Diagnosis and decision making in endodontics with the use of cone beam computed tomography
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Section 2.3
Detection of Vertical Root Fractures In Vivo in Endodontically Treated Teeth by Cone-Beam Computed Tomography Scans

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Introduction: The presence of a vertical root fracture (VRF) in an endodontically treated tooth has an immense impact on the treatment’s outcome. Early diagnosis of a VRF is imperative to avoid overtreatment and extensive bone loss. Our study aimed to examine the validity of two cone-beam computed tomography (CBCT) scanners in detecting VRFs in endodontically treated teeth in vivo.

Methods: Thirty-nine endodontically treated teeth suspected of VRFs from 39 patients were included. No fracture line was visible in periapical radiographs. Two limited-field-of-view scanners were used, the NewTom 3G and the 3D Accuitomo 170. Three observers evaluated the CBCT images independently and twice. The most frequently given score was used to calculate the validity of the CBCT systems. The findings of orthograde retreatment, endodontic microsurgery, or extraction were the gold standard. The intraobserver agreement (Cohen kappa) and the interclass correlation coefficients were calculated.

Results: The sensitivity, specificity, and accuracy for the NewTom 3G were 75%, 56%, and 68%, respectively, and for the 3D Accuitomo 170 they were 100%, 80%, and 93%, respectively. The positive predictive value and the negative predictive values were 75% and 55%, respectively, for NewTom 3G and 90% and 100%, respectively, for 3D Accuitomo 170.

Conclusions: The results of our study support the use of 3D Accuitomo 170 for the detection of VRFs in endodontically treated teeth. They also suggest that the reproducibility and accuracy in VRF detection depend on the CBCT system used.
Introduction

The presence of a vertical root fracture (VRF) in endodontically treated teeth significantly reduces their long-term prognosis, leading ultimately to extraction (1). VRFs that remain undetected may lead to extensive bone loss and unnecessary overtreatment (orthograde, retrograde). For both the patient and the dentist, their early diagnosis is imperative. This can be a true challenge because the related clinical and radiographic signs are not pathognomonic (2). The need for more evidence-based data for the detection of VRFs became apparent in the systematic review by Tsesis et al (3). According to the literature, the clinical signs that are frequently correlated with an extensive VRF are multiple sinus tracts and the presence of a deep osseous defect isolated in one tooth (3–5). A VRF is radiographically visible only if it is in the same plane with the x-ray beam or at an angle of 40 to either side (6). The superimposition of adjacent tissues and materials also makes the 2-dimensional radiographic detection of VRF difficult (7).

The introduction of cone-beam computed tomography (CBCT) in dentistry allowed the acquisition of 3-dimensional volumes of dental arches with high spatial resolution and low radiation as compared with conventional CT (8). Ex vivo studies support the use of CBCT scans for the detection of VRFs in endodontically treated teeth (9–13). However, the VRFs in these studies were artificially created, which could be different from the “naturally” occurring ones. Also, when the detection of VRFs by different CBCT scanners was compared, there was always a difference in their detection accuracy both ex vivo and in vivo (10, 14). Therefore, the aim of this study was to examine the validity of 2 CBCT scanners (NewTom 3G, 3D Accuitomo 170) in detecting VRFs in endodontically treated teeth.
Materials and Methods

CBCT scan images of 39 endodontically treated teeth from 39 patients were analyzed for the study. These patients were referred to the Postgraduate Endodontology Clinic of the Academic Centre for Dentistry Amsterdam (ACTA) from 2009–2011 for further diagnosis and treatment. All teeth were suspected to have VRFs. The clinical and radiographic signs suggesting the presence of VRFs in endodontically treated teeth were the following: pain on percussion and/or palpation, presence of a deep isolated periodontal pocket (bone loss), presence of one or multiple sinus tracts, and halo or J-type radiolucency around the corresponding tooth on the periapical radiograph (PR).

No fracture line was visible on PRs in any of the cases. The CBCT scans were taken for diagnostic purposes before any treatment took place. All patients gave their consent to include their radiologic data in the study. The institutional review board approved the protocol of the study.

