywords: cone-beam computed tomography, endodontic complications, periapical radiography.

Received 24 March 2010; accepted 6 September 2010

Introduction

Dental radiography provides essential information for the diagnosis, treatment planning and follow-up of cases (Gröndahl & Huumonen 2004). However, a general problem in endodontics is the limitation of conventional radiographic images where anatomical landmarks may be confused with periapical pathosis. This is mainly because of the three-dimensional anatomy being restricted to a two-dimensional image (Patel *et al.* 2007), the superimposition of overlying anatomy and the density of cortical bone (Patel *et al.* 2009a).

Although periapical radiographs can reveal details on the mesiodistal aspect of teeth and periradicular bone, the observation of features on the bucco-lingual axis is often insufficient. This makes it difficult, in many cases, to visualize lesions and juxtaposed structures (Tsurumachi & Honda 2007). These problems may be overcome with cone-beam computed tomography

Correspondence: Mutlu Özcan, Head of Dental Materials Unit, Center for Dental and Oral Medicine, University of Zurich, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Plattenstrasse 11 CH-8032, Zürich, Switzerland (Tel.: +41 44 6345600; fax: +41 44 6344305; e-mail: mutluozcan@hotmail.com).

(CBCT) techniques developed specifically for dentistry. This three-dimensional imaging system could have great potential in the field of endodontics and may become valuable in the diagnosis and management of endodontic problems (Cotton *et al.* 2007, Patel *et al.* 2007, Patel 2009).

The correct diagnosis of complications such as perforations and resorptions can be challenging and may result in inappropriate treatment. An accurate diagnosis is essential for an appropriate treatment plan to be devised (Patel *et al.* 2009b). Therefore, assessment of such complications is of special importance in endodontics. This study aims to compare the accuracy of simulated endodontic complications in images obtained with conventional radiographs with CBCT.

Materials and methods

Sample

Sixteen sound human teeth, in three human mandibles, obtained from the Department of Morphology ICB/UFJF, were submitted to the preparation of 20 simulated defects to establish situations that may result in complications for endodontic diagnosis and treatment. The jaws were immersed in distilled water at 37 °C for 12 h, and the teeth were then carefully removed from their alveolus with the use of forceps. They were then examined meticulously, under magnification with a magnifying glass, for the assessment of any external alteration such as natural external resorption or superficial injuries after their removal from the respective sockets.

Preparation of simulated defects

The defects ($n = 20$) were divided into four groups ($n = 5$), according to the type of defect. Some teeth were submitted to more than one defect (Table 1). Preparation on the teeth was performed as follows:

Group 1: A portion of a fractured file in the canal: initially, instrumentation of the root canal was performed to simulate root canal treatment. Next, size 06 hand files (Dentsply Maillefer, Ballaigues, Switzerland) were abraded with a diamond bur no. 3203 (KGS®; KG Sorensen, São Paulo, Brazil) 2 mm from the tip to create a fracture point. Subsequently, the endodontic files were inserted in the canals, through the apical foramen, and twisted in the canal to cause an intentional fracture.

Table 1 List of all simulated endodontic complications in the respective tooth

Tooth number	Alteration
1	Perforation in the mesial side of the distal root
	Fragment of the fractured file at the apex of the mesial root
	Fragment of the fractured file at the apex of the distal root
2	External resorption on the lingual root
	Fragment of fractured file at the apex of the root tip
3	External resorption on the lingual root
4	Cast post with deviation to the lingual surface
5	Cast post with deviation to the lingual surface
6	Fragment of the fractured file at the apex of the root tip
7	External resorption on the lingual root
8	Cast post with deviation to the lingual surface
9	Fragment of the fractured file at the apex of the root tip
	External resorption on the buccal root
10	Perforation in the mesial root (mesiolingual canal)
11	External resorption on the buccal root
12	Perforation in the distal side of the distal root
13	Perforation in the distal side of the distal root
14	Cast post with deviation to the lingual surface
15	Cast post with deviation to the lingual surface
16	Perforation in the mesial side of the distal root

Group 2: Perforations in the canal walls: The canals were instrumented with crown-down instrumentation technique using size 1–4 Gates-Glidden drills (Maillefer®; Dentsply Maillefer), 15–80 K files (Maillefer®; Dentsply Maillefer) and 15–80 Hedström files (Maillefer®; Dentsply Maillefer) in sequence. The instruments were forced against the thin walls until the root wall was perforated. The size of the perforation was approximately 1 mm in diameter and was cylindrical in shape.

