A Comparison of Cone-beam Computed Tomography with Periapical Radiography in the Detection of Separated Instruments Retained in the Apical Third of Root Canal–filled Teeth

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Abstract

Introduction: This study compared the diagnostic efficacies of cone-beam computed tomographic (CBCT) imaging and periapical radiography (PR) in the detection of retained separated instruments located at the apical third of filled root canals. Methods: Sixty single-rooted extracted human teeth were instrumented to size #25 and were randomly divided to a simulated 2-mm #30 K-file (stainless steel or nickel-titanium) segment separation at the apical third of the canal (n = 40) or a control group without a separated instrument (n = 20). The canals were obturated to the separated instrument or the working length for the teeth without an instrument using gutta-percha with AH26 (Dentsply DeTrey GmbH, Konstanz, Germany) or Roth sealer (Roth International Ltd, Chicago, IL). The teeth were invested in a mandible model simulating the bone density and imaged using CBCT imaging and PR. The images were evaluated separately by 2 calibrated observers twice with an interval of 4 weeks. Cohen kappa was used to evaluate the observer agreement. Receiver operating characteristic curve analysis was used to evaluate the discrimination ability. Results: The intraobserver kappa was 0.744 and 0.627, and between the observers, it was 0.593 and 0.275 for PR and CBCT imaging, respectively. Using PR, the mean sensitivity was 71.25%, and the specificity was 93.75%. Using CBCT imaging, the sensitivity and specificity were 41.25% and 71.25%, respectively. Although for PR the area under the curve values ranged between 0.75 and 0.91 (P < .05), for CBCT they ranged between 0.48 and 0.60 (P > .05), regardless of the instrument or the sealer type. Conclusions: PR performed better than CBCT imaging for the detection of retained separated instruments located at the apical third of extracted human root canal–filled teeth. (J Endod 2016;42:1035–1039)

Key Words
Cone-beam computed tomography, diagnostic efficacy, periapical radiography, root canal–filled teeth, separated instruments

A separated instrument located in the apical third of root canal–filled teeth with apical periodontitis might lead to a compromised ability to adequately treat the entire root canal system as well as reduced root strength and an increased risk of perforation in retreatment procedures during fragment removal or bypass attempts (1–5). Therefore, preoperative detection of these retained separated instruments is crucial for a rational decision-making process regarding the treatment plan (4, 6–8), and it should be one of the goals of the preoperative evaluation (4).

Periapical radiography is the principal radiographic modality used for diagnosis and treatment planning before endodontic re-treatments (3, 4, 9). Therefore, the preoperative detection of a retained separated instrument in root canal–filled teeth relies primarily on the practitioner’s ability to identify the instrument fragment in the vicinity of the root canal filling based on a periapical radiograph (4, 10, 11). However, a recent study revealed that it may be difficult to radiographically detect a

Significance
In extracted human root canal filled teeth, CBCT is inferior to periapical radiography in the detection of retained separated instruments located at the apical third, regardless of the instrument type or the sealer type. Furthermore, CBCT-undetectable separated instruments in root canal filled teeth may be identified by using periapical radiography, thus stressing the importance and validity of periapical radiography as the principal radiographic modality used for diagnosis and treatment planning prior to endodontic re-treatments.
A tooth with a separated instrument before and after root canal filling to the separated instrument imaged by periapical (PA) radiography and CBCT imaging.

**Materials and Methods**

Sixty single-rooted extracted human teeth with 1 patent straight root canal and without any previous endodontic treatment, root caries, root perforation, root resorption, or visible fractures or cracks were selected. The teeth were allocated to groups and prepared as was previously described (4). In brief, a standard endodontic access was prepared, the root canals were instrumented to size #25 using hand files, and then the teeth were randomly divided into 2 groups: simulation of a 2-mm #30 K-file segment separation at the apical third of the root canal (n = 40) and a control group (n = 20). In order to simulate a file separation, a groove was prepared at 2 mm from the tip of the K-file #30 (either stainless steel [SS] [n = 20] or nickel-titanium [NiTi] [n = 20]) using a high-speed bur. Then, the files were inserted to the working length and rotated counterclockwise until separation of the apical segment occurred. The teeth were then radiographed to ensure that the separation occurred at the working length (4).