The patients were scanned by using limited-area field of view either by the NewTom3G (110 kv, 3.90–5.6 mA; QR SLR, Verona, Italy) or by the 3D Accuitomo 170 (90 kv, 5 mA; J. Morita, Kyoto, Japan) at the Department of Oral Radiology of ACTA. The smallest isotropic voxel size (0.2 mm for NewTom 3G and 0.08 mm for 3D Accuitomo 170) was selected for both scanners. Following the as low as reasonably achievable principle and the manufacturer’s recommendations, the lowest possible radiation was used for both PRs and CBCT scans.

The cases were distributed between the 2 CBCT systems according to their availability at the time of the study. The NewTom 3G was not available in ACTA’s Department of Oral Radiology since the beginning of 2011. Twenty-five cases, 10 of which had a restoration, were scanned by NewTom 3G. Fourteen cases, 7 of which had a restoration, were scanned with the 3D Accuitomo 170. Three case-blinded and calibrated endodontists assessed all images twice and independently. There was at least 1-week interval between the sessions.
The calibration included training on the radiographic features of VRFs on CBCT scans with vertically fractured extracted teeth. The visibility of a radiolucent line crossing the root completely or partially on at least 2 consecutive slices was the main radiographic feature for detecting a VRF (9, 10, 16). The observers received no clinical information before the examination of the images except for the site of the concerned tooth. The CBCT images were displayed on a 22-inch flat-screen panel (L2245wg LCD; Hewlett Packard, Palo Alto, CA). The assessment of the scans was performed on the software recommended by each manufacturer (NNT for the NewTom 3G and i-Dixel for the 3D Accuitomo 170).

All observers could scroll through the entire reconstruction volume and interactively manipulate the images to simulate the clinical situation. The images were viewed in 3 reconstruction planes (axial, coronal, and sagittal). Each observer scanned all the images for the presence of a VRF and recorded the outcome on a dichotomous scale (fracture present or absent).

The diagnosis of VRF based on the CBCT scans was confirmed by orthograde retreatment, endodontic microsurgery, or ultimately extraction of the tooth. The teeth were inspected under a dental operating microscope (SOM 62; Karl Kaps GmbH & Co. KG, Asslar, Germany) for the visualization of a VRF (Fig. 1). In case of retreatment, the root canal surfaces were inspected for the presence of a fracture line after removal of the coronal restoration and the root canal filling material. In case of surgery, a full mucoperiosteal thickness flap was elevated. The exposed root surface could be directly examined when a bony dehiscence was present. When a VRF was diagnosed, tooth extraction or root amputation was performed. If no VRF was detected, the appropriate treatment was performed, and the tooth was monitored for at least 1 more year.
The confirmation of the presence of a VRF in this phase of the study was regarded as the gold standard that was used to assess the validity (sensitivity, specificity, accuracy, negative predictive value, and positive predictive value) of the 2 CBCT scanners. The intraobserver agreement (Cohen kappa) was calculated for each observer and for each scanner independently. The interobserver agreement was calculated with interclass correlation coefficients (ICCs) for the first and second readings of all 3 observers for each scanner independently (16). In cases of disagreement between the observers, the score that was given most frequently was used to assess the validity.

**Figure 1.** A case of tooth #14, which was endodontically treated and suspected of VRF. At the time of the consultation, the tooth was not sensitive to percussion and palpation, and there was neither an isolated pocket present nor a local swelling. (A) Digital PR; the periapical radiolucency around the mesiobuccal root is visible. (B) Axial image of the same tooth; a radiolucent line on the buccal and palatal side (arrows) of the mesiobuccal root is visible. (C) Preoperative photograph. (D) The exposed root surface after flap elevation. (E) The fracture line is visible (arrow) in the resected mesiobuccal root.
Results

