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Periapical bone defects of root filled teeth with persistent lesions evaluated by cone-beam computed tomography

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Abstract

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Aim To evaluate and categorize the bone defects of root filled teeth with persistent periapical lesions by cone-beam computed tomography (CBCT).

Methodology Slice images of 532 teeth with persistent periapical lesions were obtained by CBCT in 427 patients and were examined by two endodontists. The periapical lesions were categorized into five types according to the characteristics of the bone defect based on CBCT images. The prevalence of each type was determined and analysed statistically at a 5% significance level using logistic regression.

Results Of the 532 teeth analysed, 67% had buccal or labial bone plate defects (type II), 4% palatal or lingual bone plate defects (type III), 7% 'through and through' defects (type IV) and 10% apical root protrusions from the bone plate (type V). Mandibular teeth had a significantly greater prevalence of type I lesions ($P = 0.0005$) and a significantly lower prevalence for types IV ($P = 0.041$), V ($P = 0.001$), V-1 ($P = 0.015$) and V-2 ($P < 0.001$) as compared to maxillary teeth.

Conclusion CBCT accurately identified the type of periapical bone defect in persistent lesions. Because 10% of the teeth had apical root protrusions, which could not be identified by periapical radiography, the diagnostic information obtained by CBCT was an essential component of the treatment planning process.

Keywords: apical fenestration, apical protrusion, cone-beam computerized tomography, periapical bone defect.

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Introduction

High-quality diagnostic images are essential for the management of endodontic diseases. For example, multiple roots or root canals are often superimposed in conventional periapical radiographs making correct interpretation difficult, although they can be separated by taking radiographs from different angles. In periapical radiography, an optimal irradiation angle is not easy to obtain, especially in the maxillary molar region. Excessive vertical angles of the X-ray beam superimpose the maxillary zygomatic process and the zygomatic bone onto the roots, producing a geometrically distorted image (Patel 2009). Another limitation of these techniques is the lack of information in the buccal-lingual plane (Patel *et al.* 2009).

Cone-beam computerized tomography (CBCT) (Arai *et al.* 1999), developed in the late 1990s, has been added to dental radiology as a viable diagnostic option. CBCT should provide an effective and safe way of producing three-dimensional information of individual teeth and adjacent structures and may in time change the way in which the outcome of endodontic treatment is assessed (Patel *et al.* 2007). The device works more effectively in endodontic treatment than in the other

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dental fields (Simon *et al.* 2006, Cotton *et al.* 2007, Patel & Dawood 2007, Tsurumachi & Honda 2007). Advantages of CBCT include low cost and low radiation dose (Ludlow & Ivanovic 2008) compared with conventional computed tomography (CT) (Hashimoto *et al.* 2007), although conventional CT may give important information for re-treatment decisions when considering root fillings in maxillary molars (Huumonen *et al.* 2006).

Lesions in the cortical bone can only be detected radiographically when there is perforation of the bone cortex, erosion from the inner surface of the bone cortex, or extensive erosion or defects on the outer surface. It is known that periapical lesions in cancellous bone cannot be detected radiographically (Bender & Seltzer 2003). Moreover, according to a recent study (Paula-Silva *et al.* 2009a,b), periapical radiography is limited for recognizing an absence of periapical periodontitis. CBCT, however, can reveal bone defects of the cancellous bone and cortical bone separately. The prevalence of apical periodontitis was found to be significantly higher when using CBCT, in comparison with periapical and panoramic radiographs (Estrela *et al.* 2008a,b). Moreover, the information obtained by CBCT evaluation of periapical repair following root canal treatment was comparable to histological analysis, whereas conventional radiographs underestimated the size of the periapical lesion (Paula-Silva *et al.* 2009a,b). Low *et al.* (2008) showed that 34% of the lesions detected with CBCT were missed with periapical radiography in maxillary premolars and molars. Estrela *et al.* (2008a,b) concluded that the detection of apical periodontitis was considerably higher with CBCT than with periapical radiography. Thus, CBCT was found to be an accurate diagnostic method to identify apical periodontitis.

