Dental Traumatology

Dental Traumatology 2012; **28**: 268–272; doi: 10.1111/j.1600-9657.2011.01113.x

Comparative study of cone beam computed tomography and intraoral periapical radiographs in diagnosis of lingual-simulated external root resorptions

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Key words: external root resorption, cone beam computed tomography, intraoral periapical radiography

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Accepted 5 September, 2011

Abstract – *Background*: Owing to a lack of symptoms and difficult visualization in routine intraoral radiographs, diagnosis of external root resorptions can be challenging. *Aim*: The goal of this study was to compare two image acquisition methods, intraoral radiographs and cone beam computed tomography (CBCT), in the diagnosis of external resorption. *Material and Methods*: Thirty-four maxillary and mandibular bicuspids were divided into three groups. Perforations measuring 0.3 and 0.6 mm in diameter and 0.15 and 0.3 mm in depth, respectively, were made on the lingual root surfaces in thirty teeth, and four were used as controls. Next, teeth were mounted on an apparatus and radiographed at mesial, distal, and orthoradial angulations. CBCT images were also taken. The analysis of the intraoral radiographic and tomographic images was carried out by two experts using standardized scores. Data were then compared statistically. *Results*: A strong agreement between the examiners was observed in both diagnosis methods, the intraoral radiographic ($r = 0.93$) and the tomographic analysis ($r = 1.0$). Tomography had higher statistically significant detection values than intraoral radiography ($P < 0.05$). In intraoral radiographs, the detection was significantly greater ($P < 0.05$) in the mandibular bicuspids, compared with their maxillary counterparts. The ability to detect 0.6-mm perforations by intraoral radiography was significantly higher than that of 0.3-mm perforations ($P < 0.05$). *Conclusion*: Cone beam computed tomography showed better diagnostic ability compared with intraoral radiography, regardless of the tooth or the dimensions of the resorption evaluated.

The etiology of external root resorptions is extremely complex, and their classification depends on the location and the stimulus that lead to their formation. Resorptions observed in permanent teeth generally result from trauma and chronic pulpal and/or periodontal inflammation. Moreover, the development of these lesions can be induced by pressure on the periodontal ligament caused by orthodontic movement, tumors, or dental eruption (1).

All root resorptions can be divided into four types: inflammatory (external or internal), non-inflammatory, invasive cervical, and replacement resorptions. The development of these lesions involves a complex interaction between inflammatory and resorption cells, hard tissues, cytokines, and enzymes such as collagenases, metalloproteinases, and cysteine proteases (2).

The prognosis of root resorptions is more favorable when the detection occurs in the early stages of their development. In some cases, treatment consists solely in the removal of the stimulus and endodontic therapy. However, in the initial phases, resorptions are generally asymptomatic and cannot be detected by routine radiographs.

The difficulties in early detection of external root resorptions depend on the location, and the dimensions of the lesions, small areas of resorption (0.3 mm in diameter and 0.15 mm in depth), are more difficult to diagnose (3). Additionally, lesions occurring on buccal or lingual surfaces are more difficult to see than those on proximal surfaces, owing to radiographic superimposition of anatomic structures (4–6).

The introduction of spiral computed tomography brought significant improvement to diagnostic imaging. Three-dimensional images provide greater detail of the tooth as well as of adjacent tissues. Spiral computed tomography, which was used often earlier, presented limitations for use in Dentistry, such as high radiation and cost, presence of image artifacts, and inability to detect the lesions in the initial stages of development (7).

Cone beam computed tomography (CBCT) represents a better alternative owing to its lower cost and reduced incidence of image artifacts (3, 6). In CBCT, the image is acquired in a single step and volumetric data are logarithmically converted into X, Y, and Z planes, allowing the capture of clearer images in the axial, sagittal, and coronal planes. For these reasons, CBCT is recommended for visualization of root canal morphology and for (8), diagnosis of fractures (9), lesions (10), and resorptions (3, 11).

To achieve earlier diagnosis with greater precision, it is important to evaluate the ability of different techniques in detecting the external root resorptions with different dimensions.

The objective of this study was to compare the ability of two imaging techniques in diagnosing external root resorption lesions: conventional radiographs taken using Clark's technique (horizontal tube shift) and 3-D imaging by CBCT.

Materials and methods

Thirty-four maxillary and mandibular bicuspids were randomly divided into two groups of 15 teeth, as follows:

Group 1 – 10 maxillary bicuspids (teeth numbered from 1 to 10) and five mandibular bicuspids (11–15);
Group 2 – 10 mandibular bicuspids (16–25) and five maxillary bicuspids (26–30).
Group 3 – Control, two maxillary bicuspids (31–32) and two mandibular bicuspids (33–34).