The purpose of the present study was to compare the diagnostic efficacies of CBCT imaging and periapical radiography for the detection of retained separated instruments located at the apical third of filled root canals.

Retained separated instrument located at the apical third of filled root canals by using periapical radiography alone (4).

Cone-beam computed tomographic (CBCT) imaging enables visualization of the dentition, the maxillofacial skeleton, and the surrounding anatomic structures in 3 dimensions, and it has gained popularity among endodontic practitioners (12, 13). In CBCT imaging, voxels are isotropic (equal in all dimensions) and range from 0.4 mm to as small as 0.075 mm. Because voxels are isotropic, images can be reconstructed in any plane with high fidelity. The ability to discriminate objects separated by very small distances is one of the most attractive qualities of CBCT imaging (14–16). The use of CBCT imaging in endodontics has been recommended for the assessment of complex endodontic conditions such as separated instruments (12, 13). Nevertheless, the presence of filling materials such as gutta-percha (GP) in the vicinity of the retained separated instrument and the metallic nature of the instrument itself may create artifacts on the CBCT images, potentially reducing the diagnostic efficacy of CBCT imaging in detecting the retained instrument (17, 18). However, the diagnostic efficacy of CBCT imaging and its comparability to periapical radiography in the identification of retained separated instruments in root canal–filled teeth has not been fully elucidated (4, 13).

The root canals were then obturated to the separated instrument or to the working length for the teeth without a separated instrument and divided into 6 subgroups of 10 teeth each based on file type and sealer type as follows (4):

1. Separated SS file segment (Mani Inc, Takanezawa, Japan) + root canal filling to the separated instrument with laterally condensed GP and AH 26 sealer (AH) (Dentsply DeTrey, GmbH, Konstanz, Germany)
2. Separated NiTi file (NiTi Flex; Dentsply Maillefer, Ballaigues, Switzerland) + root canal filling to the separated instrument with laterally condensed GP and AH
3. Separated SS + root canal filling to the separated instrument with laterally condensed GP and Roth sealer (Roth) (RC, Roth International Ltd, Chicago, IL)
4. Separated NiTi + root canal filling to the separated instrument with laterally condensed GP and Roth
5. Root canal filling to the working length with laterally condensed GP and AH
6. Root canal filling to the working length with laterally condensed GP and Roth

Subsequently, all teeth were invested in 5 mandible-shaped putty models (Elite HD + Putty Soft Normal; ZhermackSpA, BadiaPolesine,
All teeth were then radiographed using CBCT imaging enabling reproducible CBCT scans and periapical radiographs to be accurately repositioned at each stage of the investigation, thus preventing the sealer type (AH or Roth) (4, 16) on the detection of a separated instrument were calculated for the 2 imaging modalities (CBCT imaging or periapical radiography) using SPSS version 22 (SPSS Inc, Chicago, IL) and WinPepi version 11.44 (http://publichealth.jbpub.com/book/gerstman/winpepi.cfm). Receiver operating characteristic curve analysis was used to evaluate the discrimination ability. P < .05 was considered a significant result.

### Results

The mean intraobserver kappa values were 0.744 and 0.627 for periapical radiographic and CBCT imaging, respectively; the mean kappa values between the observers were 0.593 and 0.275 for periapical radiographic and CBCT imaging, respectively.

Using periapical radiography, the mean sensitivity to detect the separated instruments was 71.25%, and the mean specificity was 93.75%. When using CBCT imaging, the mean sensitivity and specificity to detect the separated instruments were lower (41.25% and 71.25%, respectively; Table 1).