Group 3: Cast post with deviation in relation to the long axis of the tooth: The teeth were submitted to conventional root canal treatment, and the canals were then prepared with sizes 1–3 peeso reamers (Maillefer®; Dentsply Maillefer) buccally or lingually, causing a deviation of approximately 45 degrees in relation to the long axis of the tooth. Next, direct acrylic (Duralay®; Reliance Dental Mfg Co., Worth, IL, USA) patterns were created and cast in silver alloy (Super Alloy®; Laboratório Super, Rio de Janeiro, Brazil). The posts were adjusted in the canal and then cemented with zinc phosphate cement in the respective teeth.

Group 4: Simulated external root resorption: these were created with a size 014 spherical bur (Dentsply Maillefer) in a slow handpiece and were approximately

Figure 1 Human mandible with prepared teeth.

2 mm in diameter. Half of the active tip of the bur was used in random regions of the buccal or lingual surfaces, so that they overlapped the root canal, with the aim of making differential diagnosis difficult.

Examination procedure

Each tooth, inserted in its respective socket (Fig. 1), was submitted to standardized periapical radiographic examination (Dabi Atlante 1070X equipment; Dabi Atlante, São Paulo, Brazil) with an exposure time of 0.7 s, 70 kV and 10 mA (Fig. 2). An X-ray cone was used in three directions in the horizontal plane: orthoradial, mesioradial and distoradial, with 10° angle. The films were processed in an automatic developer (Revell®; Del Grandi Produtos Radiológicos Ltd, São Paulo, Brazil). Each jaw was then submitted to CBCT examination (i-CAT® equipment; Imaging Science International, Hatfield, PA, USA), using the image protocol for mandible, with the following exposure parameters: 13 cm acquisition field, 40 s of acquisition duration, 0.25 mm of voxel, 120 kV, 46.72 mA (Fig. 3). Primary cuts were 0.25 mm wide at axial, sagittal and coronal (frontal), and secondary cuts were panoramic (1.0 and 1.5 mm wide), transversal (1 mm wide) and sagittal (1 mm wide).

One calibrated specialist, dental radiologist, analysed the radiographs and the CBCTs. Initially, the radiographs were interpreted on the same illuminator, and the diagnosis identified in each tooth. After thirty days elapsed, the same examiner analysed the CBCT images and made the diagnosis.

The tomography images were analysed, on a 21-mm liquid crystal display screen that had a pixel resolution of 1280 × 1024, with Xoran Cat® software (Ann Arbor, MI, USA).

For calibration of the observer, a pilot experiment was conducted on 10 periapical radiographs. These were obtained from a mandible that contained five teeth having one of the simulated endodontic complications. The observer was asked to assess the radiographs twice within 10 days. The results were submitted to the kappa test, yielding a value of 0.8943. With regard to CT scan, the examiner was calibrated on the CT scans obtained from the pilot experiment. The examiner also had extensive experience with CBCT.

The reports issued by the examiner were classified according to the following scoring system: 0-unidentified alteration; 1-alteration identified with inaccurate diagnosis; and 2-alteration identified with accurate diagnosis.

Statistical analysis

The data obtained from the examinations were compared statistically with McNemar tests (SPSS, Chicago, IL, USA) for overall assessment. Specific results for each simulated alteration were analysed using Wilcoxon test (SPSS). P values <0.05 were considered to be significant in all tests.

