Micro–computed Tomography Study of Oval-shaped Canals Prepared with the Self-adjusting File, Reciproc, WaveOne, and ProTaper Universal Systems

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Abstract

Introduction: The newly developed single-file systems claimed to be able to prepare the root canal space with only 1 instrument. The present study was designed to test the null hypothesis that there is no significant difference in the preparation of oval-shaped root canals using single- or multiple-file systems. **Methods:** Seventy-two single-rooted mandibular canines were matched based on similar morphologic dimensions of the root canal achieved in a micro–computed tomographic evaluation and assigned to 1 of 4 experimental groups ($n = 18$) according to the preparation technique (ie, Self-Adjusting File [ReDent-Nova, Ra'anana, Israel], WaveOne [Dentsply Maillefer, Ballaigues, Switzerland], Reciproc [VDW, Munich, Germany], and ProTaper Universal [Dentsply Maillefer] systems). Changes in the 2- and 3-dimensional geometric parameters were compared with preoperative values using analysis of variance and the post hoc Tukey test between groups and the paired sample t test within groups ($\alpha = 0.05$). **Results:** Preparation significantly increased the analyzed parameters; the outline of the canals was larger and showed a smooth taper in all groups. Untouched areas occurred mainly on the lingual side of the middle third of the canal. Overall, a comparison between groups revealed that SAF presented the lowest, whereas WaveOne and ProTaper Universal showed the highest mean increase in most of the analyzed parameters ($P < .05$). **Conclusions:** All systems performed similarly in terms of the amount of touched dentin walls. Neither technique was capable of completely preparing the oval-shaped root canals. *(J Endod 2013;39:1060–1066)*

Key Words

Micro–computed tomography, nickel-titanium instruments, reciprocating motion, root canal preparation, self-adjusting file

The development of nickel-titanium (NiTi) rotary file systems has resulted in a progress in the mechanical preparation of the root canal space (1, 2). However, the current technology for mechanical preparation has failed in debriding oval-shaped canals, leaving untouched fins or recesses on the buccal and/or lingual extensions (3–6). These untouched recesses may harbor unaffected residual bacterial biofilms and serve as a potential cause of persistent infection and poor treatment outcome (5–8).

The Self-Adjusting File (SAF; ReDent-Nova, Ra'anana, Israel), a hollow file composed of 120-μm-thick NiTi lattice, was introduced with a concept of a single instrument to prepare the entire root canal. During operation, the SAF adapts itself 3 dimensionally to the irregular shape of the root canal and, rather than machining its central portion into a round cross-section, it maintains the original canal shape with slightly larger dimensions (9). Previous studies have shown that the SAF system was particularly advantageous in promoting cleaning, shaping, and disinfection of oval-shaped canals compared with rotary files (3–6, 10, 11). The newly developed reciprocating instruments Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) are made of a special NiTi alloy (M-Wire) (12) and are also claimed to be able to mechanically prepare the root canal space with only 1 instrument (12–19). These files are available in 3 different sizes, which are indicated to be used according to the canal diameter (19). Initial reports using these instruments in extracted teeth have shown that they can debride the root canal space similarly to conventional rotary systems (12, 13, 17).

Several methodologies were developed to evaluate the shaping ability of NiTi systems (2). These methodologies have been successfully used for many years; however, some inherent repeatedly discussed limitations have encouraged the search for new methods that are able to produce improved results (20, 21). The development of X-ray micro–computed tomography (μCT) has gained increasing significance in the study of dental tissues (22) because it offers a noninvasive technique for 3-dimensional (3D) assessment of the root canal system (3, 11, 20, 22–28).

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Even though there is accumulating evidence of the safety and shaping effectiveness of the Reciproc R25 and WaveOne Primary (25.08) (12, 13, 15, 18, 19), knowledge of the shaping ability of Reciproc R40 and WaveOne Large (40.08) is still lacking (16). Therefore, the purpose of this study was to compare single- and multiple-file systems by testing the null hypothesis that there is no difference between them in the preparation of oval-shaped root canals using 3D μCT analysis.

Materials and Methods

Teeth Selection

After ethics committee approval, 100 straight single-rooted human mandibular canine teeth with fully formed apices and a single root canal were randomly selected from a pool of extracted teeth, decoronated slightly above the cementoenamel junction, and stored in labeled individual plastic vials containing 0.1% thymol solution. Each root was radiographed both in buccolingual and mesiodistal projections, and the canal diameter measured 5 mm from the apex. When the buccolingual diameter was 2.5 or more times larger than that of the mesiodistal diameter, the canals were classified as oval shaped.

After being washed in running water, each tooth was dried, mounted on a custom attachment, and scanned in a μCT scanner (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium) operated at 50 kV and 800 μA (0.5-mm Al filter). The scanning was performed by 180° rotation around the vertical axis with a rotation step of 1°. The cross-sectional pixel size and intersection distance were 19.6 μm. Images of each specimen were reconstructed (NRecon v.1.6.3, Bruker-microCT) providing axial cross-sections of their inner structure. For each tooth, evaluation was performed for the full canal length in approximately 600–800 slices per specimen. CTAn v.1.12 software (Bruker-microCT) was used for the 2-dimensional (2D) (area, perimeter, roundness, major diameter, and minor diameter) and 3D (volume, surface area, and structure model index) evaluation of the root canal. The structure model index (SMI) involves a measurement of surface convexity in a 3D structure. An ideal plate, cylinder, and sphere have SMI values of 0, 3, and 4, respectively (29). CTVol v.2.2.1 software (Bruker-microCT) was used for visualization and qualitative evaluation of the specimens.

