Diagnosis of Mesiodistal Vertical Root Fractures in Teeth with Metal Posts: Influence of Applying Filters in Cone-beam Computed Tomography Images at Different Resolutions

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Abstract

Introduction: The aim of this article was to evaluate the influence of applying filters in cone-beam computed tomography (CBCT) images at different resolutions. These CBCT images were obtained for diagnosing mesiodistal vertical root fractures (VRFs) in teeth with metal posts. **Methods:** Forty teeth were treated endodontically, and 20 received metal posts. Ten teeth without posts and 10 teeth with posts were subjected to VRF in the mesiodistal direction. The sample was submitted to periapical radiographs and CBCT exams with a voxel of 0.25 and 0.30 mm. To reduce the influence of the metal artifact in the CT images, the teeth were evaluated with and without the application of filters ("Sharpen" and "Hard"). The images were evaluated by 2 radiologists who identified the presence of VRF. Accuracy values (receiver operating characteristic curves) for the different variables were compared by using analysis of variance and *t* test. **Results:** No difference was observed between images with and without filter application ($P > .05$). Images obtained with a 0.25-mm voxel were more accurate ($P < .05$). The presence of the metal post reduced the accuracy of the diagnosis of VRF ($P < .05$), and the CBCT images showed superior results compared with periapical radiographs ($P < .05$). **Conclusions:** The presence of a metal post and the voxel size significantly interfere with the diagnosis of VRF. Despite the formation of metal artifacts associated with metallic cores, applying filters did not improve the diagnosis. For mesiodistal VRF, the CBCT images are superior to the periapical radiographs. *(J Endod 2017;■:1–5)*

Key Words

Artifact, cone-beam computed tomography, diagnosis, digital radiography, enhancement filters, vertical root fracture

Significance

The presence of a metal post and the voxel size interfere with the diagnosis of vertical root fractures. Enhancement filters did not improve the diagnosis. For mesiodistal fractures, the CBCT images are superior to the periapical radiographs.

Studies investigating the indications of dental extractions report that 7.7%–32.1% of extractions are due to root fractures (1, 2). The fractures that afflict dental roots can occur in different locations with a variety of orientations. When the root fracture is vertical and characterized by an incomplete or complete fracture line extending along the axis of the root's length, it becomes difficult to detect the root fracture by conventional radiographic exams, especially when it occurs in the mesiodistal direction (3–7). This difficulty can be compounded in the early stages when the fracture is in the form of a thin crack, with its fragments still appearing to be together and without an associated bone loss.

In such cases, a cone-beam computed tomography (CBCT) exam is indicated, which allows three-dimensional visualization of the structures without superimposed images. Various studies have demonstrated the superior accuracy of CBCT for diagnosing root fractures in teeth without intracanal filling material (8, 9). However, in cases where the roots are filled with high-density materials such as posts and cast metal cores, artifacts can appear in the tomography images, making the exam difficult to interpret (10).

Some studies have been undertaken to minimize these effects in the diagnosis of root fractures by applying digital image enhancement filters and metal artifacts reduction algorithms; however, such studies are few and have quite divergent results (11, 12). Furthermore, some variables in the tomographic image acquisition protocol may also influence image quality such as voxel size, which is correlated with image resolution (5) and can interfere in the diagnosis of root fractures (4, 13, 14).

This variation in the results of various studies may be associated with methodological variations such as the direction of the fracture lines, the tomographic equipment used, and the protocol for image acquisition. Thus, because of the divergence of the findings in the literature and the importance of a correct diagnosis of root fracture for the prognosis of a tooth, the objective in this study was to evaluate the application of digital filters in CBCT images at different resolutions; these CBCT images were obtained for diagnosing mesiodistal vertical root fractures (VRFs) associated with teeth with endodontic treatment and intracanal metal posts.

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Materials and Methods

Sample Preparation

After approval of this study by the Research Ethics Committee of the Federal University of Juiz de Fora (Juiz de Fora, Minas Gerais, Brazil; Opinion No. 996.011/2015), 40 single-rooted human teeth (incisors and canines) were selected from the tooth bank of the School of Dentistry, University of Juiz de Fora. Teeth with fractured roots, decay, or wear/resorption were excluded.

The crowns of the teeth were sectioned at the cementoenamel junction. Root canals were prepared endodontically and filled by using gutta-percha points (Dentsply Maillefer, Ballaigues, Switzerland) and Sealer 26 endodontic cement (Dentsply Maillefer). After endodontic treatment, 20 teeth were randomly selected to receive prefabricated metal posts (Reforpost I Metálico; Angelus, Londrina, Paraná, Brazil) and cemented with zinc phosphate cement (SS White, Rio de Janeiro, RJ, Brazil).

