Method to Evaluate Inflammatory Root Resorption by Using Cone Beam Computed Tomography

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Abstract

Introduction: The aim of this study was to evaluate a method to measure inflammatory root resorption (IRR) by using cone beam computed tomography (CBCT) scans. **Methods:** IRR sites were classified according to root third and root surface, and IRR extension was measured on the axial, transverse, and tangent views of 3-dimensional CBCT scans by using the Planimp software. A 5-point (0–4) scoring system was used to measure the largest extension of root resorption. A total of 48 periapical radiographs and CBCT scans originally taken from 40 patients were evaluated. The kappa coefficient was used to assess interobserver agreement and the χ^2 test to determine significant differences between the imaging methods. The level of significance was set at α = 1%. **Results:** IRR was detected in 68.8% (83 root surfaces) of the radiographs and 100% (154 root surfaces) of the CBCT scans (P < .001). The extension of IRR was >1–4 mm in 95.8% of the CBCT images and in 52.1% of the images obtained by using the conventional method (P < .001). **Conclusions:** CBCT seems to be useful in the evaluation of IRR, and its diagnostic performance was better than that of periapical radiography. *(J Endod 2009;35:1491–1497)*

Key Words

Apical periodontitis, cone beam computed tomography, diagnostic imaging, root resorption, traumatic dental injury

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Root resorption (RR) is either a physiologic or pathologic condition associated with tooth structure loss caused by clastic cells. Permanent RR is invariably a local pathologic condition caused by orthodontic treatment, traumatic dental injury, apical periodontitis, intracoronal bleaching, autotransplantation, dentigerous cyst, neoplasia, or idiopathic factors (1–7). The external or internal superficial protective cell layer might be damaged, and inflammatory or replacement RR might affect any part of the root (6).

Several aspects of inflammatory root resorption (IRR), such as prevalence, etiologic factors, and classification based on dental surface, progression, extension, and pathologic mechanisms, have been extensively discussed (1–13). However, IRR is an asymptomatic lesion that is difficult to diagnose and treat (1–4). The criterion standard for the diagnosis of IRR is microscopic analysis (14), and IRR might be classified as active, arrested, or repaired according to microscopic findings. The prevalence of each stage affects prognosis and treatment (1).

Conventional radiographic images are frequently used to detect and follow up IRR (1–8). However, apical shortening, lateral or cervical root gaps, enlargement of root canal, and external root radiolucencies are not detectable on radiographs at their early stages, when they are small, or because of limitations of this 2-dimensional method. An alternative diagnostic tool for the early detection of external apical RR in 36 orthodontic cases simulated under 3 test conditions (bracketed, non-bracketed, and with subtraction registration templates) was recently discussed (12). The use of the subtraction registration templates was significantly more accurate than the use of the brackets alone for digital subtraction radiographic reconstructions. This is a promising model for the detection of external IRR before a decrease in root length is noticeable and for the early detection of resorptive lesions during routine orthodontic treatment (9).

However, new diagnostic methods and more powerful research tools have brought about a technological revolution (15–25). Mol et al (13) tested a tuned-aperture computed tomography (TACT) application and assessed the validity of the crown-root ratio method for the *in vitro* detection and measurement of small oblique apical root resorptive (ARR) lesions and found that they were not useful for RR detection. Imaging techniques with greater angular differences between baseline images reduce cross-talk effects and are likely to improve performance. The diagnosis of simulated external RR defects was tested in 131 cavities by using single-slice CT scans, and results showed higher sensitivity and excellent specificity to detect simulated resorption in small cavities in the apical third of extracted human incisors (26).

High-resolution 3-dimensional images have improved dental diagnoses (15–27). Several studies have investigated the possibility of accurately detecting dental lesions on tooth surfaces and the periapical area by using cone beam computed tomography (CBCT) (15–23, 26, 28–32). Some studies reported on the accuracy and diagnostic performance of CBCT scans to detect IRR in comparison with conventional radiographs (26, 28–32). Because few *in vivo* studies have been conducted in this area, the purpose of this study was to evaluate a method to measure IRR by using CBCT scans.

