Evaluation and Reduction of Artifacts Generated by 4 Different Root-end Filling Materials by Using Multiple Cone-beam Computed Tomography Imaging Settings

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Abstract

Introduction: After endodontic surgery, radiographic assessment is the method of choice to monitor bone defect healing. Cone-beam computed tomography scans are useful to check and identify the reasons of failure of surgical intervention or confirm healing; however, the artifact generated by some root-end filling material might compromise this task. The objective of the study was to compare the amount of artifacts generated by 4 root-end filling materials and to test multiple exposure settings used with these materials, when the effective dose generated by each protocol was taken into consideration. **Methods:** Twenty central incisors were endodontically treated with retrograde obturation by using amalgam, Biodentine, MTA, and Super-EBA (5 of each). They were placed in a skull with soft tissue simulation and scanned by using the Planmeca Promax Max with different kilovolt peaks (kVp): 66, 76, 84, and 96 with and without the use of metal artifact reduction (MAR) algorithm and with low, normal, and high resolution and high definition. The Dose Area Product was registered, and the effective dose was calculated. **Results:** Amalgam generated the highest amount of artifacts, whereas MAR and low resolution created fewer artifacts than other settings. The artifacts were also reduced with 96 kVp. The effective dose calculated with low resolution was remarkably lower than other resolutions. **Conclusions:** When used as root-end filling material, Biodentine, MTA, and Super-EBA generated fewer artifacts than amalgam. The use of 96 kVp with MAR and low resolution also reduced artifacts on the image and at the same time generated the lowest effective dose. *(J Endod 2016;42:307–314)*

Key Words

Artifact, beam hardening, CBCT, root-end filling

Artifacts are discrepancies between the reconstructed visual image and the actual content of the subject in relation to its characteristics. Accuracy of the radiographic images is reduced by these artifacts (1). Cone-beam computed tomography (CBCT) is suggested to be more sensitive and accurate diagnostic tool than conventional methods in various endodontic cases (2). However, the accuracy of CBCT can be compromised in root-filled teeth because of the presence of many artifacts such as noise, scatter, motion missing values, and rings as well as beam-hardening and streaking artifacts presenting image interpretation challenges (3). Image quality can be improved by changing some parameters during scanning procedure such as scan field of view (FOV) selection and voxel size (4). However, despite better image quality and high resolution, high-density materials such as metals can still cause some artifacts.

A surgical approach may be necessary when periapical inflammation cannot be resolved by conventional root canal treatment. An ideal root-end filling placed at the time of surgery is intended to provide a tight apical seal to prevent passage of microorganisms or their products into periradicular tissues. It should be dimensionally stable and induce healing of periradicular tissue (5). Furthermore, it must be clearly visible on radiographs to allow distinguishing materials from root dentin and adjacent bone (6, 7). Several root-end filling materials are currently in use. Among them, amalgam has been, and still is to some extent, an extensively used material. Super-EBA is a modified type of zinc oxide–eugenol cement with increased physical properties such as high strength, adhesion to dentin, low solubility, and low leakage (8). It also possesses increased biologic properties when compared with amalgam (9). Mineral trioxide aggregate (MTA) is very popular and widely used because it has many of the properties of an ideal root-end filling material including high biocompatibility, sealing ability, and low solubility (10). MTA-Angelus is produced from Portland cement with addition of bismuth oxide with higher radiopacity. Most recently, a new calcium silicate–based material Biodentine has become available with improved handling characteristics and mechanical properties (11).

The assessment of healing after endodontic surgery is often judged radiologically in follow-up examinations (6). CBCT scans can be useful to check and identify the reasons for failure of previous surgical procedure because of missed canals, recesses, isthmi, or undetectable apical cracks. Moreover, the root or root-end filling's quality and adaptation to root canal walls should be assessed. When determined by conventional radiography, the information about the 3-dimensional quality of root fillings is questionable in most cases (12). CBCT can provide multislice information in 3 dimensions that periapical radiography cannot (13). However, understanding the image formation principles and being familiar with the nature of the artifacts and their char-

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acteristic appearances in CBCT images are very important to avoid confusion with normal anatomy or postsurgical variations (1). Liang et al (14) emphasized that clinicians should be aware of "Mach band effect," which is the radiolucent line between the root filling and canal wall in CBCT images, and not to interpret this as a void. They also suggested training on interpretation of CBCT images of root fillings is needed. No information is provided about the identification of artifacts related to root-end filling materials during interpretation of CBCT images. This information could be helpful to reduce potential risks of misdiagnosing artifacts and voids in evaluating the adequate technical quality of root-end fillings. It is presently unknown whether these artifacts can be reduced by using different CBCT scan techniques or settings. The goal of a follow-up radiographic evaluation is to assess the healing process; the presence of artifacts compromises the ability to distinguish between anatomic low-density areas and dark areas caused by the artifacts. Therefore, the aim of this study was to evaluate CBCT scan techniques for interpretation and reduction of artifacts produced by 4 different root-end filling materials.

Materials and Methods

Sample Selection and Preparation

Twenty freshly extracted single-rooted maxillary central incisors were used for this study. Teeth were obtained from the collections of the Department of Oral and Maxillofacial Surgery, Kocaeli University, Faculty of Dentistry. The Ethics Committee of Kocaeli University approved this *in vitro* study (KOU KAEK 2015/161). The inclusion criteria were that the teeth have straight single roots with mature apices and similar lengths. Teeth presenting with apical curvature, root caries, resorption, previous root canal treatment, or restorations were excluded from the study. The teeth were circumferentially cleaned and stored in 0.1% thymol solution.

