

Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems

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ABSTRACT

Objectives: The aim of this study was to compare the amount of apically extruded debris during preparation with ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Next (Dentsply Maillefer), a reciprocating single-file (WaveOne; VDW GmbH, Munich, Germany), and a self-adjusting file (SAF; ReDent Nova, Ra'anna, Israel). **Materials and Methods:** Fifty-six intact mandibular premolar teeth were randomly assigned to four groups. The root canals were prepared according to the manufacturers' instructions using the ProTaper Universal, ProTaper Next, WaveOne, and SAF. Apically extruded debris was collected in preweighted Eppendorf tubes during instrumentation. The net weight of the apically extruded debris was determined by subtracting the preweights and postweights of the tubes. The data were statistically analyzed using the one-way analysis of variance and the least significant difference tests at a significance level of $P < 0.05$. **Results:** A measurable amount of debris was apically extruded in all groups, and the amounts of debris extrusion in the groups were statistically significant ($P < 0.001$). The ProTaper Next and WaveOne groups resulted in less debris extrusion than the ProTaper Universal group ($P < 0.05$), and the SAF group resulted in the least debris extrusion. **Conclusions:** Within the limitations of the present study, it can be concluded that all systems extruded debris beyond the apical foramen.

Key words: Apically extruded debris, ProTaper Next, ProTaper Universal, self-adjusting file, WaveOne

INTRODUCTION

Root canal preparation is one of the most important stages in endodontic treatment. For successful treatment, vital and necrotic tissue, microorganisms, and dentinal debris should be removed from the root canal system.^[1,2] However, these materials may be extruded through the apical foramen into the periapical tissues during root canal preparation.^[3] This results in postoperative complications such as a flare-up, which is described by periapical inflammation, pain and swelling.^[4,5]

Advancements in rotary instruments have facilitated and fastened the root canal procedures

and resulted in less iatrogenic error.^[6] In recent times, a new root canal instrumentation system, ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), was introduced. This system is made with M-wire nickel-titanium alloy. The advantages of this M-wire alloy are increased flexibility and greater resistance to cyclic fatigue of the instruments. The ProTaper Next instruments are designed with variable tapers and an off-centered rectangular cross section. This design makes it possible to completely prepare root canals using fewer instruments than the number required by the ProTaper Universal. Moreover, an offset design maximizes the augering of debris out of the canal,

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compared with a file with a centered mass and axis of rotation.^[7]

Until date, no studies have been conducted to determine the amount of debris extrusion resulting from the use of the new rotary instrument, ProTaper Next. Thus, the aim of this study was to compare the amount of apically extruded debris during preparation with ProTaper Universal (Dentsply Maillefer), ProTaper Next, a reciprocating single-file (WaveOne; VDW GmbH, Munich, Germany), and a self-adjusting file (SAF; ReDent Nova, Ra'anna, Israel). The null hypothesis was that there would be no difference among the various instrumentation techniques in terms of the quantity of apically extruded debris.

MATERIALS AND METHODS

Fifty-six human-extracted single-rooted intact mandibular premolars with mature apices and curvatures between 0° and 10° were selected. Only single-rooted teeth with a single-canal and a single apical foramen were included. This was verified by viewing their buccolingual and mesiodistal radiographs and checking apical foramen under a stereomicroscope with a × 20 magnification (Novex, Arnhem, Holland). The root surfaces were cleaned of debris and soft tissue remnants with a periodontal curette. The coronal access cavity was prepared using diamond burs and all of the canals were confirmed for apical patency with a size 10 K-file (Dentsply Maillefer). The file was inserted into the canal until its tip was slightly visible at the apical foramen. Endodontic working lengths (WLs) were set by deducting 1 mm from the initial length. The root canal width near the apex was controlled with a size 15 K-file; teeth with an apical width size larger than 15 were excluded. The 56 teeth were randomly assigned to four groups for instrumentation, as follows ($n = 14$).

ProTaper universal

In this group, the root canals were prepared with ProTaper Universal instruments used at 300 rpm with 2 Ncm torque (X-Smart, Dentsply Maillefer). An SX file was used at 1/2 of the WL; S1 and S2 files were at 2/3 of the WL; and F1, F2, F3, and F4 files were at full WL. SX, S1, and S2 files were used in the canals with a brushing motion, and the others were used with a gently in- and out-motion until the instrument had reached into the full WL. The root canals were irrigated with 1 mL distilled water after each instrument using a 31-gauge double side-port

needle (NaviTip Sideport; Ultradent, USA). After instrumentation 1 mL, distilled water was used as a final rinse. A volume of 8 mL distilled water was used for irrigation.

