Cone-beam Computed Tomography for Detecting Vertical Root Fractures in Endodontically Treated Teeth: A Systematic Review

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Abstract

Introduction: A vertical root fracture (VRF), commonly found in teeth with endodontic treatment, is challenging to diagnose and has poor treatment outcomes. Cone-beam computed tomography (CBCT) has become an increasingly popular imaging modality in endodontics, but image artifacts arising from root-filling materials may hinder VRF detection. The aim of this investigation was to conduct a systematic review to assess the diagnostic ability of CBCT for detecting VRFs in endodontically treated teeth. **Methods:** A systematic review of *in vivo* clinical diagnostic literature (initial search December 2014, updated August 2015) was conducted. Assessment of methodological quality was performed by using the modified Quality Assessment of Diagnostic Accuracy Studies tool. **Results:** Four studies with a total of 130 patients were included. The reported ranges of values were 40%–90% for VRF prevalence, 84% (0.64–0.95) to 100% (0.83–1.00) for sensitivity, 64% (0.35–0.87) to 100% (0.03–1.00) for specificity, 71% (0.51–0.87) to 100% (0.63–1.00) for positive predictive value, and 50% (0.01–0.99) to 100% (0.84–1.00) for negative predictive value. All 4 studies revealed multiple items at high risk or unclear risk of bias. **Conclusions:** Because of the significant imprecision in the range of reported estimates and the biases observed in the included studies, there is currently insufficient evidence to suggest that CBCT is a reliable test in detecting VRFs in endodontically treated teeth. *(J Endod 2016;42:177–185)*

Key Words

Cone beam computed tomography, diagnosis, review literature as topic, tooth fractures

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A vertical root fracture (VRF) is defined as a longitudinally oriented fracture plane that is confined to the tooth root. The prevalence of VRFs is not well-established, but it is thought that they are more commonly found in teeth that have undergone endodontic treatment (1). Clinical studies of endodontically treated teeth that were extracted with the presumption of VRF suggest a prevalence of 2%–5% (2–6), whereas studies that observed VRFs in extracted endodontically treated teeth report a prevalence of between 11% and 20% (7, 8). Traditional methods used to diagnose VRFs include transillumination (9), projection radiography (10), bite testing (11), periodontal probing (3), sinus tract detection (3), and direct visual examination (11). Unfortunately, all of these methods have limited diagnostic reliability because most signs and symptoms are nonspecific for VRF. Hence, distinguishing VRF from pulpal necrosis, failed root canal treatment, and/or periodontal disease is often challenging (12). Particularly in relation to projection radiography, it has been shown that to visualize a VRF, the primary beam needs to be within 4° of the fracture plane (13). Moreover, the superimposition of surrounding anatomic structures makes visualization of a VRF even more difficult (14). Therefore, it is not surprising that a fracture plane is visualized in only approximately one third of VRF cases on periapical radiographs (15). Once a diagnosis is established, the prognosis of a tooth with VRF is poor; there are currently no reliable methods of treating VRF, and the affected tooth is usually extracted (1). In this context, a reliable diagnosis of VRF is of utmost importance to prevent unnecessary extraction of an otherwise treatable tooth.

Cone-beam computed tomography (CBCT) is an imaging modality that uses a revolving cone-shaped x-ray source projected onto a reciprocating digital flat-panel receptor. The acquired projectional "basis" images are then used to construct a three-dimensional volumetric data set that can then be used to reconstruct cross-sectional images in any plane (16). Compared with conventional multidetector CT, CBCT units are typically smaller and less expensive and offer higher-resolution images with lower effective doses to the patient (17). Because of the limitations of conventional radiography, the application of high-resolution CBCT imaging in detecting VRFs has generated considerable interest. Although there are a number of *ex vivo* studies that have attempted to assess the ability of CBCT in detecting artificially induced VRFs in endodontically treated teeth (18–30), these findings do not incorporate the associated periradicular changes in the osseous structures adjacent to the fracture plane, which can often aid in the interpretation of a VRF (31). In our experience, ruling out VRF in a previously endodontically treated tooth is a common reason for CBCT imaging, yet it is one of the most difficult to interpret because of the presence of imaging artifacts that may obscure the putative fracture plane (32). Consequently, the ability of CBCT to detect VRFs in endodontically treated teeth is an important clinical question to address. The purpose of this systematic review was to investigate the diagnostic ability of CBCT in detecting VRFs in endodontically treated teeth. The review format and methodology strictly adhere to those recommended by the Cochrane Collaboration for diagnostic tests of accuracy as well as users' guide to studies of diagnosis (33–35).

Methods

Criteria for Considering Studies for This Review

Types of Studies. Prospective or retrospective clinical diagnostic studies with a consecutive period of patient enrollment were considered for inclusion.