Table 2 presents the area under the curve (AUC) from receiver operating characteristic curve analysis of periapical radiography and CBCT imaging. Although for periapical radiography the mean AUC values ranged between 0.75 and 0.91 (P < .05), for CBCT the mean AUC values ranged between 0.48 and 0.60 (P > .05), pixels and a 32-bit color depth. Dedicated software systems were used with built-in enhancement tools for CBCT (Romexis, Planmeca) and periapical radiographic (CDR DICOM-5; Sirona Dental, Inc, Long Island City, NY) image evaluation. All teeth were randomly evaluated for the presence/absence of a separated instrument. Each observer evaluated all the CBCT and periapical images twice at an interval of 4 weeks between evaluations to eliminate memory bias and to calculate intraobserver agreement. The observation time was not restricted (4, 16, 21).

The evaluation results were recorded and submitted to statistical analysis (4); the Cohen kappa was used to evaluate the intra- and interobserver agreement (22, 23). The diagnostic ability (sensitivity and specificity) (24) and the effects of the instrument type (SS or NiTi) and the sealer type (AH or Roth) (4, 16) on the detection of a separated instrument were calculated for the 2 imaging modalities (CBCT imaging or periapical radiography) using SPSS version 22 (SPSS Inc, Chicago, IL) and WinPepi version 11.44 (http://publichealth.jbpub.com/book/gerstman/winpepi.cfm). Receiver operating characteristic curve analysis was used to evaluate the discrimination ability. P < .05 was considered a significant result.

### Table 1. Sensitivity and Specificity for the Detection of Separated Instruments in Periapical Radiography or Cone-beam Computed Tomographic Imaging

<table>
<thead>
<tr>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>Area (95% CI)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Periapical radiography</td>
<td>First</td>
<td>Second</td>
<td>First</td>
</tr>
<tr>
<td>87.5% (73.89–94.54)</td>
<td>95% (76.39–99.11)</td>
<td>80 (65.24–89.5)</td>
<td>60 (44.6–73.65)</td>
</tr>
<tr>
<td>CBCT imaging</td>
<td>Sensitivity (95% CI)</td>
<td>Specificity (95% CI)</td>
<td>First</td>
</tr>
<tr>
<td>40% (27.6–52.4)</td>
<td>80 (65.24–89.5)</td>
<td>37.5 (25.25–49.75)</td>
<td>42.5 (29.99–55.01)</td>
</tr>
</tbody>
</table>

CBCT, cone-beam computed tomography; CI, confidence interval.

### Table 2. Area under the Curve (Area) from Receiver Operating Characteristic Curve Analysis of Periapical Radiography and Cone-beam Computed Tomographic Imaging

<table>
<thead>
<tr>
<th>Observer</th>
<th>Observation</th>
<th>Area (95% CI)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st observer</td>
<td>First</td>
<td>0.91 (0.83–0.99)</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>2nd observer</td>
<td>First</td>
<td>0.75 (0.62–0.87)</td>
<td>&lt;.05</td>
</tr>
</tbody>
</table>

CBCT, cone-beam computed tomography; CI, confidence interval.

*Null hypothesis: true area = 0.5.
regardless of the instrument type (SS or NiTi) or the sealer type (AH or Roth).

**Discussion**

The use of CBCT imaging in endodontics may be justified only when the integrated data from the patient’s history, clinical examination, and lower-dose conventional intraoral radiography is not sufficient for the specific diagnostic demands and the benefit to the individual patient outweigh the potential radiation exposure risks (25, 26). Therefore, any potential benefit to a patient by using CBCT imaging for detecting retained separated instruments would have to be based primarily on its superior diagnostic efficacy compared with periapical radiography (13, 25–28) and its ability to support the practitioner’s decision making, the treatment planning, and, ultimately, the treatment outcome in such cases (13, 29–31).