Apical fenestrations, the protrusion of the apical end of the root through the cortical plate following root canal treatment, although infrequent, may cause pain. The solution suggested by Boucher *et al.* (2000) is surgical intervention. However, the detection of apical fenestrations through the buccal or labial cortical plate cannot be achieved with conventional radiography because the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image (Patel *et al.* 2009). CBCT scanning can provide essential diagnostic information for the management of this complex endodontic problem.

The purpose of this study was to evaluate and to categorize the bone defects of root filled teeth with persistent periapical lesions through images obtained by CBCT.

Materials and methods

Amongst all Japanese patients referred to the Clinic of Operative Dentistry and Endodontics at the Dental Hospital of Tokyo Medical and Dental University, Tokyo, Japan, between December 2003 and December 2008, 532 teeth of 427 patients were diagnosed as having persistent periapical lesions. Diagnoses were based on the presence of a sinus tract, spontaneous pain and/or pain to percussion or palpation test. All the teeth were cases of secondary infection where the referring dentist either failed to localize the affected tooth or to eradicate the pain.

Periapical radiographs of the affected teeth were taken to confirm the presence of the periapical lesion or of previous endodontic treatment. The necessity for CBCT imaging with 3DX multi-Image Micro CT® (3DX, Morita, Kyoto, Japan) or Fine Cube® (Yoshida, Tokyo, Japan) was determined by the clinician treating the patient. Approval from the Tokyo Medical and Dental University Ethical Committee for each system was obtained before commencing the study, and written consent was obtained from each patient.

The radiation field of the 3DX was 30 mm in height and 40 mm in width at the centre of rotation. Imaging time was 17 s at 60–80 kV and 1–10 mA. Reconstructed slices were made with different directions and thicknesses (0.125–2 mm). The radiation field of the Fine Cube was 75.1 mm in height and 82 mm in width at the centre of rotation. Imaging time was 19 s at 90 kV and 4 mA. The reconstructed slices were 0.14-mm thick.

Teeth with periodontal bone defects that had progressed to periapical bone defects were excluded. CBCT images of 532 teeth with persistent periapical lesions were obtained. Horizontal and bucco/labio-lingual/palatal slice images of the teeth, including the root apex, were used to evaluate the periapical lesions. In teeth with multiple roots, the most critical root was evaluated. In each tooth, the periapical lesion according to the characteristics of the bone defect was categorized as follows:

Type I: The defect was limited to cancellous bone with intact buccal/labial and lingual/palatal bone plates. Though a lesion had invaded the inner surface of the bone plate, the outer surface of the bone plate was not destroyed in this type of bone defect (Fig. 1).

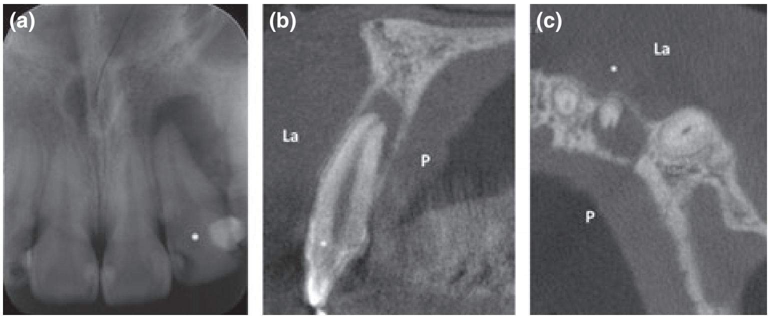

Figure 1 Type I: A cancellous bone defect was observed around the apex of the maxillary left lateral incisor (*). (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (Fine Cube). (c) Horizontal slice image of the CBCT (Fine Cube). La: labial side. P: palatal side.