Twenty teeth (10 with metal posts and 10 without metal posts) were randomly selected and subjected to VRF in the mesiodistal direction by applying mechanical force to the tooth with a chisel and hammer. The remaining 20 teeth were not subjected to a fracture. The teeth were randomly assembled on a dry human mandible for imaging exam acquisition.

Periapical Radiographs

All teeth were submitted to digital periapical radiographs, with 3 incidences obtained (orthoradial, mesioradial, and distoradial). To produce the radiographs, the Gendex Expert DC (Gendex, Des Plaines, IL) periapical x-ray apparatus was used with the following parameters: 7 mA, 65 kVp, and 0.5 second. The focus-sensor distance was set at 40 cm, and the variation of the horizontal angle was 15° and defined with the aid of a protractor. The Micro Imagem direct digital radiography system (Micro Imagem, Indaiatuba, SP, Brazil) was used.

CBCT

The same sample was submitted to CBCT exams by using the I-Cat Next Generation scanner (Imaging Sciences International, Hatfield, PA) with a 6 × 23 cm field of view, 5 mA, and 120 kVp. Two different resolutions were used, 0.25 mm voxel and 0.30 mm voxel.

For each of the CBCT scans obtained, 3 images available in i-CAT Vision software (Imaging Sciences International) were used: an image without a filter application ("Normal"), an image with a sharpness filter ("Sharpen"), and an image with an intensifying filter ("Hard").

Imaging Exams Evaluation

Two examiners (dental radiology specialists) evaluated the images (periapical and tomographic images) independently. The images were classified according to the occurrence of root fracture by using 5 scores: 1, fracture definitely present; 2, fracture probably present; 3, uncertain; 4, fracture probably absent; and 5, fracture definitely absent.

Three weeks after the first assessment, a second assessment was performed on 20% of the sample to determine intraexaminer agreement.

Data Analysis

To determine accuracy, the areas under the receiver operator characteristic (ROC) curves were calculated for each of the exams (periapical, tomography with different filters and resolutions). To compare the values of the areas under the ROC curve, analysis of variance (ANOVA) was performed for the comparison between filters, and *t* test was performed for comparisons between examiners, resolutions, and presence/absence of a post. The kappa coefficient was used to calculate intraexaminer and interexaminer agreement; for this, the 5 scores used in the evaluation were reclassified into 3 new scores. Scores of 1 and 2 were reclassified as a score of 1, and scores of 4 and 5 were reclassified as a score of 2. A score of 3 was retained, indicating cases of uncertainty. SPSS software version 15.0 (SPSS Inc, Chicago, IL) was used, and the level of significance was 5% ($P < .05$).

Results

The intraexaminer and interexaminer reliability exhibited moderate average agreement (kappa values ranging from 0.49 to 0.60). The distribution of examiner responses among the 5 scores is presented in Table 1. For the teeth without metal posts, the scores related to the "certainties" (scores 1 and 5) were the most frequent. For the teeth with metal posts, the most prominent was a score of 3 (uncertainty).

Table 2 presents the accuracy values for each radiographic technique for teeth with and without a metal post. Comparing the areas obtained for "Normal" images with those for the "Sharpen" and the "Hard" filters, no significant differences (ANOVA, $P > .05$) were obtained. When the areas (Az) obtained for the 0.25-mm and 0.30-mm voxel images were compared, the accuracy of the images obtained with the smaller voxel (0.25 mm) was significantly higher (paired *t* test, $P < .05$), regardless of the presence of the metal post. Comparing the Az values between teeth with and without metal posts, the accuracy of the images without posts was significantly increased (*t* test, $P < .05$).

TABLE 1. Mean Frequency (%) of Examiner Responses for Each Radiographic Technique with and without the Presence of Metal Posts

	CBCT						
	Voxel 0.25 mm			Voxel 0.30 mm			
Score	Normal	Sharpen	Hard	Normal	Sharpen	Hard	Periapical
Without metal posts							
1	27.50	35.00	32.50	5.00	15.00	17.50	5.00
2	7.50	10.00	12.50	12.50	12.50	15.00	17.50
3	2.50	0.00	5.00	17.50	22.50	22.50	12.50
4	22.50	20.00	10.00	37.50	30.00	27.50	37.50
5	40.00	35.00	40.00	27.50	20.00	17.50	27.50
With metal posts							
1	25.00	27.50	27.50	5.00	10.00	15.00	2.50
2	12.50	17.50	10.00	7.50	7.50	7.50	15.00
3	40.00	42.50	50.00	52.50	57.50	72.50	30.00
4	17.50	10.00	7.50	30.00	25.00	5.00	37.50
5	5.00	2.50	5.00	5.00	0.00	0.00	15.00