To simulate external root resorption lesions, 30 teeth received perforations on the lingual surfaces at the cervical, middle, and apical thirds of the root. These perforations, made using diamond burs(Kg Sp Sorensen, São Paulo, Brasil), measured 0.3 mm in diameter and 0.15 mm in depth (Group 1) and 0.6 mm in diameter and 0.30 mm in depth (Group 2). Four teeth without perforations were used as controls. The teeth were then randomly divided into groups of three specimens and placed into 10 acrylic boxes containing manipulated impression material. After setting of the material, the blocks, each containing three teeth, were removed from the acrylic boxes and numbered.

After that, the 10 blocks were radiographed using Clark's horizontal tube shift method, in which the radiographs are taken in different horizontal angulations (mesial, distal, and orthoradial), with a horizontal angular deviation of 30° in the mesial and distal projection compared with the orthoradial projection. Thirty radiographs were taken using periapical films (Eastman Kodak Company, Rochester, NY, USA) and an X-ray machine set at 58 kV and 10 mA (Max F1; J. Morita® Mfg. Corp., Fushimi-ku, Kyoto, Japan). Radiographic positioners (Indusbello; Ind de Equip. Odont. Ltda., Londrina, PR, Brazil) were used to hold the films, and the radiographs were taken using the long cone paralleling technique. Exposed films were developed in an automated processor (Automatic Processor Level 3D; J. Morita® Mfg. Corp.) for 4 min and 30-s. After that, the radiographs were photographed using a Nikon Coolpix camera (Nikon Corp., Chiyoda-ku, Tokyo, Japan) and saved as JPEG files in a CD-ROM (Fig. 1).

For CBCT evaluation, all the blocks were imaged, one at a time, using Accuitomo FPD (J. Morita® Mfg. Corp.) tomograph set at 74–80 kV and 5–6 mA with two 1-s takes: one lateral and one frontal, followed by one rotational 17-s take for each group of three teeth. Reconstruction of the images was carried out in 2 min using the software Idixel (J. Morita® Mfg. Corp.). A cylinder shape measuring 32 mm in height and 38 mm in diameter was formed; after rotation, the cylinder was converted into a rectangular image with the same dimensions (32×38 mm) (Fig. 2). The smallest unit of a volumetric image is a voxel (a cube with sides measuring 0.125 mm). After tomography, the images, measuring 329×329 mm, were saved on a CD-ROM. Each image allowed millimeter-by-millimeter section views numbered from 0 to 20 in the following three planes: x (sagittal), y (coronal), and z (axial). They were manipulated using the One Data Viewer software (J. Morita® Mfg. Corp.).

The evaluation of the images and the diagnosis were performed by two calibrated examiners specialized in Endodontics, who recorded whether the simulated root resorptions were visible or not and attributed the scores to each image ranging from 0 to 2, defined as follows:
0 – undetected;
1 – detected, but the image is not sharp;
2 – clearly detected, with a sharp image.

Agreement between the examiners was evaluated using Kendall test. Comparisons between the intraoral radiographic and tomographic images and between the different perforation dimensions were carried out using chi-square and Wilcoxon tests. The comparison between the teeth (mandibular or maxillary) was performed using Fisher's exact test. The significance level was set at 5% for all tests.

Results

Table 1 presents the percentage of detection by the two examiners, for each method.

High rates of agreement were observed between the examiners, both in the intraoral radiographic (Kendall coefficient = 0.93) and in the tomographic image analyses (Kendall coefficient = 1.0).

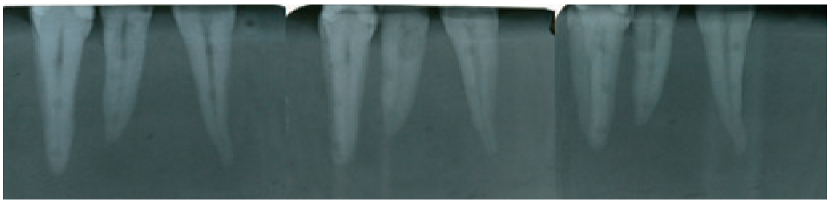

Fig. 1. Intraoral radiographies (mesial, distal, and orthoradial projections).