Participants. Studies reporting on human subjects with at least 1 endodontically treated permanent tooth suspected of having VRF on the basis of existing clinical signs and symptoms (ie, sensitivity to percussion, pain on biting and release, and/or localized periradicular bone loss and deep probing depths) were included. To eliminate VRF cases with grossly distracted root fragments that do not pose a sufficient diagnostic dilemma (33–35), the fracture plane must not have been visualized on periapical radiographs.

Index Test. The index test was CBCT imaging, regardless of the generation of development of the instrument, field-of-view size, voxel size, and exposure parameters such as milliamperes, time, and kilovolt peak.

Target Condition. The target condition was VRFs involving any permanent endodontically treated tooth. Fractures that run approximately horizontal to the long axis of the tooth root were excluded.

Reference Standards. The reference standard was direct observation of the tooth root surface via orthograde retreatment, exploratory open-flap surgery, or visual inspection of extracted teeth without or with the aid of stains. Studies with incomplete reference testing, whereby only index test positive cases were subjected to reference testing, were excluded (33–35).

Search Methods for Identification of Studies

We searched through a comprehensive list of electronic databases and indices as well as other resources to identify potentially relevant published or unpublished studies, with no language or publication restrictions (Table 1). The reference lists of relevant review articles and included studies were also hand-searched.

Data Collection and Analysis

Two review authors (E.C., A.A.) independently reviewed and selected relevant studies from the search results and extracted data by using a piloted data collection form (Table 2). The modified Quality Assessment of Diagnostic Accuracy Studies checklist, as recommended by the Cochrane Handbook for Diagnostic Tests of Accuracy (40), was applied by the 2 review authors (E.C., A.A.) for the independent assessment of risk of bias in the included studies. Any disagreements at these steps were resolved through discussion and consensus or by consulting the other review authors (E.L., P.S.). The software Meta-DiSc 1.4 (41) was used to calculate descriptive statistics of sensitivity, specificity, and positive and negative predictive values (PPV and NPV) and to plot data on the receiver operating characteristic (ROC) plane, which is a plot of sensitivity as a function of 1 − specificity.

Results

Results of the Search

In total, we identified 2360 records through electronic database searches. After screening for abstracts, 2337 records were removed. We retrieved the full-text versions of the remaining 23 records and excluded 19 articles that did not meet our inclusion criteria (Table 3). The remaining 4 records were analyzed in the review (Fig. 1). These studies were clinically significantly heterogeneous, so *a priori* decision was made to conduct only systematic review and not meta-analyses (50).

Findings

The sample sizes of the 4 included studies ranged from 10 (39) to 49 (38). The patients were selected from a wide age range and varied geographic locations, including the United States (36), Europe (37), China (38), and Iran (39). The calculated prevalence of VRF (ie, probability of VRF before CBCT) ranged from 40% (38) to 90% (39). The index test consisted of CBCT machines of varying models and imaging parameters, and the interpreters consisted of oral radiologists and/or endodontists. There was a large variation in the reported agreement values among the interpreters; 2 of the studies did not report any intra-rater or inter-rater scores (36, 39), 1 study reported a wide range of intra-rater and inter-rater agreement scores ranging from 51% to 100% and 25% to 79%, respectively (37), and 1 study reported very good inter-rater agreement (94%) (38). The reference tests

TABLE 1. Summary Table of Search Strategy

Search strategy	Time period
Electronic databases/indices	
MEDLINE (via OVID)	1946 to November 2014
EMBASE (via OVID)	1980 to week 47 2014
AMED (via OVID)	1985 to November 2014
Ovid Healthstar (via OVID)	1966 to October 2014
Science Citation Index Expanded (via Web of Science)	Inception to December 1, 2014
BIOSIS Citation Index (via Web of Science)	Inception to December 1, 2014
BIOSIS Previews (via Web of Science)	Inception to December 1, 2014
National Technology Information Service (via ProQuest)	Inception to December 2, 2014
LILACS	Inception to December 8, 2014
MEDION	Inception to December 8, 2014
Chinese Biomedical Literature Database (via CNKI)	Inception to December 8, 2014
Turning Research Into Practice (TRIP)	Inception to December 8, 2014
Scopus	Inception to December 8, 2014
Grey literature search	
ProQuest Theses and Dissertations (via ProQuest)	Inception to December 8, 2014
System for Information on Grey Literature in Europe (SIGLE)	Inception to December 8, 2014
Conference Proceedings Citation Index (via Web of Science)	Inception to December 8, 2014
COS Conference Papers Index (via ProQuest)	Inception to December 8, 2014
Google Scholar (first 100 hits by using the search terms "cone beam" and "root fracture")	December 8, 2014
Annual meeting proceedings of the American Association of Endodontists	Inception to 2014
Annual meeting proceedings of the American Academy of Oral and Maxillofacial Radiology	Inception to 2014
Annual meeting proceedings of the International Association of Dento-Maxillo-Facial Radiology	Inception to 2014
Annual meeting proceedings of the International Association of Dental Research	Inception to 2014