An *In Vitro* Comparison of Apically Extruded Debris and Instrumentation Times with ProTaper Universal, ProTaper Next, Twisted File Adaptive, and HyFlex Instruments

Ismail Davut Capar, DDS, PhD, Hakan Arslan, DDS, PhD,† Merve Akcay, DDS, PhD,‡ and Huseyin Ertas, DDS, PhD**

Abstract

Introduction: The purpose of this study was to compare the *in vitro* amount of apically extruded debris with new endodontic rotary nickel-titanium instruments. **Methods:** Sixty mandibular premolars were instrumented up to size 25 using ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Next (Dentsply Maillefer), Twisted File Adaptive (SybronEndo, Orange, CA), and HyFlex (Coltene-Whaledent, Allstetten, Switzerland) rotary systems. The apically extruded debris was collected and dried in preweighed Eppendorf tubes. The amount of extruded debris was assessed with an electronic balance. The total time required to complete root canal shaping with the different instruments was also recorded. The significance level was set at $P = .05$. **Results:** The instrumentation time with the ProTaper Universal rotary system was significantly longer than with all the other instruments ($P < .05$). The Twisted File Adaptive and ProTaper Next systems extruded significantly less debris than the ProTaper Universal and HyFlex systems ($P < .05$). **Conclusions:** The ProTaper Next and Twisted File Adaptive instrumentation systems were associated with less debris extrusion compared with the ProTaper Universal and HyFlex systems. *(J Endod 2014;40:1638–1641)*

Key Words

Controlled memory nickel-titanium, debris extrusion, HyFlex, ProTaper Next, ProTaper Universal, Twisted File Adaptive

During root canal preparation, irrigants, dentin chips, pulp tissue, and microorganisms may be extruded into the periradicular tissues, and these extruded materials may cause postoperative pain and complications (1). Studies examining the apical extrusion of debris have stated that all instrumentation techniques and instruments are associated with the extrusion of debris (2–6).

Technological advancements in rotary nickel-titanium (NiTi) instruments have led to new design concepts and easier and faster techniques that preserve the original canal shape with considerably less iatrogenic error (7, 8). Recently, HyFlex rotary instruments (Coltene-Whaledent, Allstetten, Switzerland) have been introduced. They are made from a controlled memory (CM) NiTi wire, which is manufactured by a unique process that controls the material's memory. This CM feature makes the files extremely flexible and makes the instruments more resistant to cyclic fatigue than non-CM NiTi instruments (9). The HyFlex instrument has a symmetric cross-sectional design with 3 cutting edges. Unlike other instruments, deformed HyFlex instruments are able to regain their original shape after a sterilization procedure (10).

ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) is a novel NiTi file system. It has an off-centered rectangular design and progressive and regressive percentage tapers on a single file. Having various percentage tapers decreases the effect of the screw and dangerous taper lock by minimizing the contact between the file and the dentin (11). Moreover, the offset design maximizes augering debris out of the canal compared with a file with a centered mass and axis of rotation (12).

The Twisted File Adaptive (SybronEndo, Orange, CA) is another novel file that uses a combination of continuous rotation and reciprocating motion. The file uses continuous rotation when it is exposed to minimal or no applied load and uses reciprocal motion when it engages dentin and a load is applied. Manufacturers have claimed that this adaptive technology and twisted file design using R-phase treatment increase debris removal and flexibility and allow the file to adjust to intracanal torsional forces depending on the amount of pressure placed on the file.

Investigations of apically extruded debris using these new NiTi systems with different design features and kinematics are important for understanding how the differences affect debris extrusion. However, the amount of apically extruded debris after preparation with these new NiTi rotary systems has not yet been compared. There are many articles in the literature on debris extrusion with ProTaper Universal (Dentsply Maillefer) instruments (5, 13, 14). In the present study, the debris extrusion and

From the *Department of Endodontics, Faculty of Dentistry, İzmir Katip Çelebi University, İzmir, Turkey; †Department of Endodontics, Faculty of Dentistry, Atatürk University, Erzurum, Turkey; and ‡Department of Pedodontics, Faculty of Dentistry, İzmir Katip Çelebi University, İzmir, Turkey.

