Evaluation of Debris Extruded Apically during the Removal of Root Canal Filling Material Using ProTaper, D-RaCe, and R-Endo Rotary Nickel-Titanium Retreatment Instruments and Hand Files

Hüseyin Sinan Topçuoğlu, DDS, PhD, Ahmet Aktı, DDS,* Öznur Tuncay, DDS, PhD,† Asiye Nur Dinçer, DDS,* Salih Düzgün, DDS,* and Gamze Topçuoğlu, DDS‡*

Abstract

Introduction: The aim of this study was to evaluate the amount of debris extruded apically during the removal of root canal filling material using ProTaper (Dentsply Maillefer, Ballaigues, Switzerland), D-RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland), and R-Endo (Micro-Mega, Besançon, France) nickel-titanium (NiTi) rotary retreatment instruments and hand files. **Methods:** Sixty extracted single-rooted mandibular premolar teeth were prepared with K-files and filled with gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany). The teeth were then randomly assigned to 4 groups (n = 15 for each group) for retreatment. The removal of canal filling material was performed as follows: hand files, ProTaper, D-RaCe, and R-Endo retreatment instruments. Debris extruded apically during the removal of canal filling material was collected into preweighed Eppendorf tubes. The tubes were then stored in an incubator at 70°C for 5 days. The weight of the dry extruded debris was established by subtracting the preretreatment and postretreatment weight of the Eppendorf tubes for each group. The data obtained were analyzed using 1-way analysis of variance and Tukey post hoc tests. **Results:** All retreatment techniques caused the apical extrusion of debris. Hand files produced significantly more debris when compared with ProTaper, D-RaCe, and R-Endo rotary systems ($P < .05$). There was no statistical difference between the ProTaper, D-RaCe, and R-Endo retreatment systems ($P > .05$). **Conclusions:** The findings showed that during the removal of root canal filling material, rotary NiTi retreatment instruments used in this study caused less apical extrusion of debris compared with hand files. *(J Endod 2014;40:2066–2069)*

Key Words

Apical extrusion, debris, NiTi instrument, retreatment

Nonsurgical endodontic retreatment procedures are performed as the first choice to eliminate or reduce the microbial infection when initial root canal therapy fails (1). The main goal of nonsurgical retreatment is to completely remove root canal filling material to regain access to the apical foramen and facilitate further cleaning, shaping, and refilling (2).

It has been reported that irritants in the form of filling material, necrotic pulp tissue, bacteria, or irrigants may be extruded into the periradicular tissues when endodontic retreatment is performed (3). Apically extruded materials have clinically been held responsible for discomfort, including postoperative inflammation and flare-up and even failure of apical healing (4, 5). Several studies show that the amount of debris extruded apically might vary according to the preparation technique used and the design of the root canal instruments (6, 7). A common finding is that manual instrumentation causes greater extrusion when compared with engine-driven rotary preparation. Huang et al (3) stated that the most appropriate retreatment technique should be selected to achieve the goal of removing as much of the pre-existing root canal filling material as possible while minimizing the amount of apical extrusion.

Many techniques, including the use of hand or nickel-titanium (NiTi) rotary instruments, heat, ultrasonics, or chemical solvents in different combinations, have been proposed for the removal of root filling material (8, 9). Some rotary NiTi systems have been especially designed and indicated for this purpose, such as the ProTaper Universal retreatment instruments (Dentsply Maillefer, Ballaigues, Switzerland), D-RaCe retreatment files (FKG Dentaire, La Chaux-de-Fonds, Switzerland), and the R-Endo instrumentation system (Micro-Mega, Besançon, France).