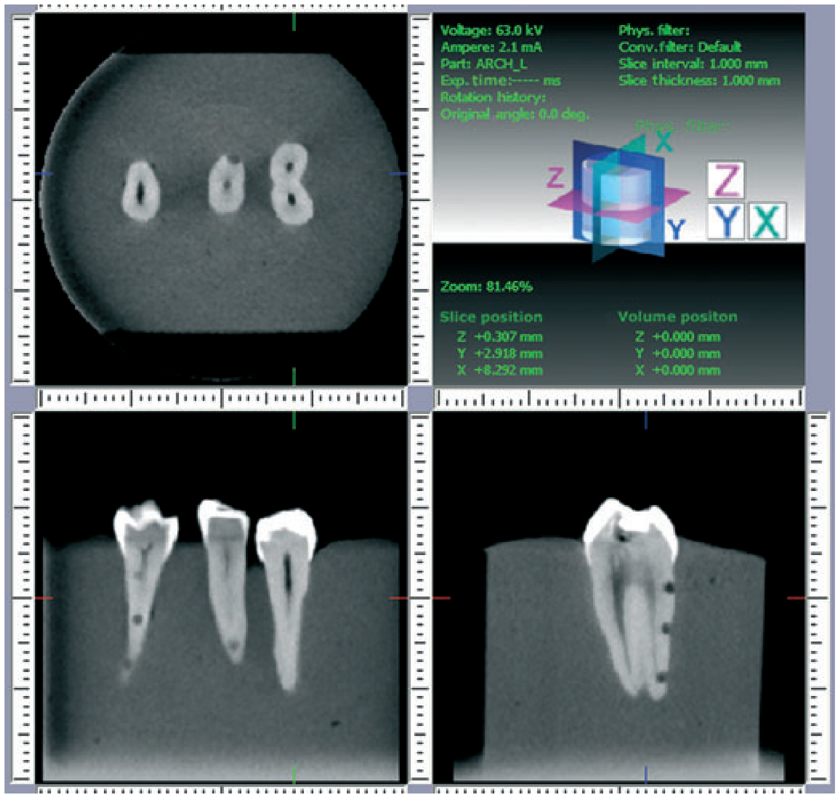

Fig. 2. Slices obtained by cone beam computed tomography.

Table 1. Percentage of detection of simulated root resorptions by each examiner, for each diagnostic method

	Examiner 1 (%)		Examiner 2 (%)	
	Intraoral radiographs	CBCT	Intraoral radiographs	CBCT
Not detected (0)	41.1	0	40	0
Detected without sharpness (1)	51.1	0	50	0
Detected with sharpness (2)	7.8	100	10	100

Comparison between the two methods showed a statistically significant difference ($P < 0.05$) between intraoral radiography and computed tomography. CBCT showed higher percentages of perforation detection.

Table 2 shows the percentage of perforations detected, according to tooth category (mandibular or maxillary).

A statistically significant difference ($P < 0.05$) was observed in the radiographic detection of perforations in maxillary and mandibular bicuspids. On the other hand, in tomography, the detection in maxillary or mandibular teeth did not significantly differ ($P > 0.05$).

Table 3 presents the percentage of detection of simulated root resorptions for each method and for the two perforation dimensions.

The intraoral radiographic analysis showed significantly higher percentages of detection ($P < 0.05$) of 0.6-mm perforations, compared with those with 0.3-mm diameter. In the tomographic analysis, the results were statistically similar ($P > 0.05$) for the two perforation diameters.

Table 2. Percentage of detection by the two methods in each tooth category (mandibular or maxillary)

	Maxillary bicuspid (%)		Mandibular bicuspid (%)	
	Intraoral radiographs	CBCT	Intraoral radiographs	CBCT
Not detected (0)	50	0	31	0
Detected without sharpness (1)	43	0	57	0
Detected with sharpness (2)	7	100	12	100

Table 3. Percentage of detection of simulated lesion by each method, for the two perforation diameters

	0.3-mm perforations (%)		0.6-mm perforations (%)	
	Intraoral radiographs	CBCT	Intraoral radiographs	CBCT
Not detected (0)	48	0	31	0
Detected without sharpness (1)	38	0	62	0
Detected with sharpness (2)	14	100	7	100

Discussion

The prognosis of external root resorptions is more favorable when these lesions are detected in their early stages of development (1, 4–7). However, one of the greatest clinical challenges is to establish such early diagnosis, as at these stages, the lesions are asymptomatic and difficult to detect during routine radiographic examinations (12–14).

