Identification of a C-shaped Canal System in Mandibular Second Molars—Part III: Anatomic Features Revealed by Digital Subtraction Radiography

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Abstract

The purpose of this study was to investigate the ability of digital subtraction radiography (DSR) to reveal anatomic features of C-shaped canal systems in mandibular second molars with the aid of an intraradicular contrast medium. Thirty mandibular second molars with fused roots were collected and stored in 10% formalin solution. After being scanned with microcomputed tomography (μCT) 20 and reconstructed, the root canals were mechanically and chemically cleaned of their pulp tissue. Buccal-lingual digital radiographic (radiovisiography [RVG]) images were taken with mandibular bone plates for each tooth. After the introduction of contrast medium into canals, RVG images were taken again in the same way as before. The digital images taken before and after contrast medium introduction were overlapped, and the image subtraction was performed by using the 3D Doctor software (Able Software Corp, Lexington, MA). All the subtracted canal images (DSR) and reconstructed canal images based on μCT scanning were classified into three categories (ie, type I, II, and III). The classifications based on reconstructed canal images were used as the standard to evaluate the sensitivity (Se) and specificity (Sp) of DSR classification. The results were subjected to the Wilcoxon statistical test, which showed there was no significant difference between the two classifications ($p > 0.05$). The DSR classification had a very high Se and Sp in all three categories. It is feasible to use the DSR technique clinically to identify anatomic features of the C-shaped canal system in mandibular second molars. *(J Endod 2008;34:1187–1190)*

Key Words

Anatomy, contrast medium, C-shaped canal, digital subtraction radiography, mandibualr second molar

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Successful root canal treatment is highly dependent on the thorough management of the canal anatomy (1–3). The use of periapical radiographs before, during, and after treatment is essential in order that canal anatomic details, canal length, quality of obturation, and bone pathology can be identified and monitored. Standard intraoral radiography using silver halide film is used widely as a reliable clinical method of determining canal anatomy (4, 5). The reported disadvantages of this method are exposure to ionizing radiation, especially when combined with the need for more than one view, and the time and facilities required to process and store films (4). Another problem that complicates radiographic assessment is that the radiographs may differ in brightness, contrast, and acquisition geometry (6) even if the conditions of film exposure and development are strictly controlled.

Direct digital systems for intraoral radiography have been available since the late 1980s and were based on charged-coupled device systems (7). Radiovisiography (RVG) is a type of direct digital radiography (DDR) system that is now used clinically as an adjunct for alternative radiographic documentation (4, 6). The DDR system offers many advantages over the conventional radiography such as ease and speed of use, reduction in time between exposure and image interpretation, less radiation dosage to the patient, elimination of chemical waste hazard, and the ability to digitally manipulate the captured image.

Although the RVG systems have many potential benefits, an important factor that limits the efficiency of RVG system lies primarily in the identification of image features buried in a background of normal anatomic structures (ie, "noises") such as the tooth and bone tissue images. Reduction of the background noise can be achieved by the digital subtraction radiography (DSR), which eliminates the identical image regions in a series of radiographs obtained in the same exposure position and at different time intervals. After the DSR, the image of changed anatomic structures will stand out and be shown clearly, whereas the image of unchanged anatomic structures will have been eliminated. To date, the application of DSR in observing the root canal anatomy has not been investigated fully.

To use DSR effectively to determine the presence of anatomic changes, whether natural or artificial, the use of a contrast medium is essential. The radiographic contrast medium is often used in clinic to change the radiopacity of some anatomic structures before the DSR. There have been many methods to introduce a water-soluble radiographic contrast medium into the root canal system, such as injecting the medium into the canal or placing the teeth under a vacuum to pull the medium into the canal irregularities (8, 9). These techniques could either only be used in a laboratory study or are ineffective in distributing a contrast medium in root canals (8, 9). In part I and II of this series studies, the device developed by Lussi et al. (10) for the noninstrumental technique was modified and proved successful in introducing contrast media into C-shaped canal systems (11, 12). This device and method satisfies the prerequisite for DSR in the determination of root canal anatomy.

Recently, microcomputed tomography (μCT) scans have been applied not only to evaluate canal shapes or cross-sections of teeth but also to diagnose or evaluate the location and size of periradicular lesions (13–16). The morphologic changes in the root canal shape before and after instrumentation may also be determined nondestructively in details by μCT (17–19). Therefore, the same apparatus is obviously suitable for an in-depth study of root canal anatomy. To obtain the real three-dimensional canal anatomy nondestructively, the root and canal cross-section images obtained by the μCT could be reconstructed by using specialized software.

The C-shaped canal system is a canal variant mostly seen in mandibular second molars, although it can also appear in maxillary and mandibular premolars and molars (20–22). The main anatomic feature of C-shaped canals is the presence of a fin or web connecting mesial and distal individual canals, which makes the canal cross-section C-shaped and presents much difficulty in its thorough cleaning and shaping. Recognition of a C-shaped canal configuration before treatment can surely facilitate a more effective management. Recent studies have revealed some radiographic features of the mandibular second molars with the C-shaped canal system (11, 23, 24) and found that there may be certain links existing between these radiographic features and the canal anatomy. These findings would help to determine the anatomy of the C-shaped canal system in mandibular second molars from preoperative radiographs.

The purpose of this study was to investigate the ability of DSR to reveal anatomic features of the C-shaped canal system in mandibular second molars with the aid of intraradicular contrast medium.