The ProTaper Universal Retreatment system has 3 files, D1, D2, and D3, one for each third of the root canal. These instruments have a convex, triangular cross-section, and the D1 file has an active working tip that facilitates penetration into the filling material (10). D-RaCe retreatment files comprise 2 retreatment instruments, DR1 and DR2, with various tapers and diameters at the tip. These 2 instruments were designed with alternating cutting edges as well as a triangular cross-section. The DR1 instrument has an active working tip to facilitate initial penetration of the filling material (11). The R-Endo system is composed of 4 instruments: an Re file to flare the first few millimeters of the canal and 3 files, R1, R2, and R3, each dedicated to a specific third of the root

From the Departments of *Endodontics and ‡Pedodontics, Faculty of Dentistry, Erciyes University, Kayseri, Turkey; and †Department of Endodontics, Faculty of Dentistry, Akdeniz University, Antalya, Turkey.

Address requests for reprints to Dr Hüseyin Sinan TOPÇUOĞLU, Faculty of Dentistry, Department of Endodontics, Erciyes University, Melikgazi, Kayseri, Turkey 38039. E-mail address: topcuogluhs@hotmail.com

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canal. An optional finishing file, Rs, is available if required. These files have a triangular cross-section with 3 equally spaced cutting edges and no radial land; it is claimed that the tip of each file is inactive (12).

There are few studies evaluating the amount of apically extruded debris during the removal of root canal filling material using the ProTaper retreatment instruments (3, 13). Furthermore, no studies have quantitatively assessed the amount of debris extruded apically in the retreatment procedure performed using the D-RaCe and R-Endo retreatment systems. Therefore, the purpose of this study was to quantitatively evaluate the amount of debris extruded apically during the removal of root canal filling material using the ProTaper, D-RaCe, and R-Endo retreatment systems and hand files.

Materials and Methods

Extracted human single-rooted mandibular premolar teeth were used for this study. Criteria for tooth selection included a single root canal; no visible root caries, fractures, or cracks; no signs of internal or external resorption or calcification; a completely formed apex; and a curvature <5° according to Schneider (14). The teeth were radiographed from both the buccolingual and mesiodistal directions to rule out any aberrant canal morphology and to confirm a single canal. The soft tissue remnants were removed from the outer surface of the root using a hand scaler. Endodontic access cavities were prepared using diamond burs (Diatech; Coltene Whaledent, Altststten, Switzerland) and a high-speed handpiece under water cooling. After preparing the access cavity, the canal patency was established using a #10 K-file (Dentsply Maillefer). Canals that were patent to greater than ISO size 15 were discarded (3), and 60 teeth were finally selected. To ensure standardization and to obtain a reference point, the buccal cusp edge of each tooth was flattened using a high-speed bur and the length of all teeth were standardized to 19 mm. A #10 K-file (Dentsply Maillefer) was introduced into the canal until the file tip was observed at the apical foramen. The working length (WL) was determined by subtracting 1 mm from this measurement. The canals were prepared to a master apical size 35 with K-files (Dentsply Maillefer) using the balanced force technique as described by Roane et al (15). Step back was performed using K-file sizes 40–70. The canals were irrigated with 2 mL 1% sodium hypochlorite (NaOCl) between each file size using a syringe and a 29-G double-side port NaviTip irrigation needle (Ultradent, South Jordan, UT). After completion of the preparation, the canals were irrigated with 5 mL 17% EDTA for 1 minute and subsequently rinsed with 5 mL distilled water. Canal patency was maintained by inserting a #10 K-file slightly beyond the apical foramen during recapitulation.

Root Canal Obturation

All canals were obturated with gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) using the cold lateral compaction technique. AH Plus was introduced into the root canal using a Lentulo spiral filler. A 0.02/35 master gutta-percha cone (Dentsply Maillefer) with good tugback was coated with sealer and slowly inserted into the canal until the WL was reached. Lateral condensation was performed using a size 25 finger spreader and accessory cones. Mesiodistal and buccolingual radiographs were taken to confirm complete filling. After root filling, the coronal 1 mm of the filling material was removed, and the spaces were filled with a temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). The teeth were stored at 37°C and 100% humidity for 2 weeks to allow the sealers to set.