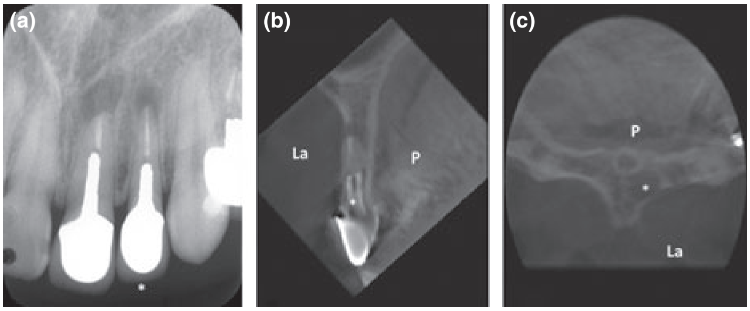

Figure 2 Type II: A periapical bone defect was observed on the labial side of the bone around the apex of the maxillary left lateral incisor (*). (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. P: palatal side.

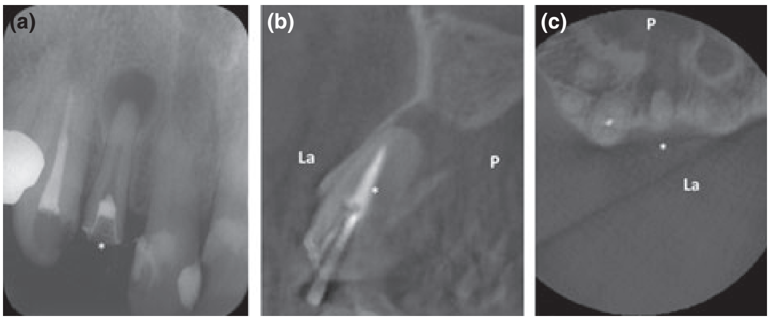

Figure 3 Type III: A periapical bone defect was observed on the palatal side of the bone around the apex of the maxillary right lateral incisor (*). (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. P: palatal side.

Type II: A bone plate defect was observed on the buccal or labial aspect, whilst the bone plate on the opposite side remained intact on the horizontal and labio/bucco-palatal/lingual slice CBCT images (Fig. 2).

Type III: A bone plate defect was observed on the lingual or palatal aspect, whilst the bone plate on the opposite side remained intact on the horizontal and labio/bucco-palatal/lingual slice CBCT image (Fig. 3).

Type IV: The 'through and through' bone defect. The bone defect showed penetration from the buccal or labial aspect to the lingual or palatal aspect (Fig. 4).

Type V: This type showed apical root protrusion from the buccal or labial bone surface and was accompanied with the type II bone defect. The apical foramen was positioned outside of the space limited by the line connecting the apical to coronal edge and/or the mesial to distal edge of the bone defect. Type V was classified into three sub-categories.

Type V-1: Only the apical foramen protruded (Fig. 5).

Type V-2: The apical one-third of the root together with the apical foramen protruded (Fig. 6).

Type V-3: The whole root, including the apical foramen, protruded (Fig. 7).

Two endodontists examined each image independently, followed by a consensus reading. In cases of disagreement, the observers reached consensus through discussion. The prevalence of each periapical lesion type was determined and analysed statistically using logistic regression analysis at a 5% significance level.

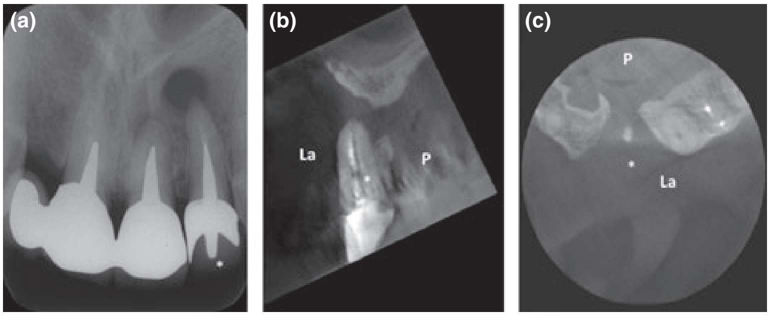

Figure 4 Type IV: A 'through and through' bone defect was observed around the apex of the maxillary left lateral incisor (*). (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. P: palatal side.

