Influence of Tooth Orientation on the Detection of Vertical Root Fracture in Cone-beam Computed Tomography

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Abstract

Introduction: The purpose of this study was to assess the influence of tooth orientation in relation to the projection plane of the x-rays on the detection of vertical root fracture (VRF) with different filling materials using cone-beam computed tomographic (CBCT) imaging. **Methods:** Thirty single-rooted human teeth were endodontically instrumented, and VRF was induced in half of the sample. The roots were individually placed in the dental socket of a phantom head composed of a dry human skull and mandible, and CBCT images were obtained of each root with the longitudinal axis in 2 orientations: perpendicular and parallel to the projection plane of the x-rays. Also, each root was scanned under 3 filling conditions: without filling material, with gutta-percha, and with a metal post. Radiation doses at specific anatomic regions of the phantom were obtained for the 2 orientations. Five radiologists evaluated all images and rated the fractures on a 5-point scale. The sensitivity, specificity, accuracy, and positive and negative predictive values were calculated. The area under the receiver operating characteristic curve and the dosimetric outcomes for each root orientation and filling material were compared, respectively, with 2-way and 1-way analysis of variance with the post hoc Tukey test ($\alpha = 0.05$). **Results:** There was no significant difference ($P \geq .05$) in the detection of VRF between root orientations regardless of the filling material. Az values were significantly lower ($P < .05$) in the presence of gutta-percha and a metal post. The root orientation varied the absorbed dose at some anatomic regions. **Conclusions:** The orientation of the tooth in relation to the projection plane of the x-rays does not influence the detection of VRF using CBCT imaging irrespective of the intracanal material. *(J Endod 2018;■:1–5)*

Key Words

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

The diagnosis of vertical root fracture (VRF) is a challenging task because the traditional techniques of transillumination, bite test, periodontal probing, and periapical radiography do not present high sensitivity (1, 2). An accurate diagnosis prevents additional damage to the periodontal tissues as well as unnecessary treatment and costs (3). Thus, precise clinical and radiographic examinations become relevant (4).

Significance

Because of inherent geometric factors, important artifacts in cone-beam computed tomographic imaging are more prominent along the longitudinal axis of the tooth. Despite this, root fracture detection remains a challenging diagnostic task in the presence of metallic filling even when the tooth is scanned in a different spatial orientation.

A radiographic modality that has been used in the diagnosis of VRF is cone-beam computed tomographic (CBCT) imaging (1, 2, 5–8). With the advent of CBCT imaging, the overlap of structures that is observed in plain radiography does not occur because CBCT images are 3-dimensional and allow for the sectional view of a region of interest (9). Nevertheless, a major disadvantage of CBCT imaging is the formation of image artifacts in the presence of metallic materials, which can compromise the image quality. Because VRF is mostly present in endodontically treated teeth, the occurrence of artifacts in suspected cases impairs the diagnostic accuracy (10–13).

Image artifacts can be defined as an error or distortion in the reconstructed data that is not present in the investigated object (12). One of the most common sources of artifacts is the beam hardening effect (14, 15), which results in hypodense (dark) streaks and is caused by the absorption of low-energy x-ray photons when interacting with highly dense objects with high atomic numbers, consequently increasing the mean energy of the x-ray beam (12).

This type of artifact has been noted to be more prominent along the longitudinal axis of the tooth (axial reconstruction), which is the projection plane of the x-rays because of the geometric relationship between the radiation source and the image receptor (16–18). Therefore, the aim of this study was to assess the influence of tooth orientation in relation to the projection plane of the x-rays on the detection of VRF with different intracanal materials using CBCT imaging.

Material and Methods

The present study was designed according to the local institutional research ethics committee and was performed after approval (CAAE 57793316.4.0000.5418). Thirty single-rooted human teeth were clinically and radiographically evaluated to confirm the absence of an open apex, dilaceration, supernumerary root, pulp calcifications,

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or internal and/or external root resorption. Only single-rooted teeth were used to better standardize the sample and prevent important anatomic discrepancy.

In an endeavor to eliminate the bias of coronary fracture identification at a later stage, all dental crowns were sectioned with a diamond saw (Isomet 1000; Buehler Ltd, Lake Bluff, IL). The root canals were instrumented with the Mtwo NiTi rotary system (VDW, Munich, Germany) and irrigated with distilled water. The full length of the root canal was instrumented in sequence using nickel-titanium instruments, and two thirds were prepared for posts (Exacto; Angelus, Londrina, Brazil) with a low-speed bur (Largo no. 2; Dentsply Maillefer, Ballaigues, Switzerland). The Mtwo rotary file (VDW) consisted of 4 nickel-titanium instruments with different tip diameters and tapers (30.05, 35.04, 40.04, and 25.07).

Each root was temporarily fixed in an acrylic resin block of 25 mm in height with a hole of 10 mm in diameter. An Instron machine (Instron Corporation, Norwood, MA) induced VRF in half of the sample by introducing a conical metal tip in the canal opening, applying a 500-N load cell at a cross-speed of 1 mm/min and stopping automatically when the fracture occurred to prevent fragment displacement. All fractured roots were inspected by means of transillumination to confirm the presence of a vertical fracture line. The roots were individually placed in a radiographic phantom composed of a dry adult human skull and mandible. The socket of the lower right first premolar was enlarged with a cylindrical bur to achieve passive fit with all roots. The mandible was covered with a 10-mm-thick layer of utility wax on the lingual and buccal cortical plates to simulate soft tissue (19).