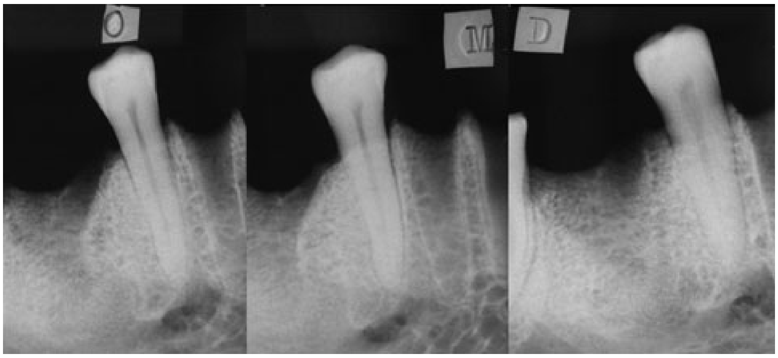

Figure 2 Periapical radiographs, in three horizontal projections (orthoradial, mesioradial and distoradial). Note that teeth with simulated external resorption were prepared on the buccal side.

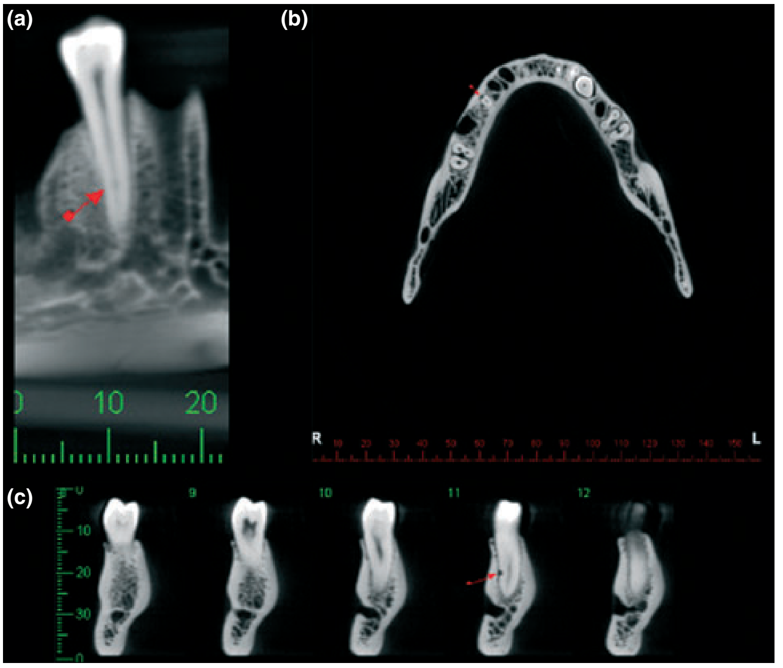

Figure 3 Representative cone-beam computed tomography images of external root resorption on the buccal side: (a) coronal, (b) axial and (c) sagittal views of the same tooth.

Table 2 Distribution of the scores based on periapical radiographs (X-ray) and cone-beam computed tomography (CBCT)

Simulated endodontic complication	Score (X-ray)			Score (CBCT)		
	0	1	2	0	1	2
Fractured file	2	0	3	3	0	2
External resorption	0	5	0	0	0	5
Cast post-deviation	1	3	1	0	2	3
Perforation	4	1	0	0	4	1
Total	7	9	4	3	6	11

Score 0: unidentified alteration; Score 1: alteration identified with inaccurate diagnosis; Score 2: alteration identified with accurate diagnosis.

Results

The results of the examinations and distribution of scores according to the simulated alterations are outlined in Table 2. Overall, there was significant superiority of CBCT over the periapical radiographs ($P \leq 0.05$) for recognizing the defects (Table 3).

Table 3 McNemar test (chi-square tests) result for CBCT versus X-ray comparison in overall assessment

	Valid cases	*P*-value
Overall assessment	20	0.013*

CBCT, cone-beam computed tomography.
*$P < 0.05$.

Cone-beam computed tomography received 100% Score 2 ($n = 5$) for external resorptions; 60% ($n = 3$) for cast post with deviation; 40% ($n = 2$) for the fractured file; and 20% ($n = 1$) for perforation. Periapical radiographs on the other hand revealed only the fractured files ($n = 3$) and post-deviations ($n = 1$) in 60% and 20% of cases, respectively (Fig. 4).

