Micro–computed Tomographic Evaluation of Dentinal Microcrack Formation after Using New Heat-treated Nickel-titanium Systems

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Abstract

Introduction: The aim of the present study was to evaluate the frequency of dentinal microcracks observed after root canal preparation with HyFlex CM (Coltène/Whaledent, Altstätten, Switzerland), HyFlex EDM (Coltène/Whaledent), Vortex Blue (Dentsply Tulsa Dental Specialties, Tulsa, OK), and TRUShape (Dentsply Tulsa Dental Specialties) systems using micro–computed tomographic (micro-CT) analysis. **Methods:** Forty human mandibular incisors with 1 and straight root canals were randomly assigned to 4 experimental groups (n = 10) and 1 control group for root canal preparation: group 1, HyFlex CM; group 2, HyFlex EDM; group 3, Vortex Blue; and group 4, TRUShape. The specimens were scanned using high-resolution micro-CT imaging before and after root canal preparation. Afterward, preoperative and postoperative cross-sectional images of the teeth were screened to identify the presence of dentinal defects. The number of microcracks was determined as a percentage for each group. **Results:** Before and after canal preparation, 36,152 cross-sectional images were examined. Four thousand four hundred fifty-two (12.31%) dentinal defects were observed. No new microcracks were observed after root canal instrumentation with the tested systems. **Conclusions:** Root canal preparation with the HyFlex CM, HyFlex EDM, Vortex Blue, and TRUShape systems did not induce the formation of new dentinal microcracks on straight root canals of mandibular incisors. *(J Endod 2017;■:1–4)*

Key Words

Dentinal microcracks, heat-treated nickel-titanium files, micro–computed tomography, root canal preparation

Significance

There is no causal relationship between instrumentation with heat-treated NiTi files and dentin damage.

The development of new nickel-titanium (NiTi)-based root canal preparation systems has primarily been based on changes in instrument design, alloys, and kinematics (1). Recently, manufacturers have developed NiTi superelastic alloys with special thermomechanical processing so that these NiTi alloys include a martensitic phase that is stable under clinical conditions (2). These new heat-treated NiTi instruments (eg, R-Phase NiTi [SybronEndo, Orange, CA], M-Wire [Dentsply Tulsa Dental Specialties, Tulsa, OK], and CM Wire [Coltène/Whaledent, Cuyahoga Falls, OH]) have shown better physical and mechanical properties compared with NiTi instruments with the traditional alloy (3, 4).

The main aim is to produce heat-treated instruments that are more flexible and more resistant to cyclic fatigue compared with instruments made with the traditional NiTi alloy (5). The result is the development of a novel heat-treated NiTi root canal preparation instrument called TRUShape (Dentsply Tulsa Dental Specialties). The heat treatment is applied after flutes are ground into blanks from commercially available NiTi to shape set a file into characteristic bends (6). There is an S-curve and a taper of 0.06 in the apical 2 mm; however, because of the specific shape, the overall taper of the instrument is variable and is therefore denoted as /.06v. The set of files consists of number #20, #25, #30, and #40 instruments, and all instruments have the same symmetric triangular cross section. The maximum fluted diameter for all sizes is limited to 0.80 mm with a regressive taper (7).

Vortex Blue rotary files (Dentsply Tulsa Dental Specialties) use a new and proprietary method of processing NiTi wire that results in a distinctive blue color because of a visible titanium oxide layer. The proprietary processing of Vortex Blue rotary files is said to reduce shape memory with respect to standard NiTi files, which tend to revert to their original straight shape because of the shape memory characteristics of standard NiTi. This property gives the Vortex Blue files the ability to maintain the shape given them (2).

Recently, controlled memory (CM) wire (Coltène/Whaledent, Altstätten, Switzerland) made with thermally treated NiTi alloy has been introduced. Because of the austenite/martensite transformation as a result of heat treatment, CM wire has a stable martensitic microstructure at body temperature (8). Therefore, the structure of HyFlex CM (Coltène/Whaledent) enables significant fatigue resistance, ease of bending, and the ability to return to its original shape when heated above the transformation temperature (9). The recently introduced HyFlex EDM (HEDM) file (Coltène/Whaledent) is

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the first endodontic instrument produced using electrodischarge machining (EDM) (9). HEDM instruments are manufactured from the same CM wire, similar to HyFlex CM. However, EDM technology involves a noncontact thermal erosion process that partially melts and evaporates the wire via high-frequency spark discharges (9, 10). HEDM files have a tip size of 25 with a 0.08 taper. This new file has 3 different cross-sectional zones over the entire length of the working part (rectangular in the apical part and 2 different trapezoidal cross sections in the middle and coronal parts of the instrument's working portion) to increase its fracture resistance and cutting efficiency (11).

In recent years, micro–computed tomographic (micro-CT) technology has opened new possibilities for endodontic research by allowing nondestructive volumetric quantitative and qualitative assessments before and after different endodontic procedures (12). To the best of our knowledge, no studies have evaluated the incidence of dentinal microcracks resulting from the use of the new heat-treated NiTi file systems. Therefore, the present study was designed to evaluate the frequency of dentinal microcracks observed after root canal preparation with HyFlex CM, HyFlex EDM, Vortex Blue, and TRUShape systems using micro-CT analysis.