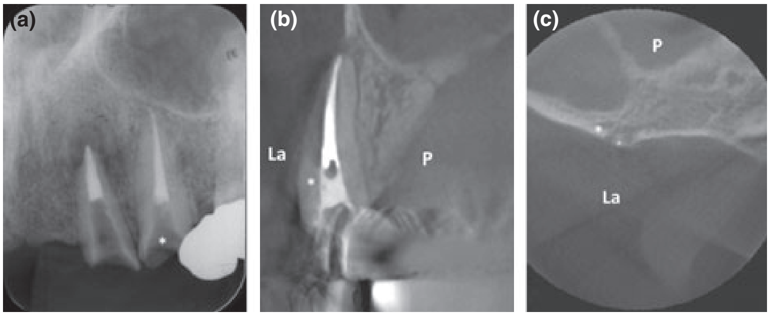

Figure 5 Type V-1: The apical root and apical foramen of the maxillary left canine (*) were extruded from the labial bone plate. (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. P: palatal side.

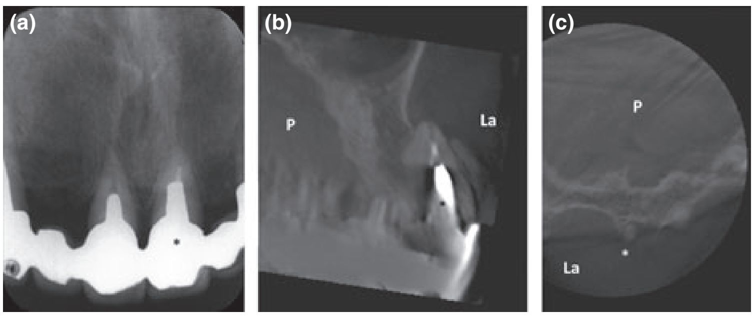

Figure 6 Type V-2: The apical one-third of the root and apical foramen of the maxillary left central incisor (*) were extruded from the labial bone plate. (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. P: palatal side.

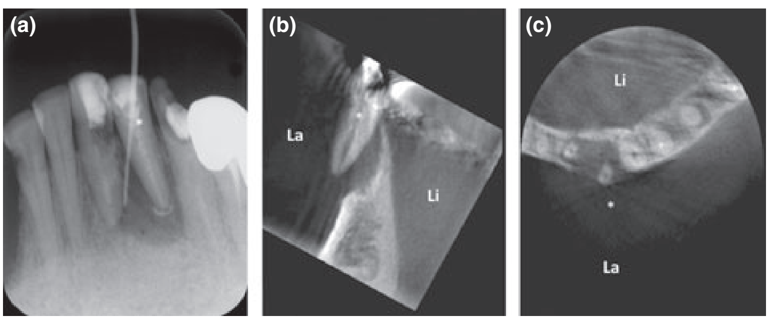

Figure 7 Type V-3: The whole root of the mandibular left lateral incisor (*) was extruded from the labial bone plate. (a) Periapical radiograph. (b) Labio-palatal slice image of the CBCT (3DX). (c) Horizontal slice image of the CBCT (3DX). La: labial side. Li: lingual side.

Results

Table 1 shows the prevalence of each periapical lesion type. Of the 532 teeth analysed, 67% had buccal or labial bone plate defects (type II), 4% palatal or lingual bone plate defects (type III), 7% 'through and through' defects (type IV) and 10% apical root protrusion from the bone plate (type V). Protrusion of the apical

Table 1 Prevalence of periapical lesion types

Periapical lesion types		N = 532
Type I	Cancellous bone defect	22
Type II	Buccal/labial bone defect	67
Type III	Palatal/lingual bone defect	4
Type IV	Through & through bone defect	7
Type V	Apical root protrusion through bone plate	10
Type V-1	Protrusion of apical foramen	4
Type V-2	Protrusion of apical one third of the root	5
Type V-3	Protrusion of whole root	1

Values are in percentages.

foramen (type V-1) or the apical one-third of the root (type V-2) were found in 4% and 5%, respectively.