In the detection of external resorptions, CBCT was significantly superior to radiographs ($P < 0.05$) (Table 4). CBCT tended to be superior in the identification of perforations, but no significant difference was detected compared to radiographs ($P > 0.05$). As for the detection of fractured files, a slight superiority of radiographs was apparent however with no statistical significance ($P > 0.05$). For the identification of post-deviation, CBCT was superior when compared with radiographs but without a statistical difference compared to radiographs ($P > 0.05$).

Discussion

The methodology of this study allowed a comparative analysis between the periapical radiographs exposed at different horizontal projections (parallax) and CBCT for the identification of several simulated endodontic complications. Periapical radiographs in this study were exposed using angle incidence (Kamburoglu *et al.* 2008) because the use of multiple radiographic views may provide additional information (Sogur *et al.* 2007).

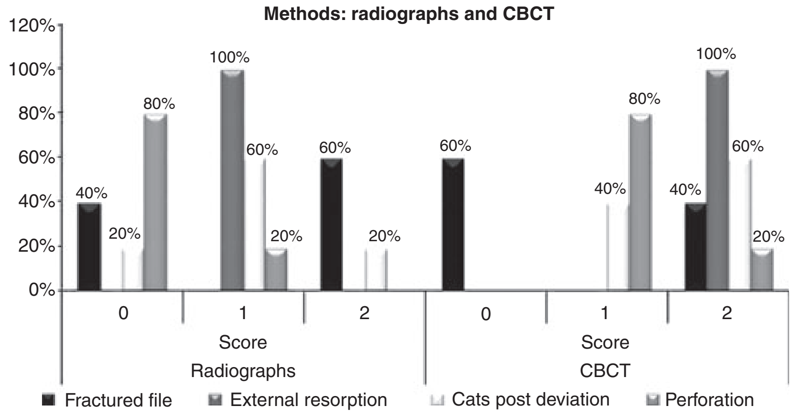

Figure 4 Distribution of the scores per assessment criteria in percentage.

Table 4 Wilcoxon signed ranks test for CBCT versus X-ray comparison for each simulated complication type

Alteration	CBCT vs. Radiograph	*P*-value
Fractured file	CBCT < Radiograph = 2	0.564
	CBCT > Radiograph = 1	
	CBCT = Radiograph = 2	
External resorption	CBCT < Radiograph = 0	0.025*
	CBCT > Radiograph = 5	
	CBCT = Radiograph = 0	
Cast post-deviation	CBCT < Radiograph = 0	0.180
	CBCT > Radiograph = 2	
	CBCT = Radiograph = 3	
Perforation	CBCT < Radiograph = 0	0.059
	CBCT > Radiograph = 4	
	CBCT = Radiograph = 1	

CBCT, cone-beam computed tomography.
*$P < 0.05$.

The i-CAT® scanner allows quick visualization of the area of interest in three orthogonal planes (Cohenca *et al.* 2007a,b). Previous studies have shown great capacity to assess internal anatomy of teeth (Matherne *et al.* 2008), as well as the accurate identification of external resorption or periapical lesions (Patel & Dawood 2007, Estrela *et al.* 2008, Jorge *et al.* 2008, Low *et al.* 2008, Patel *et al.* 2009a). CBCT is therefore indicated for complex situations and is presented as having the perspective of good visualization of lesions and complications that are usually difficult to observe in periapical radiographs depending on their angulation (Cotton *et al.* 2007, Tsurumachi & Honda 2007, Young 2007). It has been also proposed as an excellent tool to identify root resorption (Cohenca *et al.* 2007a, Patel & Dawood 2007). In a clinical setting, a small field of vision would be desirable.

