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ORIGINAL ARTICLE

Comparison of apically extruded debris during canal shaping with single-file systems

ABSTRACT

Aim: *To assess the amount of apically extruded debris during root canal shaping using various nickel-titanium single-file systems.*
Methodology: *Seventy-two extracted single-rooted human mandibular incisors were assigned randomly to six groups (n=12). The canals were instrumented with the following nickel-titanium single-file systems 25 diameter at the tip: WaveOne (Dentsply Sirona Endodontics), WaveOne Gold (Dentsply Sirona Endodontics), Reciproc (VDW, Munich, Germany), Reciproc Blue (VDW, Munich, Germany), OneShape (Micro-Mega, Besançon Cedex, France) and Hyflex EDM (Coltene/Whaledent AG, Switzerland). Apically extruded debris during root canal shaping were collected into pre-weighed Eppendorf tubes stored in an incubator at 70 °C for five days. The weight of the dry extruded debris was established by subtracting the pre-instrumentation and post-instrumentation weight of the Eppendorf tubes for each group. Data were analyzed using one-way analysis of variance (ANOVA) and Tukey's post hoc tests.*
Results: *All the tested files were associated with apical extrusion of debris. There was no significant difference between examined files regarding the amount of debris extruded during canal shaping (P>0.05).*
Conclusions: *Single-file tested systems produced debris extrusion, and the amount of debris was independent of the used instrumentation technique.*

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Introduction

One of the most fundamental aspects of root canal treatment is the chemo-mechanical preparation that includes mechanical cleansing with instruments and the use of irrigant solutions. However, dentinal chips, pulpal fragments, necrotic debris, and microorganisms may be accidentally pushed out from the root canal into periapical tissues during canal preparation. Extrusion of these elements into periradicular space may cause undesired consequences such as induction of inflammation, postoperative pain, and delayed periapical healing (1, 2). Both manual and rotary Nickel-Titanium (NiTi) preparation sequences are demonstrated to be inevitably associated with extrusion of debris (3).

In the last years, instrument sequence simplification has been proposed through single-file systems as canal preparation may be reliable and faster than that obtainable with conventional multi-file sequences (4, 5).

Improved mechanical properties of single-file NiTi systems achieved through various thermomechanical treatments aimed to optimize the microstructure of the alloys (6) and different kinematics such as reciprocating motion (7) have been proposed as an alternative to the conventional continuous rotation for single-file NiTi systems.

OneShape (MicroMega, Besançon, France) was launched on the dental market in 2011 as the first single-file shaping system conceived for a continuous rotation movement. Made of a conventional austenite 55-NiTi alloy, the design consists of a size 25/.06 file with a passive tip and three different cross-section zones; the first with a 3-cutting-edge design. The second changes from 3 to 2 cutting edges, and the last (coronal) is provided with two cutting edges (8).

In 2011, Dentsply Tulsa Dental (Tulsa, OK, USA) developed the first NiTi endodontic instrument with a molecular structure altered by heat treatment. There are now Gold and Blue heat-treated NiTi systems used in a reciprocating motion (WaveOne Gold, Dentsply Sirona Endodontics; Reciproc Blue, VDW). They are considered as the improved version of the precursors WaveOne and Reciproc, respectively. WaveOne Gold files are manufactured using gold heat treatment performed by heating and then slowly cooling the file after production (9). The reciprocating motion of WaveOne was maintained, but their geometry was altered. The cross-section of the WaveOne Gold was modified to a parallelogram, having two cutting edges and the off-center design. As Reciproc file, Reciproc Blue has an S-shaped cross-section, two cutting edges, and a noncutting tip. However, Reciproc Blue files are manufactured by altering the molecular structure through a new heat treatment that creates a blue-colored titanium oxide layer to increase the cyclic fatigue resistance (9).

Hyflex EDM (Coltene/Whaledent) is manufactured through an innovative patented treatment that is the electro-discharge machining (EDM) process. HyFlex EDM OneFile 25/.~ has a constant 8% taper in the apical 4 mm; the taper decreases to 4% toward the coronal region. Throughout the entire working part of the file, the horizontal cross-section changes from quadratic in the apical region to trapezoidal in the middle region, and almost triangular in the coronal region (10).

This *ex vivo* research aimed to compare the amount of apically extruded debris after the preparation of straight root canals in extracted human teeth using four reciprocating single-file systems (Reciproc, Reciproc Blue, WaveOne, WaveOne Gold) compared with two rotary single-file systems (OneShape, Hyflex EDM).

Materials and Methods

Sample size calculation

A previous study (5) was used to identify an effect size of 0.50 required to calculate the total sample size for this study. a-type error=0.05 and power b=0.80 were also input. A total of 72 samples were indicated as the minimum to observe differences between the systems (F test family, ANOVA, G*Power for Mac).