Address requests for reprints to Dr Ismail Davut Capar, Department of Endodontics, Faculty of Dentistry, İzmir Katip Çelebi University, İzmir, 35620, Turkey. E-mail address: capardt@hotmail.com

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instrumentation time with the ProTaper Universal rotary system were compared with those of the ProTaper Next, Twisted File Adaptive, and HyFlex systems.

Materials and Methods

Mandibular premolars were selected from a collection of teeth that had been freshly extracted from patients (aged 40–60 years) for periodontal and prosthodontic reasons. The reasons of the extraction were not unrelated to this study. Specimens were immersed in 0.5% chloramine-T solution (Merck, Darmstadt, Germany) for 48 hours for disinfection. The teeth were stored in 4°C distilled water and used within 2 months. Soft tissue and calculus were removed mechanically from the root surfaces with a periodontal scaler. The teeth were verified radiographically as having a single root canal without calcification. The exclusion criteria were a tooth having more than a single root canal and apical foramen, root canal treatment, internal/external resorption, immature root apices, caries/cracks/fractures on the root surface, and/or root canal curvature more than 10°. After preparation of the access cavity, a size #10 stainless steel K-file was moved down in the canal until the file was just visible. Endodontic working lengths were set by deducting 1 mm from these lengths. The size of the minor foramen was controlled by moving a #15 K-file down to the working length. When the K-file extruded beyond the apical foramen, the tooth was excluded from the study.

According to these criteria, 60 mandibular premolar teeth were selected. The specimens were distributed equally across 4 groups (n = 15) according to the length of the root below the cementoenamel junction. Statistical analysis using 1-way analysis of variance confirmed no significant differences among the groups in terms of their lengths (P = 1.000). Apical preparation was completed with a size 25 instrument by using the instrument order specified by the manufacturer. Except for the Twisted File Adaptive groups, all the instruments were operated with a low-torque motor (VDW Silver; VDW, Munich, Germany). The Twisted File Adaptive groups were operated with their own motor (Elements Motor, SybronEndo). The teeth were irrigated with 2 mL bidistilled water using a 27-G side-vented tip needle (Ultradent, South Jordan, UT) during each instrument change. Each instrument was used in 3 canals. To standardize the irrigation protocol, the needle was attached to a Surgic XT plus device (NSK, Kanuma, Japan) and inserted into the canal within 2 mm from the working length without binding and moved in an up-and-down motion. In all the groups, the flow rate of the irrigating solution was constant and equal to 0.16 mL/s. The preparation sequences were as follows.

ProTaper Universal

For each ProTaper Universal file, the individual rotational speed and torque limit programmed in the file library of the motor were used. The sequence was as follows: SX (two thirds of the working length), S1, S2, F1, and F2 (full working length). The first 3 shaping files were used with a brushing motion away from the root concavities before light resistance was encountered, and the last 2 finishing files were used with a nonbrushing action until the working length was reached.

HyFlex

The instruments were used in a gentle in-and-out motion with a rotational speed of 500 rpm and 250-g/cm torque. The HyFlex files were used with the sequence of 25.08 (two thirds of the working length) and 25.06 (full working length).

Twisted File Adaptive

The instruments were used with the Twisted File Adaptive program of their motor in the sequence of SM1 and SM2 (full working length). The file was advanced to the canal with a single controlled motion.

ProTaper Next

The files were used in the sequence of X1 and X2 (full working length) at a rotational speed of 300 rpm and 200-g/cm torque. Each file was used with a brushing motion similar to the ProTaper Universal files.

As soon as the instrument reached the working length, it was removed, and the next instrument in the sequence was used. The root canal preparation was completed when the final instrument of each system had reached the working length. The instrumentation of the root canal preparations was completed by 1 operator. The total time for the canal preparation was also recorded, including total active instrumentation, changes of instrument within the sequence, and irrigation.

Debris Collection

To evaluate the collection of the apically extruded debris, a similar method as described in previous studies (15, 16) was used. Empty vials without stoppers were weighed with an electronic balance (Sartorius Weighing Technology, Gottingen, Germany) with an accuracy of 10^{-6} g. After calibrating the scales, each specimen was placed on the scale for 100 seconds, and each value per second was noted automatically using the program included with the electronic balance. Finally, the mean weight of each vial was determined.