In this study, one experienced examiner made the diagnosis. When the examiner received the radiographs for examination, he was not informed whether he would later receive the tomography. With this approach, the diagnosis from the periapical radiographs would not interfere in the analysis of the CBCT. The examiner in this study not only had experience in dental radiology but also had expertise in the use of the software tools of the CBCT equipment. According to Patel (2009), 'users of CBCT must be adequately trained in CBCT radiology as well as interpretation of these images as they are completely different from conventional radiography systems'.

The results of this study showed that CBCT allowed the correct identification of a higher percentage of defects than that of periapical radiographs. This result corroborates the results of other studies that have found CBCT a more accurate tool than periapical radiographs for the assessment and management of complex endodontic problems (Cotton *et al.* 2007, Estrela *et al.* 2008, Low *et al.* 2008, Patel 2009). In the assessment of periapical radiographs, the simulated alterations were not identified in 35% of the total number of cases, representing a considerable number of undetected lesions. In 45% of the instances, the examiner noticed some alteration but was not able to specify it. Only in 20% of the cases was the identification accurate. When CBCT images were assessed, 15% of the alterations remained undetected, 30% were identified partially, and 55% were identified accurately. These results may be attributed to the two-dimensional views of conventional radiographic images that limit the identification of certain conditions (Patel *et al.* 2007) such as the evaluations in the bucco-lingual direction (Tsurumachi & Honda 2007). In such cases, CBCT overcomes this limitation of radiographs as it allows the observation in several angles in three dimensions, offering an in-depth view of the region examined (Cohenca *et al.* 2007a,b).

In the identification of post-deviations, with the CBCT examinations, 60% of these deviations were identified with accuracy and 40% without. In the periapical radiographs, 20% of the post-deviations were not identified at all, 20% were identified with accuracy and 60% without accuracy. With regard to this type of simulated alteration, CBCT shows better results than periapical radiographs, despite the generation of image artefacts close to metallic structures in the CBCT. This is a common inherent characteristic of CBCT images that may make visualization of the area difficult (Katsumata *et al.* 2006, Tsuchida *et al.* 2007).

The external resorptions were performed in the buccal or lingual faces of the roots to have juxtaposition over the root canal. This was because of the differential diagnosis between internal and external resorptions that is difficult to identify (Patel & Dawood 2007, Patel *et al.* 2009b). On the other hand, the lesions located in the interproximal areas are easily detectable (Goldberg *et al.* 1998). For this kind of simulated defect, periapical radiographs could identify some irregularities in 100% of the cases. However, the location, whether they were internal or external, buccal or lingual lesions could not be identified. On the contrary, CBCT identified resorption with 100% accuracy, showing statistically significant superiority compared to the periapical radiographs. These results corroborate those found in the literature (Kamburoglu *et al.* 2008). On the other hand, CBCT offers the visualization of structures in different planes, allowing an accurate diagnosis of the resorption lesions (Cohenca *et al.* 2007b, Patel & Dawood 2007). Although the studies present different methodologies, the results of this laboratory study confirm the findings of an *in vivo* study (Patel *et al.* 2009b) where CBCT was used to diagnose external root resorption.

Conventional radiographic examinations are of limited diagnostic value, often allowing the identification of a periapical lesion only when it is at an advanced stage (Jorge *et al.* 2008). This also applies for root resorption where anatomy may lead to an underestimation of the size of the resorption and lesion (Patel *et al.* 2009b).

In the observation of file fragments, CBCT images were less accurate compared to periapical radiographs. In the CBCT examination, 60% of the files were not visualized and 40% of the files were identified accurately. On the other hand, in the radiographic examination, 40% of the files were not identified but 60% of the fragments were identified accurately. These results suggest a slight superiority of periapical radiograph, yet not statistically significant, when compared to CBCT, in the identification of fragments of endodontics instruments. According to Patel *et al.* (2007), such results may be attributed to the limitations of CBCT resolution.

In the diagnosis of root canal perforations, periapical radiographs did not identify the majority (80%) of the alterations, leading to inaccurate diagnosis in 20% of the cases. With CBCT however, all alterations were identified, 80% of which were inaccurate and 20% accurate. However, the results need to be verified on a larger sample size.