Materials and Methods

Thirty mandibular second molars with fused roots and a deep lingual longitudinal groove on the root surface were selected and stored in 10% formalin solution. All the teeth were scanned with μCT 20 (Scanco Medical AG, Brüttisellen, Switzerland) from crown to apex at 0.5-mm intervals. Based on these μCT images, the three-dimensional canal configuration of each tooth was reconstructed by using the 3D Doctor software (Able Software Corp, Lexington, MA) and were referred to as the gold standard for the assessment of subsequent canal image reading.

After scanning, the pulp chamber of each tooth was accessed by using an engine-driven fissure bur and unroofed completely with an Endo Z bur (Dentsply Surrey Ltd, United Kingdom) to gain the unimpeded entry to the canals and to prevent cutting on the chamber floor. The pulp tissue in each canal was removed by a fine-barbed broach (Dentsply Maillefer, Bailluges, Switzerland) without exerting any apical or lateral pressure. Subsequently, the teeth were soaked in 5% sodium hypochlorite (NaOCl) solution for 30 minutes to make sure the NaOCl solution dissolved the pulp tissue residues in the root canal system (11). The canals were then irrigated with 20 mL distilled water, and a jet of water from apical foramina indicated patency. Canals without a visible jet of water from apical foramina were instrumented carefully with a No.20 Lightspeed (Lightspeed Technology Inc, San Antonio, TX) instrument until all of the canals were negotiated through the apical foramen (11). Then, the canals were irrigated with 20 mL 5% NaOCl solution and 20 mL distilled water and dried briefly with an air syringe.

The roots of all thirty teeth were covered totally with sticky wax to seal all possible canal exits on the root surface. Then, the teeth were put onto the same radiographic device described in part I and II of this continuing study (Fig. 1) (11, 12), and buccal-lingual radiographic RVG digital images were taken with mandible plates in the same way as that in part II (12). The vacuum device designed in part I was used to introduce the 76% compound meglumine diatrizoate (Xudong Haipu Pharmaceutical Co Ltd, Shanghai, China), a commonly used contrast medium, into the canal system. After the contrast medium was introduced, the RVG digital images with the mandible plates were taken as aforementioned. During image exposure, the positions of teeth, bone plates, x-ray tube, and RVG charged-coupled device were strictly kept unchanged. The x-ray exposure time was 0.16 seconds. A 4-mm wide step wedge made of aluminum 1100 (25, 26) was fixed onto the jig 3 mm above the occlusal surface of the teeth as the reference standard of radiographic density in all images. The step wedge contained 10 steps with 2 mm as each step span. All the digital images were captured and stored in a computer. The digital images taken before and after introducing the contrast medium were overlapped and subtracted by using the software 3D Doctor to obtain the DSR images of C-shaped canal system. All the DSR images and buccal-lingual reconstructed canal images based on μCT scanning were classified by three precalibrated and standardized endodontic postgraduate students into the following three categories (Fig. 2): (1) type I (merging type): canal images merged into one major canal before exiting from the apical foramen; (2) type II (symmetrical type): there were separate mesial and distal canals, and the mesial and distal canals appeared to be symmetrical in their size and continued on their own pathway to the apex; and (3) type III (asymmetrical type): there were separate mesial and distal canals, and the mesial and distal canals appeared to be asymmetrical in their size and continued on their own pathway to the apex; the distal canal seems much wider than the mesial canal.

Any variances or disagreements in the classification were discussed among the observers until an agreement was reached. The kappa value, which was subject to the U test for significance at $p = 0.05$, was calculated to be 0.85, suggesting very good interobserver agreement (9). The classifications based on reconstructed canal images were used as the standard to evaluate the sensitivity (Se) and specificity (Sp) of DSR image classification, and the results were subjected to the Wilcoxon statistical test. The statistical significance was considered at $p < 0.05$.

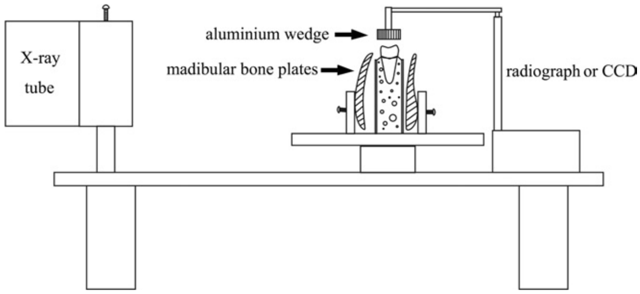

Figure 1. An illustration of the radiographic device used in this study.

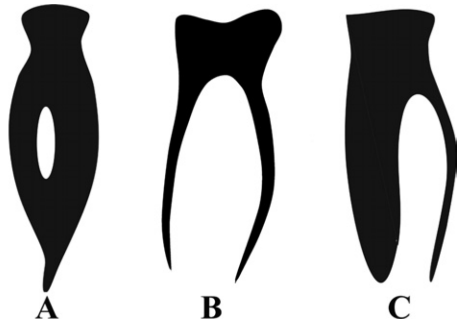

Figure 2. Canal image classification: (*A*) type I, (*B*) type II, and (*C*) type III.

TABLE 1. Classifications Based on DSR Images and μCT Reconstruction

Observation Methods	Classification (No. of Teeth)		
	I	II	III
DSR	11	11	8
reconstruction	12	9	9

DSR, digital subtraction radiography; μCT, microcomputed tomography.

T (T value, Wilcoxon statistical test) = 0.001, p = 1.00.