Detection of Incomplete Root Fractures in Endodontically Treated Teeth Using Different High-resolution Cone-beam Computed Tomographic Imaging Protocols

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Abstract

Introduction: The purpose of this study was to compare different high-resolution cone-beam computed tomographic (CBCT) imaging protocols in the diagnosis of incomplete root fractures of endodontically treated teeth. **Methods:** Twenty single-rooted human teeth were endodontically treated, and an incomplete root fracture was induced. The teeth were scanned with the CBCT unit PreXion 3D (Teracom, San Mateo, CA) operating at 2 different protocols: high resolution/standard (HI-STD) (19 seconds and 512 basis images) and high resolution/high density (HI-HI) (37 seconds and 1024 basis images). Three oral radiologists evaluated all images using multiplanar reconstructions. The diagnostic tests and the receiver operating characteristic (ROC) curve were calculated. **Results:** The HI-STD and HI-HI protocols presented an accuracy of 0.90 and 0.93, respectively, and both protocols had a sensitivity of 0.97. The HI-HI protocol showed a higher positive predictive value and slightly higher areas under the ROC curve. **Conclusions:** Both high-resolution imaging protocols presented high accuracy in the detection of incomplete root fracture of endodontically teeth. Thus, the HI-STD protocol should be indicated this reduces the radiation dose. *(J Endod 2017;■:1–5)*

Key Words

Artifacts, cone-beam computed tomography, diagnosis, endodontics, tooth fractures

Significance

To our knowledge, no previous studies have investigated the influence of basis images in the detection of incomplete root fracture using gutta-percha and sealer as intracanal filling material on a high-resolution CBCT unit.

The correct diagnosis of root fractures is essential because treatment failure can cause pain, stress, and, mainly, damage to the tooth (1). Furthermore, these fractures generally have a poor prognosis, and, in many cases, tooth extraction is the only treatment option (2, 3). Therefore, a precise clinical examination and a detailed radiographic analysis are relevant (4).

Periapical radiography is the most common method used for the diagnosis of root fractures (5) and is adequate for evaluating the crown, root, and surrounding structures (6). Despite the wide use, this imaging method has important limitations for producing 2-dimensional images of 3-dimensional structures and partially compromising the interpretation of teeth and adjacent tissues (7).

Currently, cone-beam computed tomographic (CBCT) imaging has shown better accuracy in the evaluation of teeth and the surrounding structures and in the detection of root fractures when compared with periapical radiographs (2, 8–10). This results from the volumetric nature of CBCT imaging, which allows the fracture line to be viewed at multiple angles and different orientations in a fine-slice reconstruction. Despite this advantage, high-density materials, such as gutta-percha and metal post, can be a source of image artifact and significantly degrade image quality, which could mask or mimic fracture lines and result in an incorrect diagnosis (11, 12). Clinical examination and the use of appropriate radiographic techniques are of fundamental importance when prescribing CBCT imaging. Considering the wide range of CBCT protocols for different diagnostic tasks, it is necessary to identify protocols that are not significantly affected by endodontic material–related artifacts and contribute to the diagnosis of root fractures.

Manufacturers of CBCT imaging typically indicate high-resolution protocols when root fracture is suspected. However, the concept of having "as high as possible" spatial resolution (sometimes referred to as the "endo mode") should consider that it might come at the expense of the radioprotection of the patient. Bearing in mind the ionizing

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radiation–related risks to the patient during any radiographic examinations, a comparative analysis of the high-resolution CBCT protocols is relevant. In this scenario, the most important risk is radiation-induced cancer (13), and the selection of a protocol should also consider the ALADA principle (As Low As Diagnostically Acceptable) (14) because it establishes an adequate balance between the patient's needs and X-ray exposure. Thus, the aim of this study was to compare different high-resolution CBCT imaging protocols in the diagnosis of incomplete root fractures of endodontically treated teeth.

Material and Methods

The present study was designed according to the local institutional research ethics committee and carried out after its approval (CAAE protocol 24437314.2.0000.5207). Twenty single-rooted human teeth were clinically and radiographically evaluated to confirm that none of them had an open apex, dilaceration, supernumerary root, pulp calcifications, or internal and/or external root resorption. The current methodology made use of single-rooted teeth in an endeavor to avoid great anatomic discrepancy between teeth and to have a more standardized sample.

The dental crowns were sectioned to eliminate the bias of coronary fractures at a later stage, and the root canals were submitted to chemomechanical procedures using ProTaper universal manual files (Dentsply Maillefer, Ballaigues, Switzerland) and 2.5% sodium hypochlorite as the main irrigant. The working length was established at 1 mm short of the apex. After the completion of instrumentation, the canals were filled with gutta-percha ProTaper and Sealer 26 sealer (Dentsply Maillefer).

Incomplete root fractures were produced in half of the sample, and the other half was used as the control group. To induce the fractures, the roots were temporarily inserted in individual polyvinyl chloride tubes (diameter = 28 mm and height = 28 mm), fixed with cyanoacrylate (Super Bonder; Henkel, Itapevi, Sao Paulo, Brazil), and placed in a universal testing machine (Kratos, Cotia, SP, Brazil). A steel conical tip was positioned at the entrance of the canals with a compression speed of 30 mm/min, which was applied until the fracture occurred and the machine automatically stopped.