Materials and Methods

Method to Evaluate IRR by Using CBCT

The method to evaluate IRR by using CBCT is the same that was described in a previous study (20) of periapical indices and CBCT scans. Our study criteria

TABLE 1. Site and Extension of IRR According to CBCT Scores

Thirds/surfaces	Mesial (1)	Distal (2)	Buccal (3)	Palatal (4)	Root apex (5)	Score, extension of RR
Apical (1)	1	2	3	4	5	0, intact structure; 1, >0.5–1 mm; 2, >1–3 mm; 3, >3–4 mm; 4, >4 mm
Middle (2)	1	2	3	4	5	0, intact structure; 1, >0.5–1 mm; 2, >1–3 mm; 3, >3–4 mm; 4, >4 mm
Cervical (3)	1	2	3	4	5	0, intact structure; 1, >0.5–1 mm; 2, >1–3 mm; 3, >3–4 mm; 4, >4 mm

RR might affect more than one third or one root surface. However, for each RR diagnosed, each measurement should be evaluated according to the largest RR extension. RR depth and direction are essential details in imaging tests, and axial, transverse, and tangent planes might provide better information. For teeth with more than 1 root, each root should be evaluated separately. IRR extension might be the same, but the number of thirds or surfaces might be different in oblique RR, apical RR, or apical and oblique RR.

CBCT, cone beam computed tomography; IRR, inflammatory root resorption; RR, root resorption.

were established according to the analysis of IRR sites: root thirds—apical, middle, and cervical; root surfaces—mesial, distal, buccal, palatal, or lingual and root apex; and IRR extension (Table 1). IRR was outlined and measured with the Planimp software (CDT Computing, Cuiabá, MT, Brazil) and 3 dimensions of CBCT scans: axial, transverse, and tangent (Fig. 1). The greatest extension of RR was measured, and a 5-point (0–4) scoring system was used for analysis (Table 1 and Figs. 2–5).

Patients

Forty-eight periapical radiographs and CBCT scans from 40 patients (28 men; mean age, 25 ± 7 years) obtained between August 2008 and April 2009 were selected from the database of the Radiological Center of Orofacial Images (CROIF, Cuiabá, MT, Brazil). All patients had 1 or more teeth with a history of traumatic dental injury or orthodontic treatment. The teeth were mandibular molars (n = 6), maxillary molars (n = 2), maxillary premolars (n = 2), mandibular premolars (n = 2), mandibular canines (n = 2), maxillary canines (n = 4), mandibular incisors (n = 6), and maxillary incisors (n = 24).

Imaging Methods and Evaluation

The periapical radiographs were taken with a Spectro 70X electronic x-ray unit (Dabi Atlante, Ribeirão Preto, SP, Brazil) by using