Debris Collection

Debris was collected as previously reported (16). A hole was created on each stopper, and a 25-G needle was inserted alongside the stopper to equalize the air pressure inside and outside the tubes. Then, each stopper with the tooth and the needle was attached to an Eppendorf tube, and each tube was fitted into a vial. The entire apparatus was handled only by the outer vial. In no case was the inner Eppendorf tube touched with fingers. Before the retreatment procedure, the Eppendorf tubes were weighed to 10^{-5} precision using a microbalance (AUW-220D; Shimadzu, Tokyo, Japan). Three consecutive measurements were taken for each tube, and the mean value was recorded. All vials were covered with aluminum leaf to prevent the operator from viewing debris extrusion during the retreatment phase. All teeth were coded and then randomly assigned to 4 groups of 15 specimens each.

Experimental Groups and Retreatment Procedures

All rotary NiTi instruments were used with a torque and speed-controlled motor (X-Smart, Dentsply Maillefer) at the torque and speed recommended by the manufacturer for each specific system used. Root fillings were removed using the following techniques.

Hand Instrument Group (*n* = 15 Teeth). Gates Glidden drills (Mani Inc, Tochigi, Japan) size 3 and subsequently size 2 at 2000 rpm were used to remove coronal filling material. The canals were reinstrumented with Hedström files (Dentsply Maillefer), sizes 30, 25, 20, and 15, in a circumferential, quarter-turn, push-pull, filing motion to remove filling material until the WL was achieved. Once the WL had been reached (with a size 15 file), files sized 20, 25, 30, 35, and 40 were used at the WL.

ProTaper Universal Retreatment Group (*n* = 15 Teeth). Root fillings were removed using the D1, D2, and D3 retreatment instruments at 2-Ncm torque and 500-rpm speed. The instruments were used with a brushing action against the canal walls in a crown-down direction until the WL was reached. D1 was used in the cervical third, D2 in the middle third, and D3 through the entire WL. Finally, apical preparation was performed with a ProTaper F4 file (size 40, 0.06 taper) at 300 rpm.

D-RaCe Retreatment Group (*n* = 15 Teeth). Canal fillings were removed using the D-RaCe retreatment instruments as follows: DR1 (size 30, 0.10 taper) at a speed of 1000 rpm and a torque of 1.5 Ncm for the cervical third and beginning of the middle third and DR2 (size 25, 0.04 taper) at a speed of 600 rpm and a torque of 1 Ncm to the WL. The DR2 instrument was used with light apical pressure until the WL was reached. Final apical preparation was performed with the BioRaCe instrument (size 40, 0.04 taper) at a speed of 600 rpm and a torque of 1 Ncm.

R-Endo Retreatment Group (*n* = 15 Teeth). In this group, the Rm stainless steel hand file (size 25, 0.04 taper) was used with one quarter turn pressure directed toward the apex to create a pathway, thus allowing the centering and alignment of the next instrument. The rotary instruments were used at a speed of 350 rpm. The Re instrument (size 25, 0.12 taper) was used to remove the first 2–3 mm of the filling. R1 (size 25, 0.08 taper) and R2 (size 25, 0.06 taper) instruments were used to one third and two thirds of the WL. R3 (size 25, 0.04 taper) and Rs (size 30, 0.04 taper) instruments were then used at the WL with a circumferential filing movement from the apical third to the coronal third. Final apical preparation was performed with a Hero 642 (MicroMega) instrument (size 40, 0.02 taper) at the WL at a speed of 350 rpm and a torque of 1.6 Ncm.

In all groups, 0.1 mL eucalyptol was introduced into each canal to soften the gutta-percha. One set of instruments was used for 1 canal. When instruments reached the WL, the irrigation needle was placed into the canal 1 mm short of the WL. Irrigation solution was then delivered into the canal using a syringe and a 29-G double-side port NaviTip irrigation needle. During retreatment of each root canal, a total of 15 mL

distilled water was used as the irrigation solution. The flutes of the instrument were cleaned after each removal of the instrument from the root canal. Retreatment was deemed complete when no debris of gutta-percha and sealer was visible on the instrument surfaces and the canal walls were smooth. A dental operating microscope (Zeiss Opmi; Carl Zeiss, Jena, Germany) was used throughout. All procedures were performed by a single operator to avoid interoperator variability.