ProTaper next

The root canals were prepared using the ProTaper Next system with gentle in- and out-motion at 300 rpm and 2 Ncm torque with a torque-controlled endodontic motor (X-Smart, Dentsply Maillefer). The instrumentation sequences were X1 (17/04), X2 (25/06), X3 (30/.075), and X4 (40/.06). All instruments were used at WL.

Waveone

The root canals were instrumented using a WaveOne reciprocating single-file (40/.08) with a gently in- and out-pecking motion using VDW SILVER® RECIPROC® (VDW GmbH, Munich, Germany).

Self-adjusting file

A glide path was confirmed using K-files to allow for insertion of a size 20 K-file into the WL. The coronal third of the root canals were prepared using a size 3 Gates-Glidden bur (Kendo Munich, Germany), with 1.5 mm of diameter and 21 mm of a SAF file used at 5000 movements/min with an amplitude of 0.4 mm. Distilled water was continuously provided by a VATEA peristaltic pump (ReDent Nova Inc., Ra'anana, Israel) at a rate of 2 mL/min. The SAF file was used for 4 min, and hence a total of 8 mL distilled water was used for irrigation.

All root canal preparations were completed by one operator according to the manufacturers' suggestions. Instruments were used only for preparation of three canals, with the exception of SAF and WaveOne files (single use). In each sample, a total of 8 mL distilled water was used as an irrigating solution with an automated irrigation system (SAF) or with a 31-gauge double side-port needle (NaviTip Sideport; Ultradent, USA) between files in the ProTaper Universal and Next groups and between pecking sequences in the WaveOne group. Apical patency was maintained by passing a size 15 file to WL after the use of each file.

Debris collection

To evaluate the collection of apically extruded debris, a similar method was used with previous studies.^[1,8] The Eppendorf tubes were weighed with an electronic balance (Denver Instrument GmbH XP series, Gottingen, Germany) with an accuracy

of 10^{-4} . Three consecutive measurements were taken, and the average measurement for each tube was calculated. Figure 1 shows the experimental setup used in the study. Stoppers were separated from Eppendorf tubes unrelated to this study and holes were created in these stoppers to place teeth into the tubes. The teeth were inserted up to the cemento-enamel junction through the caps, and then fixed with cyanoacrylate (Pattex Super Glue; Türk Henkel, Inc., Istanbul, Turkey) to prevent leakage of irrigating solution through the hole. A needle was placed alongside the stoppers to balance the internal and external air pressures. The tooth was isolated with a rubber dam and ligated with thread; an aspirator was used to suction overflowed irrigating solution from the tooth crown.

Once instrumentation was finished, the root canal was irrigated with 2 mL of distilled water and each tooth was then removed from the Eppendorf tube. The root surface was washed with 1 mL of distilled water into the Eppendorf tube to collect the debris adhering to the root surface. The Eppendorf tubes were then stored in an incubator at 37°C for 10 days to evaporate the distilled water. The net weight of the extruded debris was determined by subtracting the initial weight from the last weight measured. All of the tubes were weighted 3 more times, and the net weight of the apically extruded debris was determined by subtracting the pre- and post-weights of the tubes. The data were statistically analyzed using the one-way analysis of variance and the least significant difference tests at a significance level of $P < 0.05$. Statistical analysis was performed using IBM® SPSS® Statistics 20 software (IBM SPSS Inc., Chicago, IL, USA).



Figure 1: The experimental model system used to evaluate debris extrusion

RESULTS

Table 1 shows the quantity of apically extruded debris for each group. A measurable amount of debris was apically extruded in all groups, and the amounts of debris extrusion in the groups were statistically significant ($P < 0.001$). The ProTaper Universal group resulted in the largest amount of debris extrusion among the groups ($P < 0.05$), and the SAF group resulted in the least extrusion ($P < 0.05$). The ProTaper Next and WaveOne groups resulted in less debris extrusion than ProTaper Universal group ($P < 0.05$), but more than the SAF group ($P < 0.05$). However, the difference between the ProTaper Next and WaveOne groups was not statistically significant ($P = 0.654$).