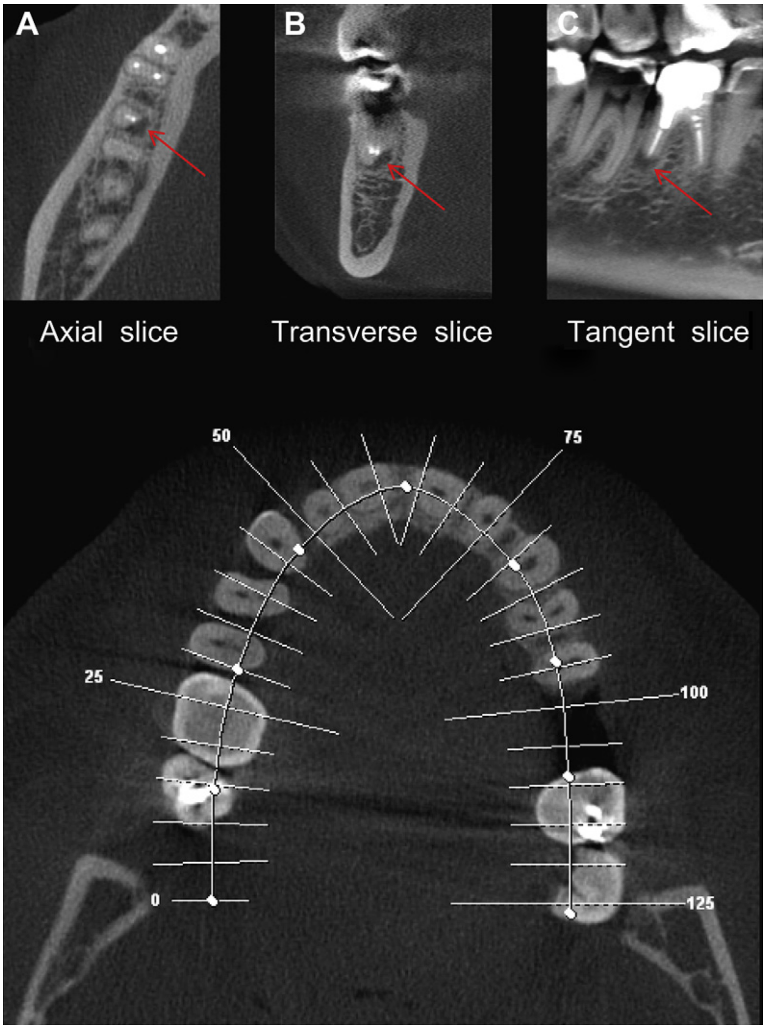

Figure 1. Axial (*A*), transverse (*B*), and tangent (*C*) views of mandibular molar. The largest extension of the lesion was used for the IRR-CBCT method.

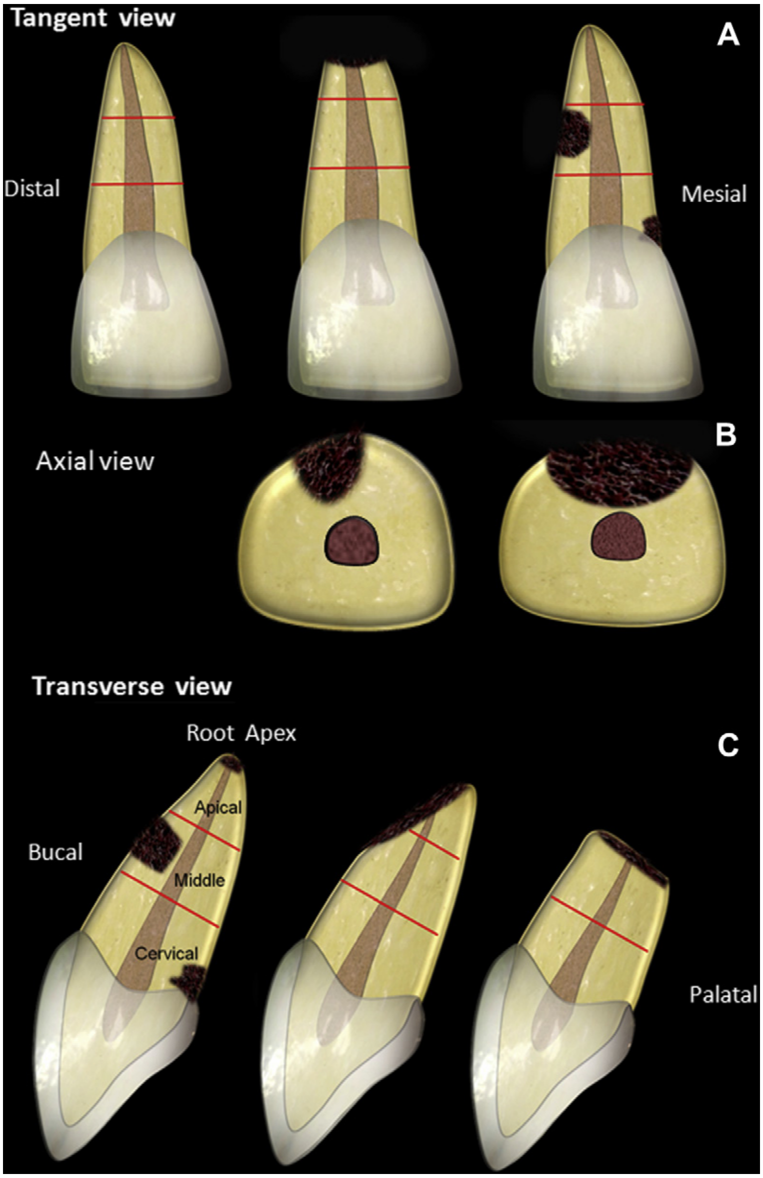

Figure 2. Schematic representation of IRR-CBCT method of maxillary incisor showing the tangent (*A*), axial (*B*), and transverse (*C*) views and the different surfaces with IRR.

a 0.8 mm × 0.8 mm tube focal spot, Kodak Insight film-E (Eastman Kodak Co, Rochester, NY) and a parallel radiography technique. All films were processed in an automatic processor and developed by using standardized methods. CBCT images were obtained with an I-CAT Cone Beam 3D imaging system (Imaging Sciences International, Hatfield, PA), 0.20 mm × 0.20 mm × 0.20 mm voxel size, 14 bits. Images were examined by using the software (Xoran version 3.1.62; Xoran Technologies, Ann Arbor, MI) in a PC workstation running Microsoft Windows XP professional SP-2 (Microsoft Corp, Redmond, WA).