The intraobserver agreement values and the ICCs are reported in Table 1. The consensus score was used to calculate the sensitivity, specificity, and accuracy together with the positive and negative predictive values. Because of the low ICCs of 1 of the 2 CBCT scanners, the data were not pooled, and the results are presented separately (Table 2). Overall, 4 false-negative cases and 5 false-positive cases were detected (Table 2). All of the false-negative cases and 4 of the 5 false-positive cases were scanned with the NewTom 3G, and their diagnosis was confirmed with the surgical findings. Only 1 of the false-positive cases was scanned with the 3D Accuitomo 170. In this case no fracture line was visible during the orthograde retreatment, no clinical signs of VRF were present at 1-year follow-up, and no further treatment took place.

Discussion

Our results suggest that the reproducibility and accuracy of CBCT scans in detecting VRFs in endodontically treated teeth depend on the CBCT system used. They also support the use of 3D Accuitomo 170 over the NewTom 3G. The different validities of the 2 CBCT scanners are attributable to various factors: the quality of the scan, the presence of materials causing artifacts, and the experience of the observers who assessed the images. The quality of the CBCT images could be influenced by the voxel size and the detector design (17–19). Whereas the NewTom 3G had an image-intensifier tube/charge coupled detector and a voxel size of 0.2 mm, the 3D Accuitomo 170 had a flat panel detector and a voxel size of 0.08 mm.

The presence of radiopaque materials such as gutta-percha, artificial crowns, or other metallic restorations can create artifacts and make interpretation of the image more difficult (7, 9, 20). All the teeth included in our study had been endodontically treated.
The percentage of cases with artificial crowns or other metallic restorations was almost the same for both CBCT systems. Although the distribution of the cases favored neither CBCT system, more artifacts were detected by the NewTom 3G images.

Although the observers who assessed the images may be another factor explaining the differences between the 2 CBCT systems, the 3 observers involved in this study were calibrated and had been similarly trained in the assessment of CBCT images. Intraobserver and interobserver agreements were both higher for the 3D Accuitomo 170 than for the NewTom 3G.

To our knowledge, 3 other in vivo studies have examined the diagnostic ability of CBCT systems in detecting root fractures. Bernardes et al (21), who used CBCT scans (Accuitomo 3DX; 80 kv, 5.6 mA) and PRs to examine endodontically treated teeth suspected of root fractures, found that CBCT scans detected more root fractures than PRs did. The cases they examined included both VRFs and horizontal root fractures. In their study the diagnoses of root fractures were not confirmed on the basis of surgery or extraction. Therefore, no conclusions could be drawn regarding the validity of the CBCT system.

Table 1. The reliability of the two CBCT scanners with regard to VRF detection.

<table>
<thead>
<tr>
<th></th>
<th>NewTom 3G</th>
<th>3D Accuitomo 170</th>
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<tbody>
<tr>
<td><strong>Intraobserver</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>agreement</td>
<td></td>
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<tr>
<td>Observer 1</td>
<td>0.51</td>
<td>0.85</td>
</tr>
<tr>
<td>Observer 2</td>
<td>0.83</td>
<td>1.00</td>
</tr>
<tr>
<td>Observer 3</td>
<td>0.60</td>
<td>0.81</td>
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<tr>
<td><strong>Interclass</strong></td>
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<tr>
<td><strong>correlation</strong></td>
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<tr>
<td>coefficients</td>
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<tr>
<td>1st reading</td>
<td>0.25</td>
<td>0.79</td>
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<tr>
<td>2nd reading</td>
<td>0.26</td>
<td>0.71</td>
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</tbody>
</table>
Table 2. Validity of the two CBCT scanners. Fr: fracture, No Fr: no fracture.