DISCUSSION

To the best of our knowledge, no previous study has evaluated the apical debris extrusion during instrumentation with the ProTaper Next file system. The results of the present study support the claim, and reveal that the ProTaper Next group extrudes less debris than the ProTaper Universal, but an amount similar to the WaveOne group. The ProTaper Next and the ProTaper Universal have variable taper performance; however, the ProTaper Next differs from the ProTaper Universal in terms of an off-centered, rectangular cross section. The axis of rotation in the ProTaper Next system differs from the center of mass. As a result, only two points of the rectangular cross section touch the canal wall at a time. The offset design of the ProTaper Next system could have enhanced the augering of debris out of the canal rather than the extrusion of debris apically.^[7] Moreover, the ProTaper Next file's asymmetric rotary motion makes it possible to achieve the root canal instrumentation with fewer files (four files). It can be speculated that the fewer number of files used for preparation in the ProTaper Next group might be another factor that accounts for the lesser amount of debris extrusion than that resulting from the use of the ProTaper Universal, in

Table 1: Mean weight and SD of apically extruded debris after the use of different instrumentation systems

Group	n	Mean weight	SD
ProTaper Universal	14	0.00028 ^a	0.00013
ProTaper next	14	0.00019 ^b	0.00007
WaveOne	14	0.00021 ^b	0.00007
SAF	14	0.00012 ^c	0.00008

Groups with different letters were statistically different at $P=0.05$. SD: Standard deviation, SAF: Self-adjusting file

which the root canal preparation could be achieved with seven files. Li *et al.*^[9] have reported that if the file insertion time increase, more debris will be produced and compacted more tightly along dentine walls and then difficult to be flushed out of the canal. In addition, the larger taper of the F3 instrument performs more aggressive cutting, and this could be the cause of the more apically extruded debris by ProTaper Universal system.^[10]

According to the results of this study, all instruments resulted in apical extrusion of debris. The results of previous studies showed that no method completely avoids debris extrusion, and the present study is in agreement with the results of these studies.^[11-14] There were statistically significant differences among the groups; therefore, the null hypothesis that there would be no difference among the various instrumentation techniques in terms of the quantity of apically extruded debris was rejected. The SAF group resulted in the least extrusion among the groups, and the difference was statistically significant ($P < 0.05$). This result is corroborated by the findings of De-Deus *et al.*^[15] This result could be, for many reasons, the most striking; it can likely be attributed to the differences in the instrument designs and movement kinematics among the SAF and the other systems' files.^[15] The SAF system also allows continuous irrigation throughout the scraping of the dentin. This could facilitate the augering of debris out of the canal and decrease the amount of apically extruded debris.

The amount of apically extruded debris during instrumentation with the reciprocating single-file (WaveOne) was less than that of the multiple-file ProTaper Universal. This observation is harmonious with the findings of Koçak *et al.*^[1] insofar as the reciprocating single-file system (RECIPROC®) multiple-file rotary instrumentation produced less debris compared with the ProTaper Universal. In contrast, Bürklein *et al.*^[3] reported that rotary instrumentation was associated with less debris extrusion compared with the use of reciprocating single-file systems. The differences between the studies may be due to a variety of differing experimental setups used in these investigations. In the present study, there were no statistically significant differences between the reciprocating single-file WaveOne and the multiple-file ProTaper Next rotary systems ($P > 0.05$). However, because no known study of the ProTaper Next system's extrusion of debris is available in the literature, this finding could not be compared with those of previous studies.

In the present study, distilled water was used as the root canal irrigating solution to prevent crystallization of sodium hypochlorite. A generally-accepted method of Myers and Montgomery^[8] was also modified for debris collection without the simulation of the periapical tissue resistance. However, in clinical situations the periapical tissues act as a natural barrier to reduce debris extrusion. The vital periapical tissues were not mimicked; therefore, the results could be changed in an *in vivo* model. Thus, although the results should not be directly extrapolated to the clinical situation, this method makes it possible to collect apical extrusion of debris.

The width of apical constriction may affect the amount of debris extruded apically. Tinaz *et al.*^[16] reported that there is an increase in the amount of the apically extruded material parallel to increase in the diameter of the apical patency. However, Lambrianidis *et al.*^[17] stated that the apically extruded material was less when the constriction was enlarged than when the constriction remained intact. In the present study, to standardization of samples in all groups, the teeth with an apical width size 15 were used.

CONCLUSIONS

According to the conditions of this study, it can be concluded that all systems extruded debris beyond the apical foramen. The SAF group resulted in the least debris extrusion, and the ProTaper Next and WaveOne groups were associated with less debris extrusion than the ProTaper Universal group. Further *in vivo* studies are required to evaluate postinstrumentation pain with these instrumentation systems.

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