A High-resolution Computed Tomographic Study of Changes in Root Canal Isthmus Area by Instrumentation and Root Filling

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Abstract

Introduction: The aim of this study was to obtain a three-dimensional analysis of the isthmus area of the mesiobuccal root canal system in mandibular molars using high-resolution micro–computed tomography (μ-CT) scanning and to measure the amount of debris and root filling material in the isthmus after instrumentation/irrigation and root filling. **Methods:** Mandibular molars with two separated mesial root canals (10 teeth) were scanned by using the Skyscan 1172 μ-CT system (Skyscan, Aartselaar, Belgium) before and after instrumentation and after filling using the Thermafil root filling technique. An isthmus was defined as the ribbon-shaped or thin connecting structure between two root canals after instrumentation. The characteristics of the isthmuses were quantitatively monitored during the whole treatment. The images were segmented and quantified. The surface area of the isthmus, volume of debris after rotary instrumentation, and volume of the filled space in the isthmus after obturation were evaluated. **Results:** Of the seven mesial roots, two had isthmus/anastomoses somewhere along its length in the apical 5 mm, and five had an isthmus that was continuous all the way from the coronal part to the apical part. The average percentage of isthmus surface area and isthmus volume after instrumentation was 21.4% and 9.4% of the whole root canal system, respectively. About 35.2% of the isthmus volume was filled with apparent hard tissue debris after instrumentation/irrigation. The average percentage of volume of filling material in the isthmus areas was significantly lower (57.5%) than in the main root canals (98.5%, $p < 0.001$). **Conclusions:** A considerable amount of dentin debris is produced and packed into the isthmus area during rotary instrumentation of mesial canals of lower molars despite continuous irrigation during and after instrumentation. The debris may partly prevent penetration of the filling material and sealer into the isthmus area. *(J Endod 2011;37:223–227)*

Key Words

Debris, isthmus, instrumentation, micro–computed tomography scanning, root filling

The goal of endodontic therapy is the removal of all vital or necrotic tissue, microorganisms, and microbial byproducts from the root canal system. Although this may be achieved through chemomechanical debridement (1), it is difficult to predictably reach this goal (2–4) because of the intricate nature of root canal anatomy (5–7). Isthmuses, fins, webs, and other irregularities within the root canal often harbor tissue, microbes, and debris after instrumentation (8).

Instrumentation of the root canal system must always be supported by an irrigation capable of removing pulp tissue remnants and other loose material. The efficacy of an irrigation delivery system is dependent not only on its ability to deliver the irrigant to the apical and noninstrumented regions of the canal space and to create a current strong enough to carry the debris away from the canal systems (9–13) but also on the ability of the irrigating solutions to dissolve both organic and inorganic matter. The effervescence created by conventional irrigation with syringes has been used to remove debris from the root canal although without tissue dissolving ability of the solutions this alone is not effective. Irrigation also is essential for eliminating or reducing the number of bacteria in an infected root canal. There has been increased interest in recent years in the effect of instrumentation and irrigation on the isthmus area. Comparative studies with traditional needle irrigation and irrigation facilitated by ultrasound indicated that complete soft-tissue removal requires effective ultrasonic agitation of sodium hypochlorite (14).

High-resolution micro–computed tomography (μ-CT) scanning is an emerging technology with several promising applications in different fields of dentistry. In endodontic research, μ-CT technology is frequently used for the study of root canal anatomy and for the assessment of changes in root canal morphology by instrumentation (7, 15–21). The quality of root canal obturation has also been investigated by μ-CT (22–26), and a few studies have focused on filling of the isthmus area by obturation. Recently, Paqué et al (8) showed that dentin debris is formed and packed into the isthmus area during rotary instrumentation. However, no irrigation was used in this study, leaving the question of the role of irrigation in debris retention unanswered. The aim of this study was therefore (1) to examine if dentin debris is packed into the isthmus area of mesial roots of lower molars during rotary instrumentation and vigorous irrigation using high-resolution μ-CT scanning; (2) to measure the amount of dentin debris, if any, in the isthmus after instrumentation/irrigation; and (3) to measure the percentage of the volume of the isthmus area filled by gutta-percha coated solid core thermoplastic root filling.

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Materials and Methods

Root Specimens

Ten extracted mandibular molars were externally cleaned with pumice and then stored in 0.001% sodium hypochlorite (NaOCl) before use. The pulp chambers and mesial root canals were accessed conventionally. Size 10 K-type files were inserted through both the mesiobuccal and mesiolingual canals 1 mm beyond the apical foramen (two separated canals all the way to the apex) to establish apical patency. The working length was established 1 mm shorter than the length of the root. The tooth specimens were embedded in acryl, which was then polymerized. Scanning of the embedded teeth was performed with the Skyscan 1172 μ-CT system (Skyscan, Aartselaar, Belgium).

The canals were prepared with six ProTaper Universal rotary instruments (Dentsply Tulsa Dental Specialties, OK) in the sequence recommended by the manufacturer (S1, S2, F1-F4). Apical enlargement of the root canal was carried out to size F4 (#40, 06 taper); 5% NaOCl was used as the first irrigating solution delivered with a 30-G Max-i-Probe needle (Dentsply-Rinn, Elgin, IL) placed to 1 mm short of working length. Each canal was filled with irrigant during instrumentation. Two milliliters of 5% NaOCl was used to irrigate the canal between each instrument. After completed instrumentation, the canal was irrigated with 10 mL 5% NaOCl for 5 minutes followed by 17% EDTA (5 mL) for 3 min. The tooth specimens were scanned for the second time with the μ-CT.