Each root canal was negotiated with a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) and the coronal third flared with a #2 LA Axxess Stainless Steel bur (SybronEndo, Orange, CA) using circumferential motion followed by irrigation with 5 mL 2.5% NaOCl. Subsequently, apical patency was determined by inserting a size 10 K-file into the root canal until its tip was visible at the apical foramen, and the working length (WL) was set 1.0 mm shorter of this measurement. Size 15 and 20 hand files were used at the WL to create a #20/.02 glide path.

From the initial sampling (N = 100), 72 teeth were matched to create 18 foursomes based on the morphologic dimensions of the root canal assessed in the initial μCT evaluation. One tooth from each foursome was randomly assigned to 1 of 4 experimental groups (n = 18). After the groups were established, a flip of a coin was used to define which group of teeth would be treated with each of the following root canal preparation techniques: SAF, WaveOne, Reciproc, or ProTaper Universal systems. After checking the normality assumption (Shapiro-Wilk test), the degree of homogeneity (baseline) of the 4 groups with respect to the previously mentioned parameters of the root canal was assessed using 1-way analysis of variance with a confidence interval of 95%.

Root Canal Preparation

A 1.5-mm diameter SAF instrument was inserted into the root canal and operated to the WL with an in-and-out motion using a vibrating handpiece (GentlePower Lux 20LP; KaVo, Biberach, Germany) combined with a RDT3 head (ReDent-Nova). Continuous irrigation with 2.5% NaOCl was applied throughout the procedure at a flow rate of 5 mL/min using a special irrigation apparatus (VATEA, ReDent-Nova). WaveOne Large (40.08) and Reciproc R40 (40.06) instruments were introduced into the canal until resistance was felt and then activated in reciprocating motion generated by a 6:1 contra-angle handpiece (Sirona, Bensheim, Germany) powered by an electric motor (VDW Silver; VDW GmbH, Munich, Germany). The instruments were moved in the apical direction using an in-and-out pecking motion of about 3 mm in amplitude with a light apical pressure. After 3 pecking motions, the instruments were removed from the canal and cleaned. ProTaper Universal instruments were used in continuous clockwise rotation (VDW Silver) using a gentle in-and-out motion in a modified crown-down manner. SX was used at two thirds of the WL, S1 and S2 at WL − 1 mm; and then F1, F2, F3, and F4 at the WL. Each set of instruments was used to enlarge 2 canals only.

All preparations were performed by 1 operator (MAV) with clinical experience in all systems. In all groups, the total preparation time was 4 minutes and included only active instrumentation. Once each instrument had been negotiated to the end of the canal and had rotated freely, it was used in a light brushing motion. In the rotary and reciprocating groups, passive ultrasonic irrigation was performed every 15 seconds at the WL using a size #15 K file with a total of 20 mL 2.5% NaOCl. At the end of preparation, the canals were flushed with 2 mL 17% EDTA for 5 minutes and 2 mL distilled water for 1 minute; the canals were dried with paper points; and the roots were submitted to a postoperative μCT scan and reconstruction, applying the initial parameter settings.

Evaluation of the Root Canal Preparation

3D root canal models were reconstructed on the basis of μCT scans, and the superimposition of pre- and postpreparation images was ensured by means of a previously validated registration software (Mosaic 0.05; Institute of Communication and Computer Systems, Athens, Greece) (30). Color-coded root canal models (green indicates preoperative and red indicates postoperative canal surfaces) enabled qualitative comparison of the matched root canals before and after shaping using CTVol v.2.2.1 software (Bruker-microCT). CTAn v.1.12 (Bruker-microCT) was used for measuring the area, perimeter, roundness, major diameter, minor diameter, volume, surface area, and SMI. The mean increase (Δ) of each analyzed parameter was calculated by subtracting the scores for the treated canals from those recorded for the untreated counterparts. 2D evaluations were performed for the full canal length in a total of 14,142 (SAF), 14,145 (WaveOne), 14,295 (Reciproc), and 14,325 (ProTaper Universal) cross-sections.

Statistical Analysis

Because normality assumptions could be verified (Shapiro-Wilk test), the mean increase (Δ) of each parameter was compared by using 1-way analysis of variance with the post hoc Tukey test between groups and the paired sample t test within groups using SPSS v17.0 for Windows (SPSS Inc, Chicago, IL) with the level of statistical significance set at 5%.

Results

Preoperatively (Fig. 1*A*), canal cross-sections presented significantly flatter and irregularly tapered by both mesiodistal and buccolingual views (Fig. 1*B* and *C*). After preparation, the outline of the canals was larger and showed a smooth taper in all

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