Assessment of Volumetric Distortion Artifact in Filled Root Canals Using Different Cone-beam Computed Tomographic Devices

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Abstract

Introduction: Artifacts in cone-beam computed tomographic (CBCT) imaging may compromise radiodiagnosis. Obturation materials for endodontic treatment may present with variable material density and thus also cause distinct artifact expression. The aim of this study was to assess the volume distortion artifact of root canal sealers using CBCT devices and micro-CT imaging as a reference. **Methods:** Thirty single-root mandibular central incisors were used for this study. Teeth were prepared with EndoSequence rotary nickel-titanium files (Brasseler USA, Savannah, GA) and divided into 3 groups. Canals were obturated with gutta-percha and AH Plus root canal sealer (Dentsply Maillefer, Ballaigues, Switzerland) using single-cone filling techniques. Each tooth was scanned with different CBCT devices (ie, Promax 3D Max [Planmeca Inc, Roselle, IL], NewTom VGi evo [NewTom, Verona, Italy], and 3D Accuitomo 170 [J Morita, Kyoto, Japan]) with the same voxel size (0.2 mm^3) and compared with micro-CT imaging as a reference standard. **Results:** The results showed a significant difference in terms of volume distortion between micro-CT and CBCT images ($P < .05$). There were also significant differences among CBCT devices. Promax 3D Max measurements showed significantly larger root canal volumes than the other CBCT machines ($P < .05$). However, NewTom VGi evo and 3D Accuitomo 170 showed similar results without any significant difference ($P > .05$). **Conclusions:** CBCT devices showed more volumetric distortion artifact than micro-CT imaging. The volume was variable for different CBCT devices while scanning at the same voxel size. However, to assess the effect of sealer materials on CBCT imaging, further studies should be conducted for different sealers. *(J Endod 2017;■:1–5)*

Key Words

Artifact, cone-beam computed tomographic machines, micro–computed tomographic imaging, root canal sealer

Significance

CBCT devices showed larger root canal volume than micro-CT examination. A lower FOV, lower mA, and high kVp are preferable for fewer volumetric distortion artifacts in CBCT scanning.

Radiographic images have been widely used in dentistry for diagnostic and therapeutic processes. In general, clinicians often prefer periapical and panoramic radiographies. However, these radiographies are limited because of superimposition and lack of definition of anatomic structures present in 2-dimensional (2D) images. Recently, cone-beam computed tomographic (CBCT) imaging has been used in dentistry for its wide clinical ability to obtain 3-dimensional (3D) images (1, 2). Petersson et al (3) reported that CBCT imaging is a more sensitive and accurate diagnostic tool than conventional imaging tools, especially for endodontic cases. However, some authors (4–6) state that endodontic-treated teeth show the presence of many artifacts when CBCT devices are used. These artifacts are caused by high-density materials used in endodontic treatment (ie, root canal sealers, root canal pins, gutta-percha cones, and so on). Moreover, the settings of CBCT devices such as kVp, mA, voxel sizes, and field of view (FOV) can affect visibility and diagnosis in filled root canals when using different root canal materials (5). The beam-hardening phenomenon, 1 of the major causes of artifacts for endodontics, can generate dark streaks, hypodense halos (dark areas), and volume distortion that could show the shape of the material imprecisely. Artifacts cannot be eliminated yet, but they can be reduced using a less dense material or by applying artifact reduction algorithms in the CBCT images (6).

Micro–computed tomographic (micro-CT) scanning is a nondestructive, 3D imaging technique that has been used in endodontics for evaluating the quality of root fillings (7), root canal morphology (8), efficiency of preparation of endodontic files (9), evaluation of irrigation procedures (10), and so on. Generally, micro-CT imaging is accepted as the gold standard in these studies.

As previously described, the image artifact is likely to occur because of the density of several materials used in root canal treatment and is a risk factor in diagnosis about decision dimension and quality of root canal filling for clinicians. On most occasions,

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TABLE 1. Acquisition Parameters of Cone-beam Computed Tomographic (CBCT) Imaging

CBCT devices	FOV (cm)	mA	kVp	Voxel size (mm)
3D Accuitomo 170	4 × 4	5.0	90	0.2
NewTom VGi evo	5 × 5	3.0	110	0.2
Promax 3D Max	5 × 5.8	5.6	96	0.2

FOV, field of view.

researchers approach a 3D artifact problem using 2D measurements (11). It seems obvious that the 3D problem should be tackled in 3 dimensions. Therefore, the aim of this study was to compare the volumetric distortion artifact of root canal sealer by comparing different CBCT devices with the micro-CT reference using a 3D assessment.