Evaluation of Debris Extruded Apically

Evaluation was performed by a second examiner who was blinded to group assignment. On completion of the retreatment procedure, the Eppendorf tubes were removed from the vials. The debris adherent to the external surface of the apex was collected by washing the root with 1 mL distilled water in the tube. The tubes were then stored in an incubator at 70°C for 5 days to evaporate the irrigation solution used in the retreatment procedure before weighing the dry debris (7). The net weight of the dry debris was determined by subtracting the original weight of the empty Eppendorf tube from the gross weight.

Statistical Analysis

The amount of extruded debris was analyzed statistically using the analysis of variance test followed by the Tukey post hoc test for multiple comparisons. The level of significance was set at $P < .05$. All statistical analyses were performed using SPSS version 20.0 for Windows (SPSS Inc, Chicago, IL).

Results

The mean and standard deviations of debris extruded apically in each group is shown in Table 1. Based on the statistical results, the hand instrumentation group extruded significantly more debris than the ProTaper, D-RaCe, and R-Endo rotary NiTi retreatment groups ($P < .05$) in the removal of root canal filling material. However, there was no statistical difference between the ProTaper, D-RaCe, and R-Endo retreatment groups ($P > .05$).

Discussion

Apically extruded debris during initial canal preparation and retreatment procedure might lead to postoperative complications such as pain and swelling. Additionally, the extruded debris to the periapical area has been associated with persistent inflammation (4). In many studies, it has been shown that initial canal preparation in endodontic treatment caused apical extrusion of debris produced during instrumentation (17–19). However, there are limited studies evaluating debris extruded apically during retreatment procedures. Moreover, no study has quantitatively evaluated the amount of debris extruded apically when using the D-RaCe and R-Endo rotary NiTi retreatment systems. Therefore, this study aimed to evaluate the debris extruded apically during the removal of root canal filling material with the ProTaper, D-RaCe, and R-Endo retreatment systems.

It has been stated that the *in vitro* setup suspended the apex in air, whereas *in vivo* the apex would be surrounded by granulomatous or periradicular tissues, which could help restrict apical extrusion to some extent (3, 16). Some investigators have suggested simulating resistance of periapical tissues using floral foam (6, 20). However, foam may absorb some irrigant and debris when used as a barrier. Therefore, no attempt has been made in the current study to simulate periapical resistance. Vande Visse and Brilliant (21) showed that instrumentation with irrigation produced significantly more extruded debris than did instrumentation without irrigation. In the current study, distilled water was used as an irrigation solution to avoid any possible crystallization of NaOCl (3). However, Bürklein and Schäfer (22) stated that it remains open to question whether the use of NaOCl and/or EDTA instead of water might increase the amount of extruded debris.

Several methods, such as the scoring system and weighing the material using a microbalance, have been proposed to evaluate the amount of debris extruded apically (13, 23). The scoring system evaluates the extruded debris in a semiquantitative form and would not be sufficiently sensitive to detect tiny differences among the various canal preparation techniques (24). However, weighing with a microbalance may provide more accurate measurements because its precision is to ten thousandths of a gram (25). The method chosen in the present study was to weigh the debris with a microbalance to evaluate the amount of debris extruded apically during the retreatment procedure.