Tables 2 and 3 show the prevalence of each periapical lesion type in maxillary and mandibular teeth, respectively. Mandibular teeth had a significantly greater prevalence of type I ($P = 0.005$) and a lower prevalence of types IV ($P = 0.041$), V ($P = 0.001$), V-1 ($P = 0.015$) and V-2 ($P < 0.001$) than maxillary teeth. There were no statistically significant differences for types II ($P = 0.077$), III ($P = 0.541$) and V-3 ($P = 0.393$) between maxillary and mandibular teeth.

Discussion

The quality and quantity of radiographic information is essential to endodontic therapy because it affects the diagnosis, treatment planning and outcome (Nakata *et al.* 2006). The image quality of CBCT has been reported to be subjectively inferior to conventional film images for the evaluation of homogeneity and the length of root fillings in single-rooted teeth (Soğur *et al.* 2007). Although the accuracy of detecting alveolar bone loss was significantly better with CBCT than with conventional periapical radiographs, the accuracy in the anterior aspect of the jaws was limited, because the quality of CBCT slice images was insufficient to reliably resolve the thin alveolar crest (Mol & Balasundaram 2008). However, Mischkowski *et al.* (2007) indicated that CBCT provides satisfactory information about linear distances and volumes. In addition, CBCT can identify periapical lesions not detected with periapical radiographs (Lofthag-Hansen *et al.* 2007). The voxel

Table 2 Prevalence of periapical lesion conditions on maxillary teeth

Tooth type	Incisor			Premolar		Molar		
	Central	Lateral	Canine	First	Second	First	Second	Total
No. of teeth	101	98	49	62	40	52	18	410
Type I	15	19	12	16	25	31	50	20
Type II	79	58	82	74	63	62	13	69
Type III	1	6	2	0	5	6	25	4
Type IV	5	16	4	10	8	2	13	8
Type V	14	2	39	11	3	10	0	12
Type V-1	3	1	16	6	3	8	0	5
Type V-2	11	1	20	3	0	0	0	6
Type V-3	0	0	2	2	0	2	0	1

Values are in percentages.

Table 3 Prevalence of periapical lesion conditions on mandibular teeth

Tooth type	Incisor			Premolar		Molar		
	Central	Lateral	Canine	First	Second	First	Second	Total
No. of teeth	17	16	6	20	15	38	10	122
Type I	6	13	67	40	47	32	50	32
Type II	76	81	33	60	53	66	0	60
Type III	18	6	0	0	0	3	40	5
Type IV	12	6	0	0	0	0	10	3
Type V	0	6	0	10	0	0	0	2
Type V-1	0	0	0	5	0	0	0	1
Type V-2	0	0	0	0	0	0	0	0
Type V-3	0	6	0	5	0	0	0	2

Values are in percentages.

size of approximately 0.125–2 mm in both systems used in this study suggests that CBCT could be useful and sufficient for periapical imaging.

In the present study, CBCT scanning could accurately distinguish periapical lesions, which could not be easily diagnosed with conventional periapical radiographs. Indeed, the horizontal and labio/buccal-palatal/lingual slice images of the tooth and the surrounding structures were useful to determine the cortical bone plate affected by the lesion. The condition of the periapical lesions was categorized into five types (types I–V) and three sub-types for type V (types V-1 to V-3), according to the periapical bone defect. Logistic regression analysis revealed a significant difference between the maxillary and mandibular teeth ($P < 0.05$). The anatomy of the teeth and the adjacent structure might explain, in part, this difference.

The apical portions of mandibular premolars and molars are surrounded by thick cortical bone. This may explain why a higher prevalence of type I lesions was observed in mandibular teeth than in maxillary teeth. However, type II bone defects were the most common, with no significant difference between maxillary and mandibular teeth. A bone defect is likely to fenestrate on the buccal or labial bone plate, because most of the root apices are positioned on the buccal or labial aspect.