Three calibrated blinded examiners evaluated all digital images by using the criteria described in Table 1. The kappa coefficient was used to assess interobserver agreement. Data were analyzed statistically with the χ^2 test to determine significant differences between the imaging methods to detect IRR. The level of significance was set at α = 1%.

Results

Table 2 shows the prevalence of IRR according to the imaging diagnostic methods and comparisons between root thirds, root surfaces, and extension. IRR was detected in 68.8% (83 root surfaces) of the radiographs and 100% (154 root surfaces) of the CBCT scans (P < .001). IRR extension was >1–4 mm in 95.8% of CBCT images and in 52.1% of the conventional images (P < .001). The kappa coefficient for interobserver agreement was 0.87. Figs. 2–5 show schematic drawing of the clinical cases evaluated with the IRR-CBCT method.

Discussion

This study evaluated an imaging method to determine the actual extension of RR and the number of affected surfaces, which cannot be detected by using conventional radiographs. Axial, transverse, and tangent slices, root third, number of root surfaces, and actual IRR extension were carefully analyzed. IRR can be classified as stage 0 (absence of IRR) or as other stages according to IRR extension, as described in Table 1. IRR was detected in 68.8% (83 root surfaces) of the radiographs and 100% (154 root surfaces) of CBCT scans (P < .001). The extension of IRR was >1–4 mm in 95.8% of the CBCT images

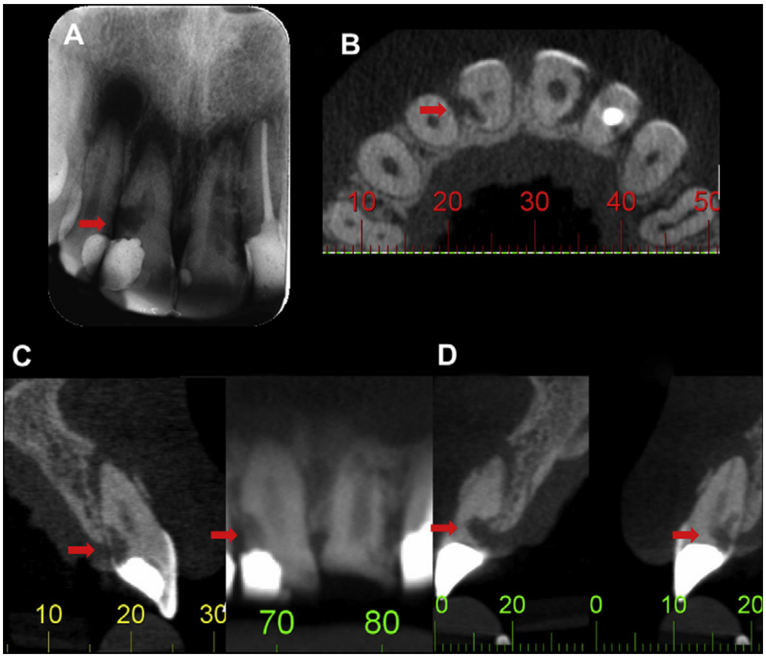

Figure 3. Clinical case of IRR of maxillary central incisor identified by radiography (*A*) and CBCT in axial (*B*), transverse (*C*), and tangent (*D*) views.

and in 52.1% of conventional radiographs ($P < .001$) (Table 2). IRR extension and surfaces were determined more accurately and at earlier stages by using CBCT scans than radiographic images in some cases, particularly because of the 3-dimensional views. Therefore, IRR might be underestimated when evaluated with only periapical radiographs (Table 2), (Figs. 1, 3–5).

Our results are in agreement with previous studies that found that CT detected RR better (26, 28, 29, 31). Kim et al (28) analyzed a case of multiple extracanal invasive resorptions by using CT and a rapid prototyping tooth model. The use of CT was very helpful in diagnosing the exact size and location of resorption. In the serial cross-sectional views, the size and the location of resorption were clearly determined. The

Figure 4. Clinical case of IRR of maxillary lateral incisor identified by radiography (*A*) and CBCT in axial (*B*), transverse (*C*), and tangent (*D*) views.

