Detection of Fractured Endodontic Instruments in Root Canals: Comparison between Different Digital Radiography Systems and Cone-beam Computed Tomography

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Abstract

Introduction: This study compared the detection of fractured instruments in root canals with and without filling by periapical radiographs from 3 digital systems and cone-beam computed tomographic (CBCT) images with different resolutions. **Methods:** Thirty-one human molars (80 canals) were used. Root canals were divided into the following groups: the control group, without fillings; the fracture group, without fillings and with fractured files; the fill group, filled; and the fill/fracture group, filled and with fractured files. Digital radiographs in ortho-, mesio-, and distoradial directions were performed in 2 semidirect systems (VistaScan [Dürr Dental, Beitigheim-Bissinger, Germany] and Express [Instrumentarium Imaging, Tuusula, Finland]) and a direct system (SnapShot [Instrumentarium Imaging]). CBCT images were acquired with 0.085-mm and 0.2-mm voxel sizes. All images were assessed and reassessed by 4 observers for the presence or absence of fractured files on a 5-point scale. The sensitivity, specificity, and accuracy were calculated. **Results:** In the absence of filling, accuracy values were high, and there were no statistical differences among the radiographic techniques, different digital systems, or the different CBCT voxels sizes. In the presence of filling, the accuracy of periapical radiographs was significantly higher than CBCT images. In general, SnapShot showed higher accuracy than VistaScan and Express. **Conclusions:** Periapical radiographs in 1 incidence were accurate for the detection of fractured endodontic instruments inside the root canal in the absence or presence of filling, suggesting that this technique should be the first choice as well as the direct digital radiographic system. In the presence of filling, the decision to perform a CBCT examination must take into consideration its low accuracy. *(J Endod 2016;■:1–6)*

Key Words

Cone-beam computed tomography, digital radiography, endodontic complications, fractured endodontic instruments

Significance

The fracture of instruments in the root canal during endodontic treatment is a common accident, so radiographic evaluation is important. We evaluated the identification of fractured endodontic instruments inside the root canals of human molars with and without filling material, comparing digital radiography and CBCT images.

The fracture of instruments inside a root canal is a frequent and undesirable accident during endodontic treatment. This intercurrence leads to a delay in concluding the treatment and may affect the prognosis of the tooth and the patient's dental experience (1–4).

The fracture may take place during all stages of treatment and may involve many types of instruments, such as endodontic files, Gates-Glidden drills, Peeso reamers, Lentulo drills, or ultrasonic tips. These instruments can be made of carbon steel, stainless steel, or alloy nickel-titanium (NiTi) (2, 5–7). Fractures may occur because of a lack of experience of professionals, excessive or improper use of the instruments, the presence of microcracks in new instruments, and curved or calcified canals (1, 3, 6, 8–11). Although most steel stainless instruments seem to fail by excessive amounts of torque, the combined action of torsional stress and cyclic loading (ie, fatigue as a result of rotational bending or repeated torsion in a curved canal) is responsible for breaking of NiTi instruments (12–14).

Fractured instruments inside the root canal should be diagnosed and documented by an appropriate image examination and recorded in the patient's record (1). The professional can opt to leave the instrument inside the canal or try to remove it via the intracanal approach or surgery (1, 15–19). This decision will depend on the tooth/canal

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involved, the position in the canal at which separation occurred, the amount of contaminated material remaining, and the extent of damage that will be caused to the remaining dental structure if instrument removal were attempted (1, 16). The patient should always be informed of instrument fracture when it occurs during endodontic treatment or when noticed during a routine radiographic examination (1) because often the patient can opt for the removal of the tooth involved for reasons such as anxiety, time, and costs (16).

Preoperative radiographs should be examined for the extent and location of the instrument (15). Periapical radiography has some inherent limitations because it produces a 2-dimensional image from a 3-dimensional structure. Thus, the overlapping of anatomic structures can impair the diagnostic ability of this examination (18, 19) even when 2 or more incidences are performed, such as with the Clark technique (20).

Cone-beam computed tomographic (CBCT) imaging can overcome the overlapping of structures, allowing an accurate assessment of dental morphology and the diagnosis of endodontic complications (18, 19, 21) and highlighting the location of fractured instruments (22, 23). Tomographic images allow a 3-dimensional evaluation of the location and morphology of the fractured instrument inside the root canal (15). Despite the advantages of CBCT scanning, this examination can produce artifacts arising from metallic objects or root filling material, which may compromise its assessment, leading to misdiagnosis (24–27).

In general, CBCT imaging has been proven to be better than periapical radiographs in detecting external root resorption, root perforation, and deviated posts (28–30). However, previous studies showed different results upon comparing CBCT imaging and periapical radiography in the diagnosis of fractured instruments (29–31), highlighting the need for further investigation regarding the best image method in such cases, especially in multiradicular teeth.

Therefore, this *in vitro* study aimed to compare the accuracy of CBCT imaging and periapical radiography in the detection of fractured endodontic instruments inside root canals with and without filling, varying the digital receptor and CBCT voxel size.