Materials and Methods

Teeth Selection

After approval by the ethics committee (15-KAEK 073), mandibular incisor teeth were collected for this study. Radiographs (mesiodistal buccolingual) were taken to detect single canal, resorption, calcification, and anatomic variation defects of the teeth. Inspection of the root surface of the teeth was performed using a stereomicroscope (×10) (Nikon, Tokyo, Japan), and roots that had cracks or external defects were excluded. After radiographic and microscopic examination, a total of 40 noncarious, closed apex, straight root canals (<5°) and single-canal mandibular incisor human teeth were used.

Before root canal instrumentation, teeth were prescanned at a low isotropic resolution (33 μm) using a micro-CT scanner (Skyscan 1174; Skyscan, Kontich, Belgium) at 50 kV and 800 μA. Each sample was then scanned with the same field correction settings, a rotational step of 0.7°, 360° rotation around the vertical axis, a 2300-millisecond exposure time, and frame averaging of 3. Reconstruction of images was performed using NRecon software (NRecon version 1.6.9.4; Bruker microCT, Skyscan). During the reconstruction, 40% beam hardening correction, ring artifact reduction, smoothing, and frame averaging were individually adjusted to optimum values for each sample. Next, 400 to 500 transverse cross-sectional micro-CT slices were obtained per root.

Specimen Preparation

The working length (WL) was determined using a size 10 K-file that was placed into the root canal until it was visible at the major apical foramen. The teeth were divided into 4 equal groups (n = 10) in preparation for root canals using different NiTi file systems.

HyFlex CM Group. HyFlex CM files were used with a rotation speed of 500 rpm and 2.5 Ncm in a gentle in-and-out motion with the endodontic motor. The HyFlex CM files were used in the following sequence: size 25, .08 taper (two thirds of the WL); size 20, .04 taper; size 20, .06 taper; and size 25, .06 taper (the full WL).

HEDM Group. Root canals were enlarged with a K-file (up to #20) to establish an apical glide path in accordance with the manufacturer's recommendations. The endodontic motor was set at 400 rpm and a torque of up to 2.5 Ncm in rotary motion. The HEDM 25/∼ OneFile was used for enlargement of the root canal up to the WL.

Vortex Blue Group. Before shaping with Vortex Blue files, orifices were enlarged with the #20/.08 instrument up to a maximum insertion depth of 3 mm. Using an electric motor at 500 rpm and 3 Ncm, rotaries were used in the following initial sequence: size #30/.04 to the midroot, #25/.04 to two thirds of the WL, #20/.04 to the WL, and 20/.06 to the WL. Canals were then further enlarged using #25/.06 to the WL.

TRUShape Group. Root canal instrumentation was performed with TRUShape instruments with sizes 20.06 and 25.06. The endodontic motor was set at 300 rpm and 3 N torque. The instruments were used in in-and-out motions using slight apical pressure and then removed and cleaned with gauze. The canal was irrigated with 3 mL sodium hypochlorite. The instruments were used until the WL was reached.

A single operator completed all root canal preparations. During the preparation process, 10 mL 1% sodium hypochlorite was used per canal in all instrument groups, and root canals were dried with absorbent paper points. After the preparation process, the teeth were rescanned using the previously described parameters.

Dentinal Microcrack Evaluation

Reconstructed images were transferred to the DataViewer program (version 1.5.2.4, Bruker microCT), and 3-dimensional reimaging was performed. In this way, coronal, sagittal, and transaxial axes images were obtained for each sample. Before and after canal preparation, the cross-sectional images from all the scans were evaluated. Ultimately, a total of 36,152 cross-sectional images of all teeth were obtained. The images of the samples before and after preparation were opened simultaneously; they were compared twice by 2 blinded observers, and any microcracks were marked. The internal surface of the root canal or external root surface of any part or the craze lines were defined as having "no defect"; all other lines (eg, a craze line, a partial crack, fractures, or microcracks) were defined as "defects" (13). In cases of disagreement between the observers, images were re-examined until a consensus was reached.

Results

Examining the 36,152 cross-sectional images, we observed 4452 (12.31%) dentinal defects. The presence of dentinal microcracks was observed in 4.30% (n = 1556), 1.91% (n = 694), 2.89% (n = 1046), and 3.19% (n = 1156) of the cross-sectional images in the HyFlex CM, HyFlex EDM, Vortex Blue, and TRUShape groups, respectively. All dentinal defects identified in the postoperative scans were already present in the corresponding preoperative images (Fig. 1). Therefore, no new microcracks were observed after root canal instrumentation with the tested systems, and there was no change in the longitudinal length of the preexisting microcracks.

Discussion

In the current study, the effect of 4 recently developed NiTi systems (HyFlex CM, HEDM, Vortex Blue, and TRUShape) in terms of the incidence of dentinal defects created during root canal preparation was evaluated. The same tip and taper (25/.06) were used for rotary instruments. In all groups, all dentinal microcracks observed in the postoperative cross-sectional images already existed in the corresponding preoperative images. Therefore, mechanical enlargement procedures could not be associated with the formation of new dentinal cracks. This result agrees with several previous micro-CT studies that have shown no correlation between root canal preparation and the initiation and/or propagation of dentinal microcracks (1, 12, 14).

Despite the existence of many microcrack studies that use destructive sectioning methods, to date, only a few dentinal microcrack studies