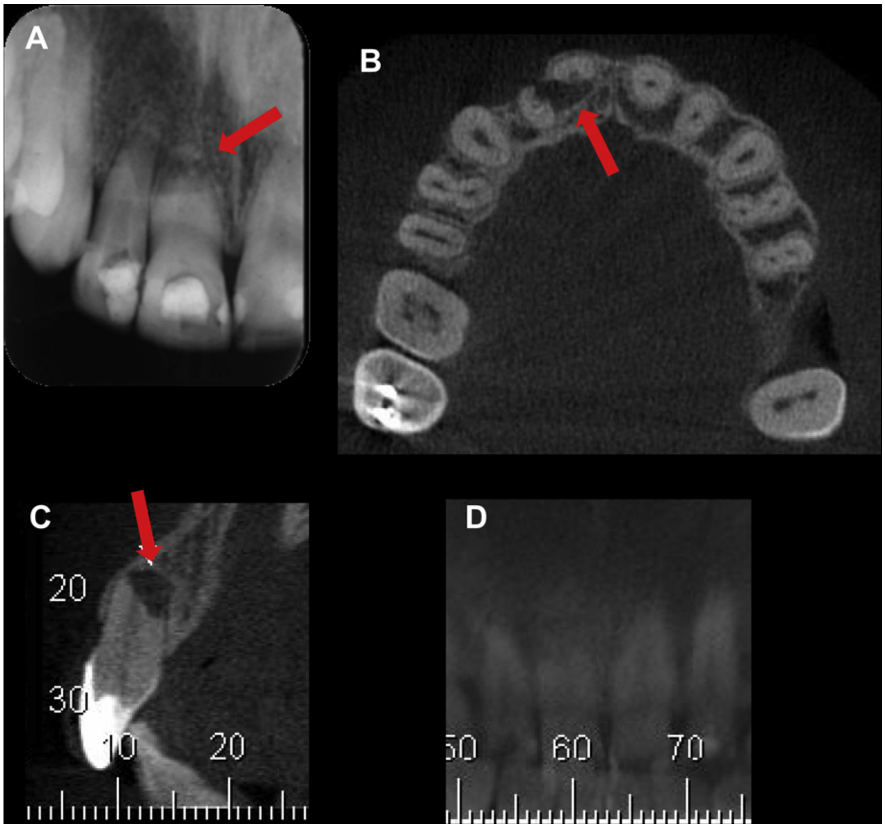

Figure 5. Clinical case of IRR of maxillary central incisor identified by radiography (*A*) and CBCT in axial (*B*), transverse (*C*), and tangent (*D*) views.

3-dimensional reconstruction and the fabrication of a rapid prototyping tooth model provided a more accurate image of the resorption area. In simulated external RR, Silveira et al (26) evaluated the diagnostic performance of a CT scan table (Single-Slice, Somaton Emotion Duo; Siemens, Erlangen, Germany). External RR defects of different sizes and in different locations were simulated in 59 human mandibular incisors. Cavities simulating RR defects of 0.6, 1.2, or 1.8 mm in diameter and 0.3, 0.6, or 0.9 mm in depth (small, medium, and large defects) were drilled in the cervical, middle, and apical thirds of buccal surfaces. Axial CT was used to obtain cross-sectional images of the teeth, and 177 root thirds were assessed by a blinded observer. CT showed good diagnostic performance, high sensitivity, and excellent specificity in the detection of simulated external resorptions. The greatest difficulty was found in the detection of small resorptions located in the apical third of tooth roots. CBCT scans were effective to identify the presence, type, and severity of RR (29, 31). Patel et al (31) reported that a diagnostic test for RR should be able to suitably identify the presence or absence of different types of RR (validity) and should be repeatable to generate the same results. The authors verified that CBCT showed superior diagnostic accuracy in a better possibility of correct management of RR.

TABLE 2. Prevalence of IRR Detected Using Periapical Radiographs and CBCT Scans Based on Criteria Established According to Measurements of Root Resorption (root third, number of surfaces, and IRR extension from - >0.5-1 mm to >4 mm)

Thirds/Surfaces/ Extension	Periapical radiograph	CBCT	*P* *Value**
Root third			
No IRR	15 (31.3%)	0 (0.0%)	
Apical	25 (52.1%)	34 (70.8%)	.005
Middle	6 (12.5%)	12 (25.0%)	
Cervical	2 (4.2%)	2 (4.2%)	
Surfaces			
Apical (n=240) (*surfaces M,D,B,P,RA*)	59 (24.58%)	103 (42.91%)	
Middle (n=192) (*surfaces M,D,B,P*)	19 (9.89%)	45 (23.45%)	<.001
Cervical (n=192) (*surfaces M,D,B,P*)	5 (2.60%)	6 (3.12%)	
Extension			
0- Intact structure	15 (31.3%)	0 (0.0%)	
1- > 0.5-1 mm	8 (16.7%)	2 (4.2%)	
2- > 1-3 mm	8 (16.7%)	18 (37.5%)	<.001
3- > 3-4 mm	10 (20.8%)	18 (37.5%)	
4- > 4 mm	7 (14.6%)	10 (20.8%)	