To confirm the fractures, the roots were scanned with a swept-source optical coherence tomographic system (Thor Labs, Newton, NJ) with a central wavelength of 1300 nm at a 16-kHz sweep rate. A data set is obtained at optical resolution in air under 12 μm in a 3.0-mm depth and a 10-mm width (Fig. 1*A* and *B*).

Afterward, the roots were individually and randomly placed in the sockets of 2 dry human mandibles. The sockets were carefully enlarged with a cylindrical bur to achieve passive fit with all roots. The mandibles were covered with a 3-mm-thick layer of utility wax (Epoxiglass, Sao Paulo, Brazil) on the lingual and buccal cortical plates to simulate soft tissue (15) and scanned with the CBCT unit PreXion 3D (Teracom, San Mateo, CA) operating at 90 kVp and 4 mA with a voxel size of 0.1 mm, a field of view (FOV) of 51 $\times$ 51 mm, and 2 different protocols (high resolution/standard [HI-STD] [19 seconds, 512 basis images and CT dose index vol 8 mGy] and high resolution/high density [HI-HI] [37 seconds, 1024 basis images and CT dose index vol 15 mGy) as shown in Figure 2*A–D*. The major steps of this methodology are summarized in a flowchart (Fig. 3).

Three oral radiologists with experience in CBCT scanning evaluated all images in a low-light environment with a 21.3-inch flat-screen computer with 1600 $\times$ 1200 pixel resolution (FlexScan S2133-BK; Eizo, Cypress, CA) and the native software PreXion 3D Viewer version 2.1.2. The images were analyzed in the axial, coronal, and sagittal reconstructions with the possibility of adjusting brightness and contrast, zooming, and rotating. The observers analyzed the image of each tooth using a 5-point scale for the presence or absence of fracture, being (1, definitely absent; 2, probably absent; 3, uncertainty; 4, probably present; and 5, definitely present).

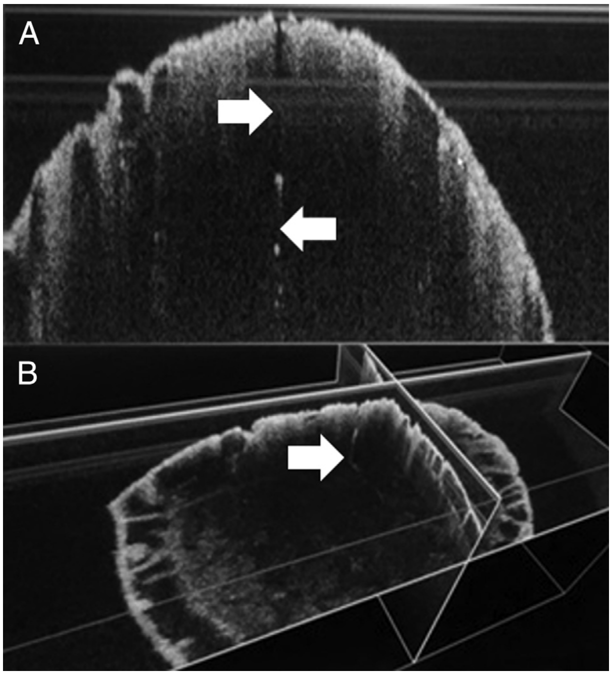

Figure 1. Optical coherence tomographic images indicating the line of fracture (*arrows*) in different views: (*A*) cross sectional and (*B*) axial, coronal, and sagittal.

Statistical analysis was performed using SPSS Statistics 22 (IBM Corporation, Armonk, NY). Weighted kappa assessed the intraobserver and interobserver agreement, considering the following level of agreement: less than 0.40 = poor, 0.40–0.59 = moderate, 0.60–0.74 = good, and 0.75–1.00 = excellent (16). The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were calculated. The receiver operating characteristic (ROC) curve was also calculated to assess the relationship between the sensitivity and specificity of the CBCT protocols in the diagnosis of root fractures. For this, the data were dichotomized, with scores 1 and 2 representing a negative finding (absence of fracture) and scores 4 and 5 representing a positive finding (presence of fracture). Because the observers had not used score 3 (uncertain) as a response, it was discarded.

Results

Table 1 shows the intraobserver and interobserver reproducibility in the detection of incomplete root fractures for different CBCT imaging protocols. The intraobserver reproducibility was excellent in the HI-STD imaging protocol for all observers and ranged from good to excellent in the HI-HI protocol. The interobserver reproducibility ranged from moderate to excellent in the HI-STD protocol and from good to excellent in the HI-HI protocol.

Table 2 summarizes, respectively, the diagnostic values and areas under the ROC curves (Az) in the detection of incomplete root fractures for the 2 CBCT imaging protocols. The HI-STD and HI-HI protocols presented an accuracy of 0.90 and 0.93, respectively, and both protocols had a sensitivity of 0.97. The HI-HI protocol showed a higher positive predictive value and slightly higher areas under the ROC curve.