Materials and Methods

The sample was composed of 30 human single-root mandibular central incisors extracted because of periodontal disease, which were without caries, root resorption, or fractures. Root surfaces were scaled with a Gracey curette (Nordent Manufacturing Inc, Elk Grove Village, IL) to remove soft tissue, calculus, and bone. Each tooth was placed in 5.25% sodium hypochlorite (NaOCl) for 2 hours for surface disinfection and then stored in distilled water until testing was performed. Preoperative periapical radiographies were taken to include only 1 straight root canal in the study. All teeth were decoronated from apical to coronal with a length of approximately 12 mm. The teeth were examined with an operating microscope (OPMI pico; Zeiss Co, Jena, Germany) and were selected only when in round canal shape.

A size #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the root canal until the tip was just visible beyond the apex. The working length was determined by subtracting 0.5 mm from this length. The canals were instrumented using a crown-down technique with EndoSequence rotary nickel-titanium files (Brasseler USA, Savannah, GA). The finishing file was 40/0.06. During the instrumentation, root canals were irrigated with 2 mL 5.25% NaOCl. The smear layer was then removed using 17% EDTA for 1 minute. The final rinse was performed with 3 mL 5.25% NaOCl and then with 3 mL distilled water. The root canals were dried using paper points, and the teeth were then divided randomly into 3 groups (10 roots per each group). Root canal sealer (AH Plus, Dentsply Maillefer) was prepared in accordance with the manufacturer's recommendations, and the root canals were then filled with a single-cone technique. After the filling process, the roots were stored at 37°C in 100% humidity for 10 days to ensure that the sealer was set.

CBCT Acquisition

Before image acquisition, the roots were placed in an empty tooth socket in a dry human mandible that was covered with a soft, tissue-mimicking material. The dry human mandible was scanned using 3 CBCT devices, namely, 3D Accuitomo 170 (J Morita, Kyoto, Japan), NewTom VGi evo (NewTom, Verona, Italy), and Promax 3D Max (Planmeca Inc, Roselle, IL). The protocols of each CBCT device are listed in Table 1.

Micro-CT Acquisition

To compare the results, all teeth were scanned with a high-resolution, desktop micro-CT system (SkyScan 1172; Bruker microCT, Kontich, Belgium) after acquiring images from CBCT imaging. The scanning conditions were set at 100 kVp, 100 mA, 0.5-mm Al/Cu filter, 13.67-μm pixel size, and 0.5 step rotation. To minimize ring artifacts, air calibration of the detector was performed before each scanning. Each sample was rotated 360° within an integration time of 5 minutes. The mean time of scanning was around 2 hours. Other settings included beam-hardening correction, and input of optimal contrast limits was set according to the manufacturer's instructions or based on prior scanning and reconstruction of the teeth.

CBCT Image Evaluation

All CBCT images were saved as a Digital Imaging and Communications in Medicine file format and transferred to Mimics software (version 17.0; Materialise NV, Leuven, Belgium). To obtain the root canal volume, segmentation was performed using automatic thresholding based on gray values. Subsequently, the 3D model was generated, and the volume of root canal was automatically obtained. One examiner trained to use the software performed the segmentation in a darkened room independently and blinded to previous readings. To segment the material inside the root canal, axial, sagittal, and coronal reconstructions were considered simultaneously.

Micro-CT Image Analysis

NRecon software (version 1.6.7.2, Bruker microCT) and CTAn (version 1.12.9, Bruker microCT) were used for the visualization and reconstruction of root canals. The modified algorithm (12) was used to obtain axial 2D images (1000 × 1000 pixels). For the reconstruction parameters, ring artifact correction and smoothing were fixed at 0, and the beam-hardening correction was set at 40%. Contrast limits were automatically applied following Bruker microCT's instructions. The CTAn software was used for the 3D volumetric visualization and the measurement of the volume of the root canal.

Statistical analysis was performed using SPSS 22.0 (SPSS Inc, Chicago, IL) software. Because the data were normally distributed, a paired sample *t* test was used to compare the intergroup differences at a significance level of 0.05.

TABLE 2. Comparison of Root Canal Sealer Cupping Artifact according to Cone-beam Computed Tomographic Devices

	Paired differences					
				95% confidence interval of the difference		
Imaging modalities	Mean	Standard deviation	Standard error of the mean	Lower	Upper	*P* value
Micro-CT–Promax 3D Max	−10.00	1.08	.34	−10.78	−9.23	.000
Micro-CT–NewTom Vgi evo	−7.15	1.16	.36	−7.98	−6.31	.000
Micro-CT–3D Accuitomo 170	−6.75	1.09	.34	−7.53	−5.96	.000
Promax 3D Max–NewTom VGi evo	2.85	1.54	.48	1.75	3.96	.000
Promax 3D Max–3D Accuitomo 170	3.25	1.53	.48	2.16	4.35	.000
NewTom VGi evo–3D Accuitomo 170	.40	1.62	.51	−.75	1.56	.452