Accuracy of Digital Subtraction Radiography in the Detection of Vertical Root Fractures

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Abstract

Introduction: The objective of this study was to evaluate the accuracy of digital subtraction radiography in the diagnosis of vertical root fractures (VRFs). **Methods:** Twenty decoronated uniradicular human teeth were placed in the alveoli of a dry mandible and radiographed twice, first without (unfilled roots) and then with (filled roots) a gutta-percha cone placed into the root canal. Roots were then removed from the dry mandible, and vertical fractures were created with the aid of a universal testing machine. The fractured roots were repositioned in the mandibular alveoli and again radiographed twice. Radiographic images were subtracted by using the Regeemy software in 3 test situations: group 1, initial radiographic images of unfilled roots and images of fractured or non-fractured unfilled roots; group 2, initial radiographic images of unfilled roots and images of fractured or non-fractured filled roots; and group 3, initial radiographic images of filled roots and images of fractured or non-fractured filled roots. Three examiners evaluated all the original digital radiographs, as well as the subtracted images, for the presence or absence of VRFs. Numerical data were subject to statistical analysis with the use of receiver operator characteristic (ROC) curves. **Results:** The areas under the ROC curve for groups 1, 2, and 3 were 0.86, 0.73, and 0.66, respectively. For the original digital radiographs, areas under the ROC curve were 0.80 (without gutta-percha) and 0.73 (with gutta-percha). No statistically significant differences were found between subtracted and original images. **Conclusions:** Digital subtraction radiography could be considered as an alternative tool for the investigation of VRFs because of its comparable diagnostic accuracy to existing methods. *(J Endod 2016;42:896–899)*

Key Words

Digital subtraction radiography (DSR), radiography, vertical root fracture

Digital subtraction radiography (DSR) is an imaging technique that determines qualitative changes between 2 radiographs taken at different times. The subtracted image is colored in neutral gray and reveals features that differ between the first and the second images (1). For instance, areas of mineral tissue loss are usually dark gray, whereas areas of mineral apposition appear as light gray (2).

DSR analysis uses serial images of similar geometric contrast and density to detect subtle visual changes (3). In the early 1980s, algorithm-based image reconstruction software was developed to project images so that the best possible superimposition could be obtained. Among those, the Regeemy suite is offered free of charge for scientific and diagnostic use; in addition, it provides both automatic and manual selection of landmarks for geometric reconstruction. Therefore, this software has been widely used in studies involving the DSR technique (4–6).

Radiography is the most commonly used imaging modality for the diagnosis of vertical root fractures (VRFs) (7). Although clinical and radiographic diagnoses of VRFs are challenging tasks for the general dentist (8), they are essential to avoid unnecessary tooth extractions (9). On a radiograph, a VRF is identified as a vertical radiolucent line that is visible only if the x-ray beam parallels the plane of fracture (10). Endodontically treated teeth are at higher risk of experiencing VRFs than vital teeth, most likely because of excessive root canal instrumentation, excessive pressure during gutta-percha filling, or inappropriate placement of intraradicular posts (11).

In the scientific and clinical settings, DSR has been used to assess dental and bone density, post-fracture mandibular bone healing and alveolar bone tissue alterations, as well as to diagnose proximal caries (1, 6, 12–14). Surprisingly, studies that use DSR for the detection of VRFs are very scarce. Considering that endodontic treatment is the major predisposing factor for VRFs and that radiographic examination is an essential component of proper endodontics (15), DSR could be a valid and easily implemented method for root fracture diagnosis. Therefore, the aim of this study was to evaluate the accuracy of DSR in the context of VRF diagnosis.

Materials and Methods

Sample Preparation and Image Acquisition

The local Research Ethics Committee reviewed and approved this work without restrictions (Protocol no. 054/2014). Twenty uniradicular human teeth were disinfected for 2 hours in a 2% glutaraldehyde solution. Subsequently, all crowns were sectioned near or at the cementoenamel junction by using a diamond disk cutter (Isomet 1000; Buehler Ltd, Lake Bluff, IL), and root length was standardized at 15 mm from the root apex. Chemical and mechanical root canal preparation was performed with the rotary system ProTaper Universal (Dentsply, Tulsa, OK) as proposed by the manufacturer. To standardize dentin removal, apical preparation was performed with the F2

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(25.08) file in all roots. The roots were irrigated with saline after every file change. After instrumentation, an F2 (Dentsply) gutta-percha cone was placed in the canal for radiographic acquisition. Pencil marks made on the buccal surfaces of all roots ensured that they were properly repositioned in the alveoli before being radiographed.

All radiographs were obtained with a GX-770 periapical machine (Gendex Dental Systems, Lake Zurich, IL; 70 kVp, 7 mA, exposure time 0.08 seconds), VistaScan phosphor plates (size 2, 30 × 40 mm active area), and the DBSWIN software (Dürr Dental, Bietigheim-Bissingen, Germany). For the initial radiographic images (non-fractured/unfilled image set), each prepared root was placed in the alveoli of the premolar region of a human dry mandible. Radiographs were taken in an orthoradial incidence (0° horizontal and vertical angles indicated by a protractor) with the aid of a custom holder designed to maintain the specimen, the film-holding device, and the image receptor in a reproducible relationship. To simulate soft tissue attenuation, a 2.5-cm-thick acrylic plate was placed in front of the specimens. Then an F2 gutta-percha cone was introduced into the root canal, and new periapical radiographs were obtained as described above to form the non-fractured/filled group image set.