The findings of the present study showed that the use of hand files during the retreatment procedure caused more apical extrusion of debris than the rotary NiTi retreatment instruments. Huang et al (3) evaluated the amount of debris extruded apically during endodontic retreatment using ProTaper Universal Tulsa retreatment files followed by additional preparation with ProTaper Universal Tulsa treatment files. They reported that the ProTaper Universal Tulsa rotary technique produced significantly less apical extrusion material than hand instrumentation did. In a study performed by Somma et al (23), it was found that a manual technique for retreatment using Hedström files produced more extrusion of debris than the Mtwo R and ProTaper retreatment files. Mollo et al (26) visually assessed material extruded through the apical foramen during retreatment procedure performed using 2 rotary NiTi retreatment systems (Mtwo R and R-Endo) and hand files. They observed that the R-Endo system caused less apical extrusion of debris than hand files. The findings of the present study are in agreement with the findings of these studies. In contrast, some studies showed no statistically significant differences between rotary NiTi instruments and hand files (27–29). Rotary NiTi instruments used in these studies to remove root canal filling material have not been designed specifically for retreatment. This could mean that instruments designed for retreatment may cause less apical extrusion of debris than instruments designed for root canal preparation.

Rotary NiTi retreatment instruments combine rotational motion with a crown-down pressureless action, whereas the technique used with the hand instrument group incorporates a push-pull filing action (30, 31). The push-pull filing action of the Hedström files acts as a piston, posing a risk of pumping the debris through the apical foramen (32). On the other hand, rotary NiTi instruments tend to direct the debris coronally rather than apically (29). The differences between hand files and rotary NiTi retreatment instrument groups concerning apically extruded debris might be caused by these action differences. Additionally, these findings may be attributed to the design of rotary NiTi retreatment instruments. Rotary NiTi retreatment instruments used in the present study have a triangular cross-section that reduces the area of contact between the instrument and the dentin walls. During the retreatment procedure, debris is positioned between the apical blades and conveyed apically in the rotating instrument in an auger-like fashion, which helps to decrease the amount of the debris extruded.

TABLE 1. Weight of Apically Extruded Debris in Grams

Group	*n*	Mean ± SD
Hand files	15	0.00858 ± 0.00521[a]
ProTaperR	15	0.00452 ± 0.00198[b]
D-Race	15	0.00450 ± 0.00285[b]
R-Endo	15	0.00385 ± 0.00232[b]

SD, standard deviation.

Values with the same letters were not statistically different at $P = .05$.

The apical diameters of the rotary NiTi retreatment instruments used in the present study were as follows: ProTaper D3 (size 20), D-RaCe R2 (size 25), and R-Endo RS (size 30). These retreatment instruments, which are designed to reach the WL, may not provide complete removal of canal filling material from the apical third. Clinically, the retreatment procedures are generally completed with the use of files with an apical diameter larger than the apical diameter of the master apical file used in the initial canal preparation. Marques da Silva et al (33) evaluated the effectiveness of ProTaper and D-RaCe retreatment files with and without supplementary instruments in the removal of root canal filling material. They found that supplementary instrumentation performed after the use of ProTaper and D-RaCe retreatment files provided more effective cleaning than the use of only retreatment instruments in the apical third. Therefore, in the present study, supplementary instrumentation was performed using size 40 files because the apical diameter of the master apical file (size 35) in the initial canal preparation was larger than that of the retreatment instruments.

There are no differences between rotary NiTi retreatment instruments regarding the debris extruded apically. This finding may be attributed to the fact that ProTaper, D-RaCe, and R-Endo retreatment instruments used in the apical third of the root canal have similar designs (triangular cross-sections and noncutting tips).

In the present study, in terms of retreatment time, the rotary NiTi retreatment instruments were faster than the hand files. This is probably caused by the gutta-percha plasticization resulting from rotation of the instrument (24). Softened gutta-percha is less resistant and is easier to penetrate and remove (27).

Conclusions

The current results indicate that all systems used in retreatment caused apical extrusion of debris. The rotary NiTi retreatment systems used in the present study caused less apical extrusion of debris than hand files during the removal of root canal filling material. Furthermore, there was no significant difference among the 3 rotary NiTi retreatment systems in the amount of debris extruded apically.

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The authors deny any conflicts of interest related to this study.

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