The stoppers of the Eppendorf tubes were separated, and a hole was drilled in the tops. Each tooth was inserted up to the cementoenamel junction into the stoppers of the Eppendorf tubes. Later, a stopper of the vial was drilled, and an Eppendorf tube that was perforated from the tip was attached to the stopper of the vial. A 27-G needle was placed alongside the stopper (to equalize the internal and external pressures). The gaps surrounding the hole, the Eppendorf tube, and the needle were carefully filled with adhesive (Pattex Super Glue; Türk Henkel, Inc, Istanbul, Turkey) to hinder irrigation solution extrusion through the hole. The stoppers of the Eppendorf tubes, including the tooth, were then attached to the vials (Fig. 1*A*). During the instrumentation procedure, the teeth were isolated with a rubber dam to preclude the operator from seeing the root and to prevent irrigation solution extrusion through the hole (Fig. 1*B*). An aspirator was used to suction the irrigating solution that overflowed from the tooth crown.

After completion of the instrumentation, the stoppers of the vial and Eppendorf tubes were removed. The surface of the root was washed with 1 mL bidistilled water into the vial to collect the debris adhering to the root surface. The vials were then stored in an incubator at 50°C for 10 days to evaporate the distilled water before weighing the dry debris. The net weight of the extruded debris was determined by subtracting the initial weight from the final weight.

The data were analyzed with 1-way analysis of variance and the Bonferroni post hoc test. The testing was performed at the 95% confidence level (P = .05). All statistical analyses were performed using SPSS software (SPSS Inc, Chicago, IL).

Results

The Twisted File Adaptive and ProTaper Next systems extruded significantly less debris than the ProTaper Universal and HyFlex files (P < .001) although no significant differences were obtained between the Twisted File Adaptive and ProTaper Next systems (P > .05).

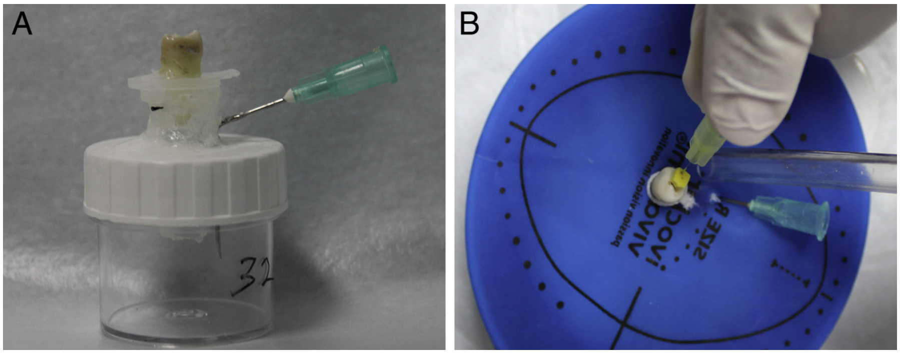

Figure 1. (*A* and *B*) An experimental model system used to evaluate debris extrusion.

Likewise, there was no significant difference between the ProTaper Universal and HyFlex systems ($P > .05$) (Table 1).

The mean time for preparation of the root canals with the different instruments is shown in Table 1. The instrumentation time with the ProTaper Universal rotary system (including 5 files) was significantly longer than with all the other instruments (including 2 files) ($P < .001$). There was no significant difference among the ProTaper Next, HyFlex, and Twisted File Adaptive systems with respect to the preparation time ($P > .05$).

Discussion

A tendency for increased apical extrusion with an increase in the diameter of the apical patency has been shown (4). Thus, in the present study, if a number 15 K-file extruded beyond the apical foramen, the tooth was excluded from the study. One study evaluating the type of irrigation needle on periapical extrusion indicated that side-vented needles extruded less irrigant compared with regular needles (17). Therefore, we used side-vented needles in all the groups to avoid irrigation extrusion. Moreover, for standardization of the irrigation protocol, a constant flow rate was provided with a device.