Roots were then removed from the alveoli, and VRFs were created with a universal testing machine (ISTRON 4411; Instron Corp, Canton, MA). In brief, a tapered metal tip placed at the entrance of the root canal was programmed to push into the canal at a speed of 1 mm/min and 500 N, stopping automatically once the fracture occurred. Although fracture width was not controlled, root fragments were not displaced and thereby mimicked a thin-line fracture. After fracture creation, roots were repositioned in the alveoli for radiographic acquisition as described above, forming the fractured/unfilled image set. After the insertion of gutta-percha cones into the root canals, radiographs were acquired to create the fractured/filled image set.

Subtraction of Radiographic Images

Radiographic images were subtracted by using the Regeemy software (Image Registration and Mosaicking version 0.2.43; DPI-INPE, São José dos Campos, São Paulo, Brazil and Vision Lab–Electrical and Computer Engineering Department, University of California, Santa Barbara, CA). First, the initial radiographic image (non-fractured/unfilled) was opened as image 1. Then the corresponding image of the same root with 1 of the tested conditions (fracture and/or filling) was opened as image 2. Subsequently, the subtraction image tool was applied to create the subtracted image. The images were shown over a neutral gray background, with dark areas corresponding to density loss (fracture) and light areas corresponding to density gain (filling material). The resulting images were saved as TIFF (Tagged Image File Format) files.

Subtracted images were grouped as follows:

Group 1: Radiographic images of unfilled and fractured or non-fractured roots were subtracted from the initial radiographic images.
Group 2: Radiographic images of filled and fractured or non-fractured roots were subtracted from the initial radiographic images.
Group 3: Radiographic images of filled and fractured or non-fractured roots were subtracted from the initial radiographic images of filled roots.

In addition, the following 2 groups made of the initial radiographic images were created for comparison with the subtracted ones:

Group 4: Radiographic images of unfilled and fractured or non-fractured roots
Group 5: Radiographic images of filled and fractured or non-fractured roots

Figure 1 shows examples of the subtracted images obtained.

Image Assessment

To check the effectiveness of DSR in VRF diagnosis, the subtracted images were randomized in a PowerPoint (Microsoft Corp, Redmond, WA) presentation with a black background and then evaluated by 3 calibrated examiners. The examiners classified fracture presence according to a 5-point scale: 1, definitely absent; 2, probably absent; 3, uncertain; 4, probably present; and 5, definitely present. After

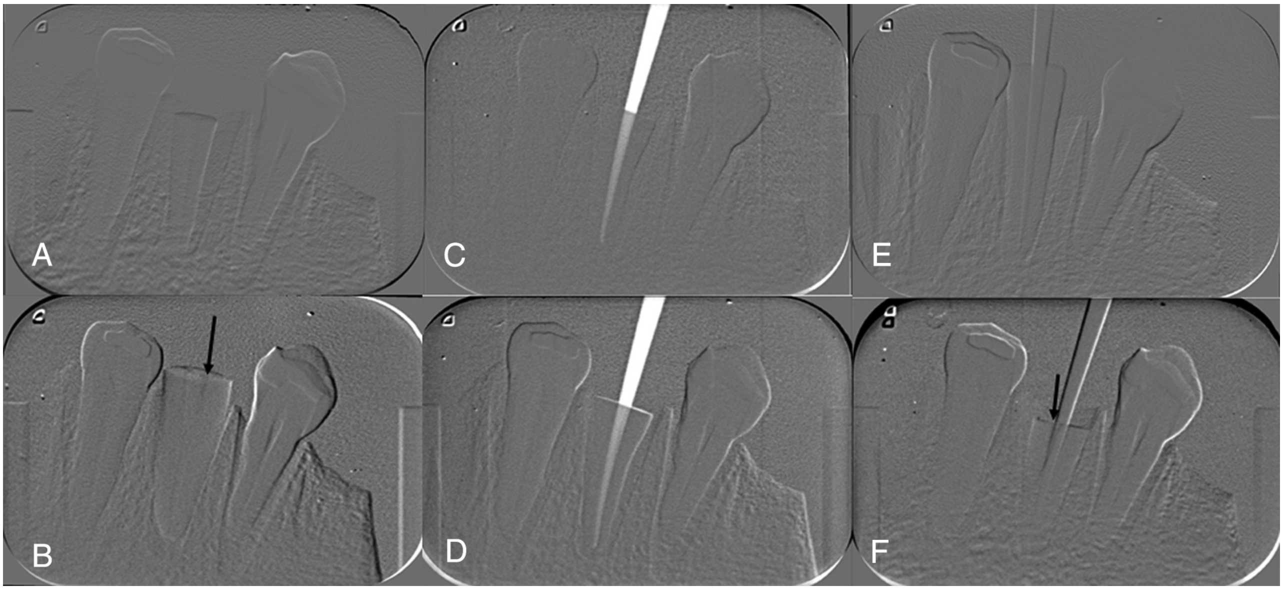

Figure 1. Examples of subtracted images. (*A* and *B*) Group 1 (without and with fracture, respectively); (*C* and *D*) group 2 (without and with fracture, respectively); (*E* and *F*) group 3 (without and with fracture, respectively). (*B* and *F*) *Arrows* indicate vertical root fracture.