Materials and Methods

Sample Selection and Preparation

After approval by the institutional ethics committee (protocol 037/2015), 31 extracted multiradicular teeth (first and second lower molars), totaling 80 canals, were selected. They were radiographed and met the following inclusion criteria: completed apexification and the absence of any previous endodontic treatment, root caries, root perforation, root resorption, or visible cracks or fractures. The crowns were removed at the cementoenamel junction using a metallographic cutter (Isomet 1000 Precision Cutter; Buehler, Lake Bluff, IL). The 80 root canals were randomly divided into 4 groups:

1. The control group, nonfilled canals (n = 10)
2. The fracture group, nonfilled canals with fractured files (n = 30)
3. The fill group, filled canals (n = 10)
4. The fill/fracture group, filled canals with fractured files (n = 30)

The distribution of such conditions was random among the canals. The roots were instrumented using a reciprocating system with a single file (R25, 25 mm; VDW, Munich, Germany). Cases in which there was an accidental fracture of the file during instrumentation were excluded from the sample. A 2.5% sodium hypochlorite solution was used as the irrigant, and, in the fill and fill/fracture groups, root filling was performed with a single gutta-percha cone (R25 cone, Reciproc, VDW) and zinc oxide–eugenol–based sealer (Dentsply Maillefer, Ballaigues, Switzerland) using the McSpadden technique.

In the fracture and fill/fracture groups before filling, the files were worn with a diamond burr (3203; KG Sorensen, Cotia, SP, Brazil) 2 mm from the tip of the instrument to create a fracture point. Then, they were inserted into the canal through the apical foramen and twisted to induce the fracture inside the canals (29). The following fractured endodontic instruments were used in the present study: stainless steel hand files (Flexofile #10, Dentsply Maillefer), NiTi reciprocating files (R25), and NiTi rotary files (ProTaper #F1, Dentsply Maillefer).

The roots were uniformly covered with a 0.3-mm layer of utility wax (NewWax; Technew, Rio de Janeiro, RJ, Brazil) to simulate the radiographic aspect of periodontal space. For each image acquisition, roots were individually placed in the alveolus of the left first molar of a dry human mandible.

Image Acquisition

Digital radiographs were acquired with 3 systems: 2 semidirect systems using photostimulable phosphor plates (PSPs), size 2 (VistaScan [Dürr Dental Beitigheim-Bissinger, Germany], 31 $\times$ 41 mm active area and 25 pairs of lines [pl] mm^{-1} and Express [Instrumentarium Imaging, Tuusula, Finland], 31 $\times$ 41 mm active area and 14.3 [pl] mm^{-1}) and 1 direct system using a complementary metal oxide semiconductor (CMOS), size 1 (SnapShot [Instrumentarium Imaging], 19.95 $\times$ 30 mm active area and 26.3 [pl] mm^{-1}). All the digital radiographs were obtained using the Focus periapical x-ray unit (Instrumentarium Imaging) operating at 7 mA, 70 kVp, and 0.06 seconds. The sensor-focus distance was set at 40 cm, and an acrylic device with the paralleling technique was used, with a 2.5-cm thickness block to simulate soft tissues. Each tooth was radiographed 3 times with different horizontal positions of the x-ray tube (ie, orthoradial, mesioradial, and distoradial) at a 15° angle [30].

For CBCT examinations, the OP300 scanner (Instrumentarium Imaging) was used with the following image acquisition protocol: 6 $\times$ 4 cm field of view, 90 kVp, 10 mA, and 2 different spacial resolutions (ie, 0.085-mm voxel size [6.1 seconds and 705 frames] and 0.2-mm voxel size [2.3 seconds and 300 frames]). The mandible was placed into an acrylic box (1-mm thick) filled with water for the attenuation of x-ray beams, simulating soft tissue of the maxillofacial region.

Image Evaluation

Periapical images (Fig. 1) were exported from the acquisition software in Tagged Image File Format, uncompressed, copied, and pasted into PowerPoint (Microsoft Corporation, Redmond, WA) for visualization in the slide show mode with a black background in a random sequence. Zoom, brightness, and contrast tools were available for use. The images were not evaluated in the original acquisition software to prevent identification of the digital system used. Periapical radiographs were evaluated at 2 different times: initially, 1 image (orthoradial incidence) and, at a second stage, a set of 3 images (orthoradial, mesioradial, and distoradial).

CBCT images (Fig. 2) were exported in the Digital Imaging and Communications in Medicine format for analysis in On Demand3D software (CyberMed, Seoul, Republic of Korea). They were evaluated dynamically through all reconstructions. Zoom, brightness, and contrast tools were available to be used. All evaluations were performed on an LCD monitor, with a resolution of 1920 $\times$ 1080 pixels and 15.6 inches (ASUS G51Jx; ASUSTek Computer Inc, Taipei City, Taiwan).

The images were evaluated by 4 examiners (1 endodontist and 3 radiologists) previously trained with experience in digital and tomographic images. They qualitatively examined each canal separately for the presence/absence of an endodontic fractured instrument according