Being a simple, quick, and inexpensive diagnostic method, intraoral radiography is generally the first choice in most clinical situations. However, this method presents limitations, such as showing a two-dimensional image of a three-dimensional object, superimposition of anatomical structures, and magnification of images (15, 16).

When using intraoroal radiographs, shifting the horizontal angle of the X-ray beam (Clark's method) increases the chances of diagnosing such resorptions. Digital radiographs are currently preferred by several clinicians because of their greater sensitivity in detecting the lesions using lower radiation doses (13, 17).

The use of computed tomography in dentistry arose from the search for better alternatives to intraoral radiography in terms of diagnostic ability (7, 18). Nevertheless, conventional computed tomography required higher doses of radiation than intraoral radiographs, and the images contained a great amount of metal artifacts that negatively affected their diagnostic accuracy (7, 18, 19).

With the introduction of CBCT, these limitations were overcome: This method has a low incidence of metal artifacts, requires lower radiation levels and, consequently, represents a better diagnostic tool (10, 12, 18, 20, 21). CBCT has proven its efficiency in diagnosing external root resorptions (3) by precisely determining the location and the dimensions of resorptions, allowing the establishment of adequate therapeutic measures and, therefore, resulting in a more favorable prognosis (22).

In the present study, maxillary and mandibular bicuspids were selected, and 30 teeth received perforations on the lingual surface of their roots measuring 0.3 or 0.6 mm in diameter and 0.15 or 0.3 mm in depth, representing small or medium lesions, respectively. The use of silicone to simulate *in vivo* conditions was used previously (23) to detect two canals at lower incisors and was intended to mimic and, to some degree, scatter arising from soft tissues *in vivo*.

The pre-established standardized scores used by two experts in Endodontics were similar to those employed in a previous study of root fracture detection (9). These scores were necessary to compare the two techniques (9–13, 17). The simulated resorptions, when evaluated by intraoral radiographs, were detected without sharpness by the examiners 1 and 2 in 41.11% and 40% of the images, respectively, while sharp images were identified in only 7.8% and 10% of the specimens, respectively.

The limitations of intraoral radiography in the diagnosis of resorptions are more evident when these lesions are in their early developmental stages and located in certain anatomic areas (2, 3).

Several authors (13, 14, 17) have reported that the diagnosis of resorptions is based on clinical and radiographic evaluations and that conventional radiography produces false-negative results in 51.9% of the cases and false positive in 15.3%. Furthermore, these authors report that areas of resorption smaller than 0.6 mm in diameter and 0.3 mm in depth usually remain undetected by conventional X-rays. This kind of simulated external inflammatory resorption was hemispheric according to Durak et al. (3). They clearly does not reflect the clinical reality, in which root resorption lesions are irregular in shape, but this is a pre-established methodology to simulate external resorption *in vitro*. (3). Future studies involving the use of standardized simulated resorption lesions of irregular shape are necessary.

In the current research, the resolution (in voxels) used for the tomography was guided by previous tests that determined the settings which yielded better sensitivity and specificity in the diagnosis (21, 22, 24, 25).

The application of Clark's horizontal cone shift localization method (9, 17) favoured the diagnostic ability of root resorptions with a score of 2 (perforation detected without sharpness) in 23.33% for examiner 1, and in 8.99% for examiner 2. On the other hand, tomography allowed the observation of the simulated lesions in 100% of the cases by both observers, demonstrating the superiority of CBCT over conventional periapical radiographs as a diagnostic tool (2, 3, 12, 21).

One of the major problems with diagnosing and predictably managing internal and external cervical root resorptions is that intraoral radiographs only reveal limited diagnostic information (2). The present study demonstrated that CBCT has better diagnostic ability than conventional radiographs in the detection of root resorptions, corroborating other studies (6, 12, 18).

The success of endodontic therapy is directly related to a precise diagnosis. In daily clinical practice, X-rays are a valuable resource owing to their low cost, simple execution, and fast image acquisition. However, this method presents several limitations, such as the representation of a three-dimensional object as a two-dimensional image, as well as the superimposition of anatomical structures. Specifically regarding dental resorptions, their size, and location pose additional difficulties in the diagnosis. Smaller lesions, as well as those located on the buccal or lingual surfaces, are likely to remain undetected by conventional radiography.

Cone beam computed tomography represents a breakthrough in the field of diagnostic imaging. The capture of 3-D images allows precise detection of surface defects, with details of location and extension. Our your study corroborates previous studies demonstrating that CBCT is an excellent resource for diagnosis of dental resorptions, showing superior results when compared with conventional periapical radiographs taken using Clark's localization method.

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