Selection of teeth
The Research Ethics Committee approved this study's protocol of the Faculty of Dentistry, Ain Shams University, Egypt. Seventy-two mandibular incisors were selected from a collection of teeth extracted for reasons unrelated to this study. Specimens were stored in 4 °C distilled water until use. Soft tissue and calculus were removed mechanically from the root surfaces with a periodontal scaler. Teeth were radiographed form the facial and proximal aspects. The exclusion criteria were a tooth having more than one root canal and apical foramen, previous root canal treatment, internal/external resorption, immature root apices, caries/cracks/fractures on the root surface, root canal curvature more than 10 degrees, and/or teeth in which the apical minor constriction was gauged larger than a size 20 hand file.

Preparation of teeth
An access cavity was prepared in each tooth using a high-speed handpiece and a round bur under water cooling. Canal patency was achieved using a size of 10 K-file. The tooth length (TL) was determined by introducing a size 15 K–file into the canal until the tip of the file was visible from the apex. The working length (WL) was determined by subtraction of 1 mm from TL. The incisal edges were slightly flattened to obtain comparable working lengths 21±1mm. A mechanical glide path was established for all groups using the R Pilot file (12.5 /.04) (VDW, Munich, Germany) before shaping with the respective single-file system.
The experimental model described by Myers & Montgomery (11) was used. The stoppers were separated from Eppendorf tubes, and their initial weight was determined using an analytical balance with an accuracy of 10^{-4} g. Each tube was weighed five times, and the mean value was calculated. Each tooth was inserted up to the cementoenamel junction (CEJ), and a 27-gauge needle was placed alongside the stopper to balance the air pressure inside and outside. Then, each stopper with the tooth and the needle was attached to its Eppendorf tube, and the tubes were fitted into the vials.
The samples were assigned randomly to six experimental groups (n=12) as follows.
Group 1: prepared with WaveOne (size 25/08 taper) reciprocating instruments.
Group 2: prepared with WaveOne Gold (size 25/.07 taper) reciprocating instruments.
Group 3: prepared with Reciproc (size 25/.08 taper) reciprocating instruments.
Group 4: prepared with Reciproc Blue (size 25/.08 taper) reciprocating instruments.
Group 5: prepared with One Shape (size 25/.06 taper) rotating instruments.
Group 6: prepared with Hyflex EDM (size 25/.08 taper) rotating instruments.
All instruments were used in a slow in-and-out pecking motion with an amplitude of about 3 mm. The instruments' flutes were cleaned after three in-and-out movements (pecks) by insertion into a sponge. Each root canal was irrigated with a total volume of 8 mL of distilled water for 4 min divided into four phases (2 mL /1 min each) as follows: before instrumentation, after reaching one-third WL, after reaching two-thirds WL, and after reaching full WL using a 30-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA). Apical patency was maintained using a size 10 K-file. Once the instrument had negotiated to the end of the canal and had rotated freely, it was removed. Each instrument was used to prepare four canals only. To avoid inter-operator variability, a single experienced operator (SS) performed all preparations under 2.5x magnification and LED illumination (Heine, Herrsching, Germany).

Evaluation of apically extruded debris
After instrumentation, stopper, needle, and tooth were separated from the Eppendorf tube, and the debris adhering to the root surface was collected by washing the root with 1 mL distilled water while in the tube. The tubes were stored in an incubator at 70 °C for five days to evaporate the distilled water, and the weight calculation was performed by a second examiner (TM) who was blinded to the group assignment. The Eppendorf tubes, including the extruded debris, were weighed

again in the same way to obtain the final weights of the tubes. Each of the tubes was weighed five times, and the mean value was calculated. The amount of the extruded debris was calculated by subtracting the initial weight from the final weight.

Statistical analysis
Data assumed normal distribution. Hence it was analyzed by parametric tests using a one-way analysis of variance (ANOVA) followed by Tukey's post hoc test for multiple comparisons. The level of significance was set at $P<0.05$. All statistical analyses were performed with SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Apical extrusion of debris was observed in all the tested groups. The mean values and the standard deviation data of each experimental group are shown in Table 1. Statistical analysis of the results showed the differences between the single-file systems used for root canal shaping were non-significant ($P>0.05$).