M, middle; D, distal; B, buccal; P, palatal; RA, root apex.
*Chi-square test,

The voxel resolution chosen for our study (0.02 mm) should provide high-resolution images to evaluate IRR in all root thirds and root surfaces. A recent *in vitro* study (30) assessed the diagnostic performance of CBCT scans at different voxel resolutions to detect simulated external RR. I-CAT was used to examine 59 teeth according to 3 protocols with different voxel resolutions (0.4, 0.3, and 0.2 mm). The results of the diagnostic performance tests revealed similar values for sensitivity and specificity between the teeth examined with different voxel resolutions. The likelihood ratio showed that the 0.3-mm and 0.2-mm voxel resolutions were better than the 0.4-mm voxel resolution (16, 12, and 6.4, respectively), which confirmed the greater probability of correctly detecting cavities when the image is acquired by using the first 2 voxel resolution parameters.

The CBCT method to detect IRR described in the present study has advantages that affect decisions made by clinicians. Early detection can lead to timely intervention and better treatment outcomes. RR extension is determined by analyzing all lesion dimensions because CBCT slices are obtained in axial, transverse, and tangent slices. RR measurement, as part of a longitudinal follow-up, can determine whether the lesion is in a stage of arrest, repair, or progression. These analyses might change diagnostic hypotheses and treatment plans and might affect the prognosis of certain clinical conditions. The prognosis of IRR is affected by pulp vitality as well as by RR site, extension, and number of affected surfaces. CBCT has several advantages over other methods when used in situations in which clinical follow-up is essential, such as the healing of luxated permanent teeth, progressive cervical resorption, resorption caused by impacted teeth, or severe resorption of incisors after orthodontic treatment.

The probability of false-negative results is one of the limitations of methods that use conventional radiography to diagnose IRR. Some of the benefits of using CBCT in the diagnosis of endodontic diseases are its high accuracy in detecting root lesions at the earliest stages, the support that it provides to establishing a differential diagnosis, and the fact that it is a noninvasive technique (15–20, 25, 28–31).

An RR index extensively used to determine the degree of apical RR during orthodontic treatment was described by Levander and Malmgren (9). This index evaluated the levels of loss of apical root structure and scored it from 1–4: (1) irregular outline of apical surface, (2) up to 2 mm reduction of root length, (3) root reduction of 2 mm to one third of the root, and (4) root length reduction larger than one third of the root. The root form, classified as normal, short, blunt, apically bent, or pipette-shaped, can affect the degree of RR. The method described in our study evaluated IRR presence, root third, number of surfaces, and extension and not the loss of apical root structure. RR might be found in more than one third or one root surface. However, for each RR site detected, one measurement should be made according to the greatest extension of each RR. RR depth and direction are essential details in imaging tests; axial, transverse, and tangent slices provide this information more accurately. For teeth with more than 1 root, each root should be evaluated separately. IRR extension might be the same, but the number of thirds or surfaces might be different in oblique RR, apical RR, or apical and oblique RR. Therefore, IRR site and extension might affect the diagnosis (3, 4, 26, 32). Advanced prognosis and early detection of IRR might favor the treatment plan and, consequently, the chances of success. Thus, CBCT scans should be indicated in patients with a history of traumatic dental injury or orthodontic treatment to detect IRR.

This study did not evaluate replacement resorptions. CBCT images detect replacement resorptions, but they do not provide clear measurements of its extension because of the similarity between dentin and bone.

Another aspect to be considered is radiation dose. CBCT dose varies substantially depending on the device, field of view, and selected technique factors (33). The image quality also might vary according to CBCT source, and a radiation dose equivalent to that needed for 4–15 panoramic radiographs (21), and less than doses for conventional CT (23, 33, 34).

This study showed that CBCT scans were better at detecting IRR than periapical radiographs when root third, root surface, and extension were determined. This method provided an accurate diagnosis with high-resolution images and little observer interference.

Acknowledgments

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