Conclusion

Cone-beam computed tomography provided more accuracy in the detection of external root resorptions. In the simulations of fractured files, cast post-deviation and perforations although CBCT showed a tendency for more accurate identification, no significant difference was detected with the periapical radiographs.

Acknowledgement

The authors would like to thank the organization CAPES, Brazil. The authors also extend their gratitude to Prof. Passoni and Prof. Carvalho for helpful discussions.

References

Cohenca N, Simon JH, Mathur A, Malfaz JM (2007a) Clinical indications for digital imaging in dento-alveolar trauma. Part 2: root resorption. *Dental Traumatology* **23**, 105–13.

Cohenca N, Simon JH, Roges R, Morag Y, Malfaz JM (2007b) Clinical indications for digital imaging in dento-alveolar trauma. Part 1: traumatic injuries. *Dental Traumatology* **23**, 95–104.

Cotton TP, Geisler TM, Holden DT, Schwartz SA, Schindler WG (2007) Endodontic applications of cone-beam volumetric tomography. *Journal of Endodontics* **33**, 1121–32.

Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR (2008) Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. *Journal of Endodontics* **34**, 273–9.

Goldberg F, De Silvio A, Dreyer C (1998) Radiographic assessment of simulated external root resorption cavities in maxillary incisors. *Endodontics and Dental Traumatology* **14**, 133–6.

Gröndahl H-G, Huumonen S (2004) Radiographic manifestations of periapical inflammatory lesions. How new radiological techniques may improve endodontic diagnosis and treatment planning. *Endodontic Topics* **8**, 55–67.

Jorge EG, Tanomaru-filho M, Gonçalves M, Tanomaru JMG (2008) Detection of periapical lesion development by conventional radiography or computed tomography. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **10**, 56–61.

Kamburoglu K, Barenboim SF, Kaffe I (2008) Comparison of conventional film with different digital and digitally filtered images in the detection of simulated internal resorption cavities – an ex vivo study in human cadaver jaws. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **105**, 790–7.

Katsumata A, Hirukawa RT, Noujeim M *et al.* (2006) Image artifact in dental cone-beam CT. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **101**, 652–7.

Low KMT, Dula K, Bürgin W, von Arx T (2008) Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. *Journal of Endodontics* **34**, 557–62.

Matherne RP, Angelopoulos C, Kulild JC, Tira D (2008) Use of cone-beam computed tomography to identify root canal systems *in vitro*. *Journal of Endodontics* **34**, 87–9.

Patel S, Dawood A (2007) The use of cone beam computed tomography in the management of external cervical resorption lesions. *International Endodontic Journal* **40**, 730–7.

Patel S (2009) New dimensions in endodontic imaging: Part 2 Cone beam computed tomography. *International Endodontic Journal* **42**, 463–75.

Patel S, Dawood A, Pitt Ford T, Whaites E (2007) The potential applications of cone beam computed tomography in the management of endodontic problems. *International Endodontic Journal* **40**, 818–30.

Patel S, Dawood A, Mannocci F, Wilson R, Pitt Ford T (2009a) Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *International Endodontic Journal* **42**, 507–15.

Patel S, Dawood A, Wilson R, Horner K, Mannocci F (2009b) The detection and management of root resorption lesions using intraoral radiography and cone beam computed tomography – *an in vivo investigation*. *International Endodontic Journal* **42**, 831–8.

Sogur E, Baksi BG, Gröndahl H-G (2007) Imaging of root canal fillings: a comparison of subjective image quality between limited conebeam CT, storage phosphor and film radiography. *International Endodontic Journal* **40**, 179–85.

Tsuchida R, Araki K, Okano T (2007) Evaluation of a limited cone-beam volumetric imaging system: comparison with film radiography in detecting incipient proximal caries. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **104**, 412–6.

Tsurumachi T, Honda K (2007) A new cone beam computerized tomography system for use in endodontic surgery. *International Endodontic Journal* **40**, 224–32.

Young GR (2007) Contemporary management of lateral root perforation diagnosed with the aid of dental computed tomography. *Australian Endodontic Journal* **33**, 112–8.