Palatal or lingual bone defects (type III) were observed in only 4% of the teeth with persistent endodontic lesions. The most commonly affected teeth were the maxillary second molar (25%) and the mandibular central incisor (18%) and second molar (40%). The prevalence of the ‘through and through’ bone defect (type IV) was 7% and was more common in maxillary teeth than in mandibular teeth. The most commonly affected teeth with a prevalence of 10% or more were the maxillary lateral incisor (16%), first premolar (10%) and second molar (13%) and the mandibular central incisor (12%) and second molar (10%).

An apical fenestration is a circumscribed defect characterized by the perforation of the bone plate by the roots of the teeth (Boucher *et al.* 2000, Jhaveri *et al.* 2010) (Figs 5–7). In many of the type V cases examined, no radiolucency was detected around the apical region of the affected teeth when observed with conventional periapical radiographs (Figs 5a and 6b). This limitation was overcome by CBCT (Figs 5b, 5c, 6b and 6c). According to the present study, the prevalence of apical root protrusion from the bone plate (type V) was significantly higher in maxillary teeth (12%) than in mandibular teeth (2%). The prevalence of type V was also different between each tooth type. The maxillary canine showed the highest prevalence (39%) of apical root protrusion from the bone plate. The root apex of the maxillary canine is located close to the thin buccal bone surface of the canine fossa of the maxilla. The thin buccal bone over the eminence often disintegrates; thus, fenestration is an occasional finding (Vertucci *et al.* 2006).

The treatment plan for persistent discomfort in type V teeth should be decided based on the extent of apical root protrusion. In cases where the protrusion is relatively small (types V-1 and 2), it has been proposed that the apical root-end should be exposed surgically and the portion of the root extending through the fenestration be ‘trimmed back’ to within the surrounding bone tissue (Ingle *et al.* 2002). For type V-3 cases, however, with the whole root protruded, tooth extraction may be indicated. Although few teeth with apical root protrusion were observed in the mandible, most of them were classified as type V-3, 6% of which were second incisor and 5% first premolar.

There is the possibility that the periapical lesions evaluated were in different stages of the disease, and some were more evolved and therefore larger than others. Nevertheless, the large sample size characterized the condition of periapical lesions in each type of tooth. Additionally, this study only identified periapical lesions without differentiating granulomas from cysts. This differentiation was previously reported to be possible (Simon *et al.* 2006, Trope *et al.* 1989). However, a recent study concluded that CBCT imaging is not a reliable diagnostic method for differentiating radicular cysts from granulomas (Rosenberg *et al.* 2010). The present study was carried out using samples from a Japanese population, but unfortunately, other data like gender and age of patients could not be collected. Further studies are necessary for different races, because of anatomical variations.

Lack of distortion, magnification and the relative low radiation dose will result in more clinicians adopting CBCT to enable accurate diagnosis and treatment planning, in addition to long-term follow-up and evaluation of healing (Nair & Nair 2007, Patel 2009). The treatment plan may vary according to the extent of bone defect or apical root protrusion. The horizontal and bucco/labio-lingual/palatal slice images of a tooth, including the root apex, by CBCT could clarify the bone defects in persistent periapical lesions of endodontically treated teeth. The conventional dental radiograph does not provide such information. The diagnostic information obtained by CBCT constitutes an excellent resource for endodontic therapy, including cases of persistent infections.

Conclusions

Persistent periapical lesions in root filled teeth was classified into five groups according to the characteristics of the bone defects. The horizontal and bucco/labio-lingual/palatal slice images obtained by CBCT were indispensable for gathering the data necessary for this study. The results indicate that CBCT could accurately identify the type of periapical bone defect in persistent lesions. Because 10% of the teeth presented apical protrusion, which could not be identified by periapical radiography, the diagnostic information obtained by CBCT was an essential component for developing an adequate treatment plan.

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