Discussion

Concern has been raised regarding the extrusion of debris using different instrumentation systems and how it impacts the patient's postoperative comfort level and treatment outcome. It has been suggested that techniques that minimize apically extruded debris should be sought (12, 13). Therefore, this *ex vivo* study was performed to quantify the amount of extruded debris associated with root canal shaping using six different single-file systems. Up to our knowledge, they were not compared all together before. Their manufacturers claim that most of these instruments have improved clinical performance following their modified design features and the proprietary thermomechanical treatment (14).
All methodologies for evaluating the apical extrusion of debris are based on the quantitative measurement of debris, liquid, or bacteria. The generally accepted method of Myers & Montgomery (11) was used to collect apically extruded debris. Some limitations in this experimental model could affect the results, such as the absence of apical backpressure, lack of control of dentine microhardness, sensitivity of the analytical balance, and hydration of samples due to humidity (15). Also, the implications of a vital or necrotic pulp and the presence of a lesion of endodontic origin in the apical extrusion of debris remain not clear (16). In the present study, straight single-rooted teeth were used to eliminate possible complications, such as WL loss or nonstandard preparation and irrigation in the curved root canals (17). The incisal edges were also slightly flattened to obtain comparable working lengths for the specimens. The results of the current investigation revealed that all the single-file systems caused apical extrusion of debris during canal shaping. This is consistent with other apical extrusion studies (14, 18-20) and reinforces that this shaping sequela is unavoidable.
Apical extrusion of debris is the consequence of the interplay amongst several variables, including the shaping technique, movement kinematics, and instrument design. The results of our study imply that adhering to a strict shaping protocol is the most critical variable. A

Table 1
The mean and standard deviation (SD) values for the amount of apically extruded debris in each study group expressed in milligrams

File type	Amount of debris (mean ± SD)
Wave One	.0002 ± .00007[a]
Wave One Gold	.0001 ± .00003[a]
Reciproc	.0002 ± .00011[a]
Reciproc Blue	.0002 ± .00009[a]
One Shape	.0002 ± .00010[a]
Hyflex EDM	.0001 ± .00003[a]
P-value	.217

Similar superscript letters in the same column indicate a non-significant difference among groups.

standardized mechanical glide path was established in our study before shaping to minimize the incidence of procedural errors and reduce the amount of apically extruded debris (21). The crown down technique was used with all file systems, as suggested by manufacturer recommendations.

Moreover, the apical diameter of all teeth was standardized to a size 25 after instrumentation. In all canals, a standard volume of distilled water was used as an irrigation solution to avoid any possible crystallization of sodium hypochlorite that could alter the weight of dentine debris and compromise the results (13).

The impact of movement kinematics on the apical extrusion of debris is controversial. Bürklein & Schäfer (5) stated that reciprocal movement might enhance debris transportation towards the apex and that continuous rotation may improve the coronal transportation of dentine chips and debris by acting as a screw conveyor. A similar finding was reported by Topcuoglu et al. (22), who found that Reciproc produces more debris extrusion than continuous rotation files as OneShape single rotary files.

Contradicting findings were reported (17) on reciprocating WaveOne files that extruded significantly less debris than the ProTaper Next rotary system because of the reciprocating action act as a type of mechanized balanced forced pressure-less technique (7, 23). Other researches (24) reported that WaveOne and Reciproc systems extruded fewer bacteria than the multifile rotary system BioRaCe; that Reciproc and WO extruded significantly less debris compared to ProTaper with no differences between them (16), and that Reciproc instruments extruded less debris when used in reciprocating motion than in continuous rotation (25). The present study reported a similar amount regarding apical extrusion of debris irrespective of the selected rotary or reciprocating instrumentation system, corroborating previous findings (26).

With the limits of this study that did not evaluate different NiTi alloys as an independent variable, present research did not find any statistically significant differences concerning different heat-treated wires. Gold thermal treatment of the WaveOne Gold and electro-discharge machining process of Hyflex EDM instruments were associated with less debris extrusion (14, 27) during treatment procedures; however, these differences were not significant. Recently (28) it was reported that Reciproc Blue extruded significantly less debris than M-Wire Reciproc during retreatment procedures. Instrument flexibility and alloy microhardness (10, 28-30) were altered by proprietary thermal treatments, which might explain the reduced amount of debris extrusion herein found. All the evaluated single-file systems (except OneShape) are characterized by different regressive taper values from the tip to the shank. Although the instrument taper of the tested files was slightly different, this aspect did not result in significant differences between systems. The cross-section design of the files is different, with a non-identical number of cutting-edge contacts against the canal wall and different symmetrical or off-centered section. Further investigations are needed to confirm the present findings.

Conclusions

Based on the results of this study, single-file tested systems produced debris extrusion; the amount of debris was independent of the kinematics or file design.

Clinical Relevance

All the single-file systems caused apical extrusion of debris during canal shaping. This reinforces the concept that shaping sequela is unavoidable.

Conflict of Interest

Authors deny any conflict of interest related to this research.

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