A size 10 K-file (Mani Inc, Tochigi-Ken, Japan) was placed passively in each root canal until it was visible at the apical foramen. The working length was set to be 0.5 mm shorter than this length. Root canals were instrumented by using ProTaper Universal rotary instruments (Dentsply Tulsa Dental Specialties, Tulsa, OK) up to size 40 (F4) operated with a torque-limited motor (VDW Silver; VDW, Munich, Germany). Throughout instrumentation, the canals were irrigated with 1 mL 2.5% sodium hypochlorite (NaOCl) at each change of instrument. A final irrigation with 5 mL 17% EDTA, 5 mL 2.5% NaOCl was followed by 5-mL rinse of distilled water. The canals were then dried with paper points (Diadent, Seoul, Korea). The root canals were filled by using the lateral condensation technique with gutta-percha and AH Plus (DeTrey Dentsply, Kontanz, Germany). Excess root filling in the coronal portion was removed 1 mm below the cementoenamel junction and vertically condensed with a heated plugger. The canal openings were sealed with temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). Teeth were stored at 37°C with 100% humidity for 1 week to allow the sealer to set.

Each root end was resected perpendicularly to its long axis at 3 mm from the apex with a diamond-coated cylindrical bur (Mani) in a high-speed handpiece under water spray. A 3-mm-deep root-end cavity was prepared with a thin fissure bur (#330; Mani). The samples were randomly assigned to 4 experimental groups (5 for each group), of which cavities were filled with 4 different root-end filling materials: amalgam (Tytin; Kerr Manufacturing Co, Romulus, MI), white MTA (Angelus; Londrina, PR, Brazil), Super-EBA cement (Harry J. Bosworth Co, Skokie, IL), and Biodentine (Septodont, Saint Maur des Faussés, France). The root-end materials were condensed by using pluggers with a snug fit. All root canal preparations, obturations, and root-end fillings were completed by the same operator. Teeth were then stored at 37°C with 100% humidity.

CBCT Imaging

Maxillary bone and soft tissues were simulated to mimic clinical situation. The root sample was placed in an empty maxillary anterior socket of a dried human skull. Unprepared anterior teeth collected from different individuals were fixed in their respective empty locations in the maxilla. The maxilla was covered with 4-mm-thick pink wax layer to simulate alveolar soft tissue during exposure.

The skull was placed in a round plastic box filled with water covering the entire maxilla. Markers were made at the edges of the plastic box to facilitate replacing the skull in the same position in the box (Fig. 1).

CBCT images for teeth filled with different material were acquired by using Planmeca CBCT machine (Promax 3D max; Planmeca, Helsinki, Finland). The CBCT images were taken with the following parameters: 66 kVp, 76 kVp, 84 kVp, and 96 kVp with no metal artifact reduction (MAR)–high resolution, no MAR–normal resolution, high MAR–low resolution, and high MAR–high definition. These were the most frequently used settings on the basis of different clinical situations. The images obtained at 6–10 mA, 100-150-200-400 μm voxel size, and approximately 4, 12, and 15 seconds of exposure time; the mA and exposure time were automatically adjusted by the machine according to the settings chosen.

Three hundred twenty volumes were exported by using multislice DICOM format with 0.16-mm thickness. For each scan acquired, an axial slice was used to evaluate the artifact that resulted from each filling material. One axial slice was chosen by the authors as the best representative for the artifact, the distance from the lower aspect of the volume to that slice was measured, and all other slices situated at the same distance from the inferior aspect of the scan were selected for each volume. Because the Phantom is exactly repositioned in the machine, all the slices would be identical.

Axial slices were evaluated with Image J (National Institutes of Health, Bethesda, MD). For gray value variation, a profile line was plotted on the wax located anterior to the apex containing the filling material (Fig. 2); the line is crossing through the straight lines of steaking artifact and beam-hardening dark bands. The difference between the highest and lowest gray values was calculated; it will be referred to as the artifact because of its major effect on the diagnostic ability of the images.

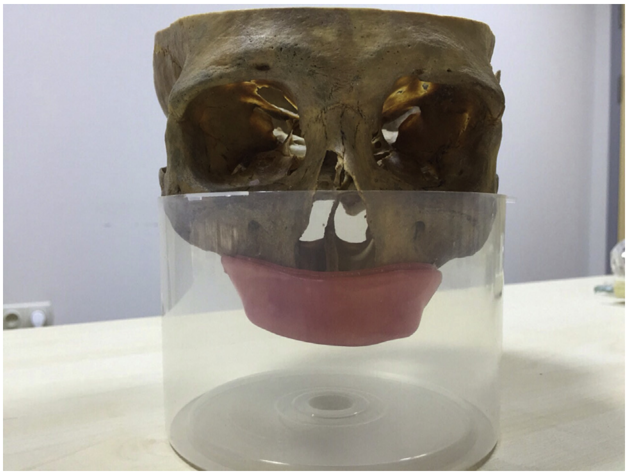

Figure 1. Skull mounted in the plastic box with wax covering the alveolar crest.