Root Filling

All canals (14 canals) were fitted with Thermafil ProTaper point (Dentsply Maillefer, Ballaigues, Switzerland) size F4. A Thermaprep oven (Dentsply, Maillefer) was used to soften the gutta-percha on the Thermafil points as recommended by the manufacturer. A thin layer of sealer (AH Plus, Tulsa Dental) was applied to the canal walls with a size 35 paper point (taper .02; Maillefer, Ballaigues, Switzerland) before filling with a size F4 Thermafil point following the manufacturer's instructions. Excess coronal gutta-percha and the plastic handle were removed with a Thermacut bur without water cooling, and the gutta-percha was vertically condensed with root canal pluggers (model LM 41-42 XSi; LM-Dental, Naantali, Finland). Access cavities were sealed with intermediate restorative material (Dentsply Caulk, Milford, DE) and the teeth were stored at 37°C in 100% humidity until being scanned for the third time by the μ-CT scanner.

μ-CT Measurements and Evaluations

A commercially available high-resolution Skyscan 1172 μ-CT system was used to scan the specimens before and after instrumentation and after obturation. The x-ray tube was operated at 75 kV and 100 mA (0.5 mm Al filter), and the scanning was performed by 360° rotation around the vertical axis and with rotation step of 0.3°. The cross-sectional pixel size and intersection distance were 11 μm. Subsequently, the cross-section image was reconstructed from the projection image with beam-hardening compensation of 45%. The cross-section images were segmented, registered, visualized, and quantified by using image software from Mevislab (Germany) (available from www.mevislab.de/) (27). The isthmus was defined as the ribbon-shaped or thin structure between the two mesial root canals after preparation. Accordingly, the isthmus was segmented with Mevislab software and the volume and the surface area of the isthmus were calculated. In addition, the following parameters were measured: the volume of debris and the volume of the filled space (by Thermafil and sealer) in the isthmus after instrumentation and obturation, respectively. Three teeth were excluded because of technical errors in scanning (because the samples mounted on stubs were slightly moved during scanning process).

The debris in the isthmus after instrumentation was identified and calculated as follows: voxels with black color were identified as soft tissue, liquid, or air (black color) in the preoperative scan; in the second scan, voxels that had changed from black to opaque were assumed to be dentin debris. The unfilled space of the isthmus after filling was identified and calculated as follows: voxels in the isthmus that were identified as soft tissue, liquid, or air (black color) in the preoperative scan and that were not occupied with debris or filling material (bright, opaque color) in the postobturation scan were considered to be the unfilled space of the isthmus. Three-dimensional images of the three stages were generated for visualization. Data were analyzed using a nonparametric test (Mann-Whitney rank sum test).

Results

Of the seven mesial roots, two had isthmus or anastomoses somewhere in the apical 5 mm of the root, and five had an isthmus that was continuous all the way from the coronal part to the apical part (Figs. 1 and 2). The percentage of isthmus surface area and volume were 21.4% (12%-27%) and 9.4% (3%-15%) of the whole root canal system after instrumentation, respectively (Table 1); 35.2% (13%-56%) of the volume of the isthmus was filled with apparent hard tissue debris after instrumentation/irrigation. The average percentage of the volume of filling material in the isthmus areas was significantly lower (57.5%: 45%-68%) than in the main root canals (98.5%: 97%-99%) ($p < 0.001$).

Discussion

The present research used a model that allows for the assessment of changes of the root canal isthmus area caused by instrumentation/irrigation and root filling. In recent years, the resolution of μ-CT has improved considerably from 81 μm (18) and values between 34 and 68 μm (7, 20, 23) to 25 μm (28). At present, axial scanning steps of 14 μm are possible (25, 29). The SkyScan 1172 system could provide nondestructive three-dimensional microscopy of the internal structures of small objects with high spatial resolution and unprecedented speed. The advantage of such a high resolution is a greater accuracy of the rendered images. The main morphologic characteristic of isthmuses in molars is the presence of a fin, web, or ribbon connecting the main root canals. In the present study, the isthmus was defined as a narrow, often ribbon-shaped communication between two root canals after instrumentation. Instrumentation created a round bulge in the main canal, leaving unprepared area(s) between the two mesial canals. Therefore, the consistent definition of boundaries of the isthmus area from μ-CT images was possible after instrumentation. A limitation in the present and similar studies is the fact that only hard-tissue debris and filling material can be viewed; the remaining soft tissue is invisible. This is because μ-CT scanning is based on radiographic images. Theoretically, it could be possible to obtain indirect evidence of the presence of residual organic/soft tissue in the root canal (eg, a thin line between an opaque root filling material and mineralized dentin might be an indication of soft-tissue debris [or predentin] that remains in the canal space after instrumentation/irrigation and filling).

To our knowledge, this is the first study in which accumulation of dentin debris in the isthmus area during rotary instrumentation/irrigation and its relationship to subsequent penetration of filling material have been quantitatively monitored in human teeth. The only previous micro-CT study in which packing of dentin debris by rotary instruments into isthmus and other noninstrumented areas was examined was done without irrigation (8). The main goals of these two studies are different; in the previous study, the goal obviously was to answer a baseline question: do rotary NiTi instruments create debris when cutting dentin and to

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