Numerous studies have reported that rotary NiTi systems are associated with less apical extrusion than manual instrumentation (14, 18–20). We compared the apically extruded debris of 3 newly developed file systems that have different designs, manufacturing methods, numbers of files, and kinematics (ie, continuous rotation and combined reciprocating and rotation motion). The results of the present study showed that all the instrumentation systems tested produced apically extruded debris *in vitro*. It has been shown that the instrumentation technique (21) and pitch design of specific instruments (22) influence the amount of extruded debris. The kinematics, number of files, and instrument design are also important factors in determining the shaping characteristics of rotary systems. Previous studies showed that single-file reciprocating systems extruded more debris than multiple-file (23) and single-file rotary systems (24). However, another study reported that the use of reciprocation motion increases the cyclic fatigue resistance of NiTi rotary instruments (25). The Twisted File Adaptive system is designed to use motion that is more similar to continuous rotation for optimal debris removal (26). When a load is applied, the Twisted File Adaptive system uses reciprocal motion, which may improve the file's fatigue behavior. The results of the present study revealed that the Twisted File Adaptive system extruded significantly less debris than the ProTaper Universal and HyFlex systems. A recent clinical study revealed that the Twisted File Adaptive system causes less postoperative pain when compared with the WaveOne single-file reciprocating system (26). However, the systems that we compared in the present study are different from those mentioned in the clinical study. Thus, assessment of the clinical performance of these systems is necessary to make further comments.

TABLE 1. Amount of Apically Extruded Debris and Preparation Times of Tested Instruments

	ProTaper Universal	HyFlex	Twisted File Adaptive	ProTaper Next
Debris extrusion				
Mean	0.001010[a]	0.000867[a]	0.000392[b]	0.000375[b]
SD	0.000709	0.000362	0.000242	0.000208
Preparation time (s)				
Mean	196[a]	86[b]	88[b]	103[b]
SD	32	11	16	29

SD, standard deviation.

Different superscript letters indicate a significant difference between groups.

To the best of our knowledge, there are no data in the literature on the extrusion of apical debris with the HyFlex, Twisted File Adaptive, and ProTaper Next systems. Previous studies comparing the extrusion of apical debris with the ProTaper and other rotary instruments revealed that the ProTaper systems extruded more debris than the ProFile (5), Mtwo (VDW, Munich, Germany), BioRace (FKG Dentaire, La Chaux-de Fonds, Switzerland) (13), and K3 systems (SybronEndo, Orange, CA) (14). In the present *in vitro* study, the ProTaper Universal and HyFlex systems extruded a greater amount of apical debris than the ProTaper Next and Twisted File Adaptive systems. The common design feature of the ProTaper Next and ProTaper Universal systems is the presence of progressive and regressive percentage tapers on a single file. However, the ProTaper Universal F2 instrument has a 0.08 taper at the apical 3 mm, whereas the ProTaper Next X2 instrument has a 0.06 taper at the apical 3 mm. The larger taper at the tip of the ProTaper Universal instrument might explain the increased amount of debris extrusion with this system. Moreover, the cross-sectional geometric design of the ProTaper Next system is different from that of the ProTaper Universal system. ProTaper Next instruments have an off-centered, rectangular design, generating traveling waves of motion along the active part of the file. The superior performance of the ProTaper Next system might be caused by the new swaggering motion, which serves to minimize the engagement between dentin and the file and enhances augering debris out of the canal (12).

Unwinding of the spirals of HyFlex instruments is well-known during root canal preparation (27). In the present study, all the instruments were used for 3 single canals. However, after the preparation procedure, 80% of the HyFlex instruments were deformed. Elmsallati et al (22) compared apically extruded debris of the same instruments with short, medium, and long pitch designs and showed that the short pitch design extruded less debris than the medium and long ones. The reason for the increased debris extrusion with the HyFlex system might be caused by this unwinding feature of the instruments.

In the present study, all the systems tested, except the ProTaper Universal system, were used with 2 files. These systems were faster than the ProTaper Universal system, and there were no significant differences between the systems. The reduction in the number of instruments is a time-saving advantage of these novel instruments. The longer instrumentation time with the ProTaper Universal instrument might explain the increased amount of debris extrusion noted when using this system.

Conclusions

Within the limitations of this *in vitro* study, all the tested systems extruded debris. However, the ProTaper Next and Twisted File Adaptive instrumentation systems were associated with less debris extrusion compared with the ProTaper Universal and HyFlex systems.

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

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