The potential benefit to the individual patient from the use of CBCT imaging to detect retained separated instruments is commonly perceived as substantial (13, 25, 32). In the recent updated American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology Joint Position Statement, limited FOV CBCT imaging was recommended as the imaging modality of choice in nonsurgical retreatment to assess endodontic treatment complications such as separated endodontic instruments (12, 25).

Nevertheless, under the limitations of the current in vitro study, we found that CBCT imaging was less successful than periapical radiography in the detection of retained separated instruments located at the apical third of filled root canals, regardless of the instrument type (NiTi or SS) or sealer type (AH or Roth).

In addition, we found in this study that some of the CBCT-undetected separated instruments were identified by using periapical radiography with sensitivity and specificity reaching 71.3% and 93.8%, respectively, which are comparable with the results of previous studies (4). These results were reached with strong intraobserver agreement and with moderate interobserver agreement as previously classified (16). This is an example that, in certain clinical situations, a more contemporary 3-dimensional imaging modality (such as CBCT imaging) may be ineffective, whereas a conventional 2-dimensional imaging modality (such as periapical radiography) may be of significant value (13, 27, 28).

One of the main reasons for the difficulty to identify separated instruments in filled root canals using CBCT images compared with periapical radiographic images is the production of artifacts, which can be defined as “a systematic discrepancy between the CT [computed tomographic] numbers in the reconstructed image and the true attenuation coefficients of the object” (29).

It has been reported that CT images are inherently more prone to artifacts than conventional radiographs because the CT image is reconstructed from many independent detector measurements (29). There is a common misconception that CBCT data sets contain fewer artifacts than their CT counterparts (18, 33). However, CBCT imaging actually involves additional artifacts, such as scatter, and a generally higher noise level (18). CBCT imaging may produce significant artifacts, especially when a high-density material is present in the scanned volume (17, 18, 34), adversely affecting its diagnostic efficacy (17, 18, 34).

It has been reported that intracanal metallic and nonmetallic filling materials such as GP may create artifacts on CBCT imaging (17, 30, 31). The type of material used for root filling and its relative radiopacity as well as the CBCT acquisition parameters such as the voxel size and the FOV may sometimes influence the presence and severity of artifacts observed in CBCT images (17, 30, 31, 34).

These filling material–related artifacts are much more extensive and significant in CBCT imaging compared with periapical radiography (29, 31), and they may significantly reduce the CBCT’s diagnostic efficacy (17, 30, 31, 35). In a recent study (31), similar CBCT artifacts were observed in root canals of extracted human anterior teeth after endodontic preparation and filling with either GP or silver points, whereas the periapical radiographs did not demonstrate such artifacts (31).

The technical community puts considerable efforts in developing techniques for artifact reduction. Many of these techniques are postprocessing algorithms operating on the 3-dimensional volume data. Although this may sometimes result in a considerable reduction of apparent artifact structures (29, 33, 34), from a physical point of view, postprocessing may not be effective for artifact reduction because the error has been integrated into the volume already (18). Nevertheless, the results of the present study will need to be reassessed in the future as newer technological developments in CBCT artifact reduction algorithms become available.

Further studies are needed to assess the effect of additional factors that were not investigated in the current study, such as various sealer types, obturation techniques, and CBCT voxel sizes, on the diagnostic efficacy for the detection of retained separated instruments in filled root canals.

**Conclusions**

Under the limitations of this study, it may be concluded that in extracted human root canal–filled teeth, CBCT imaging is inferior to periapical radiography in the detection of retained separated instruments located at the apical third, regardless of the instrument type or the sealer type.

In addition, CBCT-undetectable retained separated instruments in root canal–filled teeth may be identified by using periapical radiography, thus stressing the importance and validity of periapical radiography as the principal radiographic modality used for diagnosis and treatment planning before endodontic retreatment.

**Acknowledgments**

The authors deny any conflicts of interest related to this study.

**References**


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