CBCT scans were obtained using the Picasso Trio unit (Vatech, Gyeonggi-Do, Republic of Korea) operating at 85 kVp, 5 mA, and a voxel size of 0.2 mm, with the roots centered in a field of view (FOV) of 5 × 5 cm and the longitudinal axis in 2 orientations: perpendicular and parallel to the horizontal plane (Fig. 1). The perpendicular orientation represented standard patient positioning, and the parallel orientation represented a patient with the head tilted 90° backward. Additionally, the roots were scanned without filling material, with gutta-percha (Dentsply Maillefer), and with a metal post (a cobalt-chromium alloy). Both filling materials were carefully placed without moving the root in the socket to maintain the same position.

Five oral radiologists with over 2 years of experience in CBCT imaging evaluated all images in a low-light environment with a 24.1-inch flat-screen monitor with 1920 × 1080 pixel resolution (MDRC-2124; Barco NV, Kortrijk, Belgium) using On Demand 3D software (Cybermed Inc, Irvine, CA). The images were analyzed dynamically (axial, coronal, sagittal, and cross-sectional reconstructions) with the possibility of adjusting the brightness, contrast, zoom, and rotation settings. The observers rated the fractures on a 5-point scale as follows: 1, definitely absent; 2, probably absent; 3, uncertain; 4, probably present; and 5, definitely present. After 30 days, 25% of the samples were reevaluated to test intraobserver reproducibility.

Considering that patient positioning affects the radiation exposure of different organs, an anthropomorphic tissue-equivalent head and neck phantom was used to evaluate the absorbed doses on the skin surface according to the different orientation of the longitudinal axis of the root. A total of 30 (10 sets of 3) calibrated thermoluminescent dosimeters (TLDs; TLD-100 LiF:Mg, Ti; Thermo Fisher Scientific Inc, Waltham, MA) were placed on the surface of the phantom at anatomic regions corresponding to the thyroid, eye lens (right and left), parotid glands (right and left), sublingual glands (right and left), submandibular glands (right and left), and cranial vertex (20). The anthropomorphic phantom was positioned in the CBCT unit in the same way as the imaging phantom, and, for each orientation (perpendicular and parallel), 3 consecutive scans were performed without changing the TLDs because the small amount of radiation released by a single CBCT scan would not be sufficient to produce measurable values. A set of 3 TLDs was kept out of the examination room to measure the average background radiation. All dosimeters were read with a thermoluminescent reader (Harshaw Thermoluminescent Scanner, Model 2000, Thermo Fisher Scientific Inc). The background radiation was subtracted from the results, which were divided by 3 (the number of repeated exposures). Values obtained for each anatomic region were expressed in milligrays and tabulated. After 30 days, this procedure was repeated with new dosimeters to assess reproducibility.

Statistical analysis was performed using SPSS Statistics 22 (IBM Corporation, Armonk, NY). The weighted kappa statistic was used to assess intra- and interobserver agreement, considering the following level of agreement: <0.40, poor; 0.40–0.59, moderate; 0.60–0.74, good; and 0.75–1.00, excellent (21). The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value were calculated. Two-way analysis of variance with the post hoc Tukey test was used to compare the area under the receiver operating characteristic curve (Az; ie, the ability of the test to correctly identify those with and without root fracture) for each root orientation and filling material, and 1-way analysis of variance with the post hoc Tukey test was used to compare dosimetric outcomes between root orientations. The null hypothesis was that no significant differences in the detection of VRF would be identified between tooth orientations. The intraclass correlation coefficient was performed to test the reproducibility of dosimetry. The significance level was set at 5% (α = 0.05).

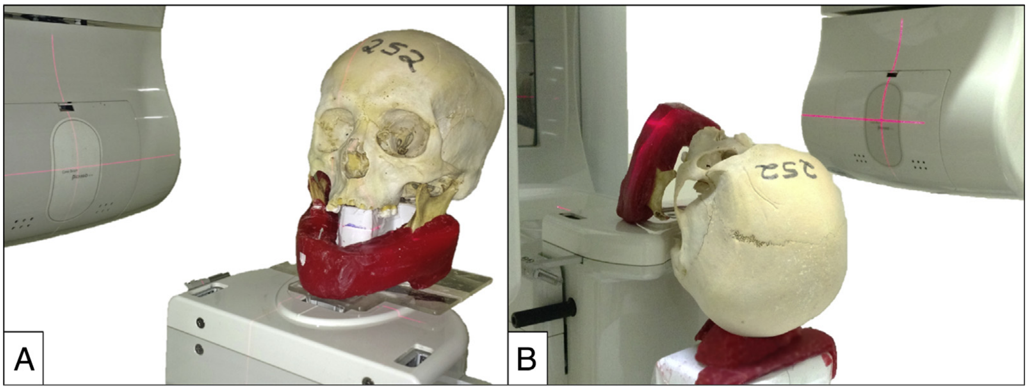

Figure 1. Phantom positioning to promote 2 orientations of the longitudinal axis of the root in relation to the projection plane of the x-rays: (*A*) perpendicular and (*B*) parallel.