<table>
<thead>
<tr>
<th></th>
<th>NewTom 3G</th>
<th>3D Accuitomo 170</th>
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<tbody>
<tr>
<td></td>
<td>Fr</td>
<td>No Fr</td>
</tr>
<tr>
<td>Gold Standard</td>
<td>Fr</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>No Fr</td>
<td>4</td>
</tr>
<tr>
<td>Number of Cases</td>
<td></td>
<td>25</td>
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<tr>
<td>Sensitivity</td>
<td>75%</td>
<td>100%</td>
</tr>
<tr>
<td>Specificity</td>
<td>56%</td>
<td>80%</td>
</tr>
<tr>
<td>Accuracy</td>
<td>68%</td>
<td>93%</td>
</tr>
<tr>
<td>Positive Predictive Value</td>
<td>75%</td>
<td>90%</td>
</tr>
<tr>
<td>Negative Predictive Value</td>
<td>55%</td>
<td>100%</td>
</tr>
</tbody>
</table>

However, a similar study by Edlund et al (14) did use surgical findings to verify the radiographic diagnosis of VRFs by using the 3D Accuitomo 80 and iCAT CBCT systems. Although the intraobserver and interobserver agreements of the 2 observers were not calculated, the authors reported accuracies of 90% for the 3D Accuitomo 80 and 82% for the iCAT. They concluded that CBCT technology is effective in detecting VRFs with a relatively high sensitivity (89%, 87%) and specificity (100%, 71%). Comparison of these results with our own findings shows that the validity of the NewTom 3G is inferior to that of the other 3 CBCT systems (3D Accuitomo 80, iCAT, and 3D Accuitomo 170). The validity of the 3D Accuitomo 170 used in the present study is similar to that of 3D Accuitomo 80 and iCAT (14, 21).

In the third study, Wang et al (20) compared the validity of conventional dental radiographs in detecting VRFs with that of the 3DX Accuitomo (80 kV, 5 mA) CBCT system; only teeth that were suspected of a VRF were included. Almost twice as many nonendodontically treated teeth were examined as...
endodontically treated ones. The radiographic diagnosis was confirmed by using surgical findings. Two observers assessed the images once independently and reached consensus through discussion. The overall accuracy of the 3DX Accuitomo for both endodontically and nonendodontically treated teeth was 91.9%, which was higher than that of the NewTom 3G (68%) in our study and close to that of the 3D Accuitomo 170 (93%). The interobserver agreement reported by Wang et al was higher than that in our study. That could be attributed to the fact that we included only endodontically treated teeth, which may have produced more artifacts on CBCT scans.

In our study, the observers independently assessed the images twice. No negative controls were present among the scans of our cases, because the patients would have been exposed to unnecessary radiation with no clinical value (22). The score used to calculate validity did not result from discussion between the observers but was the most frequently given score by each of them. This procedure is more objective. It would be helpful if future studies reported the validity as well as the reliability of a new diagnostic tool such as the CBCT. In this way the optimum use of different CBCT systems can be obtained, and the benefits to the patient of each exposure can outweigh any risks (22).

To calculate validity, a gold standard is needed. Although findings of orthograde retreatment and endodontic microsurgery may be considered as the gold standard in endodontically treated teeth suspected of VRFs, none of these methods represent a real gold standard; all have limitations, and VRFs may remain undetected. First, orthograde retreatment does not allow all parts of the root canal wall to be inspected thoroughly, and a fracture line may remain undetected. Second, if a VRF is located on the lingual or palatal part of the root surface, it will also be hard to detect in endodontic microsurgery. Findings after tooth extraction are probably the nearest we can come to a real gold standard, because extraction allows the complete root surfaces of a
tooth to be inspected. However, because extraction is not always feasible in a clinical situation, the gold standard is slightly compromised.

Our study was limited to the 2 CBCT systems that were currently available at ACTA’s Department of Oral Radiology. Our purpose was to examine the validity of 2 CBCT systems regarding the detection of VRFs in a clinical situation and not to examine the technical or scanning characteristics of the 2 systems. These should be thoroughly examined in future studies.

In conclusion, although our results corroborate those of other studies that support the use of CBCT for the detection of VRFs in endodontically treated teeth, the reproducibility and accuracy in VRF detection depend on the CBCT system used. For diagnosing VRFs, the 3D Accuitomo 170 seems to be more suitable than the NewTom 3G.
References


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