

Comparative Evaluation of Apically Extruded Debris Using Rotary and Reciprocating NiTi Instruments: An *In Vitro* Study

Arunajatesan Subbiya¹, Nagarajan Geethapriya², Siddique Jahir³, Venkatachalam Prakash⁴, Alagarsamy Venkatesh⁵, Ramu Shobhana⁶

ABSTRACT

Introduction: The objective of this *in vitro* study was to quantify the amount of apically extruded debris using rotary and reciprocating nickel–titanium instrumentation systems.

Materials and methods: Sixty mandibular central incisors were instrumented up to size 25 using WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland), and ProTaper Next (Dentsply Maillefer, Switzerland). Bidistilled water was the irrigant used. Myers and Montgomery method with preweighed Eppendorf tubes was used to estimate the apically extruded debris. The mean weight of debris was assessed after drying with a microbalance and analyzed statistically using analysis of variance and the *post hoc* Student tukey HSD test. The significance level was $p = 0.05$.

Result: The reciprocating file WaveOne produced significantly more debris compared with ProTaper Next ($p < 0.05$). No statistically significant difference was observed between WaveOne and ProTaper Universal, and between ProTaper Universal and ProTaper Next ($p > 0.05$).

Conclusion: Under the limitations of this study, all systems caused apical debris extrusion. The extrusion of ProTaper Next was the least followed by ProTaper Universal with WaveOne showing the highest extrusion.

Keywords: Apical extrusion, ProTaper, ProTaper Next, WaveOne.

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INTRODUCTION

The removal of intracanal microorganisms, which are responsible for endodontic pathosis, is the hallmark of successful root canal therapy. This is attained by use of particular instruments and irrigants that cause debridement, shaping, and disinfection of the root canal space.¹

It is critical to improve endodontic success by complete debridement of the root canal space using files and irrigating solutions. During root canal preparation, there may be extrusion of irrigants, dentin chips, pulp tissue, and microorganisms into the periradicular tissues; postoperative pain and flare-ups are caused by these extruded materials.² The incidence of flare-ups is reported in range between 1.4% and 16% during root canal treatment.³ Though critical causative factor in the occurrence of flare-ups is the extrusion of microorganisms, it is also accepted that to initiate an inflammatory reaction contaminated as well as non-contaminated dentin and pulp tissue may have the potential role.²

All instrumentation techniques and instruments are associated with the debris extrusion as stated by many studies evaluating the apical extrusion of debris.^{4–9} Foreign body reaction occurs due to extrusion of debris during cleaning and shaping procedure beyond the apical terminus into the surrounding tissues, which may result in delayed healing or even treatment failure. Even though instrumentation techniques force intracanal content through periapical tissues, the quantity of debris extrusion may differ according to the preparation techniques and the design of the various file systems.⁶

A convex triangular cross-sectional design with three cutting edges, a negative cutting angle, and a flute design that combines progressive tapers within the shaft is observed in ProTaper instruments (Dentsply Maillefer, Ballaigues, Switzerland).⁷ ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) is an innovative

^{1,2,4–6}Department of Conservative Dentistry and Endodontics, Bharath Institute of Higher Education and Research, BIHER, Chennai, Tamil Nadu, India

³Private Practitioner, Chennai, Tamil Nadu, India

Corresponding Author: Arunajatesan Subbiya, Department of Conservative Dentistry and Endodontics, Bharath Institute of Higher Education and Research, BIHER, Chennai, Tamil Nadu, India, Phone: +91 98401 97437, e-mail: drsubbiya@gmail.com

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NiTi file system. An off-centered rectangular design, and progressive and regressive percentage tapers on a single file are seen in ProTaper Next. Having various percentage tapers decreases the effect of the screwing in and dangerous taper lock by minimizing the contact between the file and the dentin.¹⁰ Additionally, there is increased augering debris out of the canal in case of offset design when compared to a file with a centered mass and axis of rotation.¹¹ WaveOne file, the single-file system is used in a reciprocal motion. The stress on the instrument is reduced by reciprocating movement by special counterclockwise (cutting action) and clockwise (release of the instrument) movements, and thus, there is a reduced risk of cyclic fatigue caused by tension and compression.¹² These three systems evaluated in this study differ in their design, metallurgy, and kinematics.

The objective of this investigation is to assess and compare the amount of apically extruded debris after preparation of single

straight root canal in extracted human mandibular incisor using reciprocating single file system WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) with two rotary full-sequence ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) and ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) systems.

MATERIALS AND METHODS

The present study was approved by the Research Ethics Committee of the Sree Balaji Dental College and Hospital, Chennai (SBDCH/IEC/09/2015/14). For this investigation, a total of 60 extracted human mandibular incisors were selected. The inclusion criteria were single-rooted teeth with a single canal and a single apical foramen without calcification. This was confirmed by viewing their buccal and proximal radiographs. The exclusion criteria were a tooth having more than a single root canal and apical foramen, internal/external resorption, immature root apices, caries/cracks/fractures on the root surface, and/or root canal curvature more than 10 degrees. After preparing 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 determined by deducting 1 mm from these lengths.

According to these criteria, 60 mandibular incisor teeth were selected. The specimens were distributed equally across 3 groups ($n = 20$). Before instrumentation, the glide path was created in all the samples with #15 K-file. The preparation sequences were as follows: Group I: A WaveOne primary file of size 25 and a taper of 0.08 were used in a reciprocating, slow in-and-out pecking motion according to the manufacturer's instructions. After 3 pecks, the flutes of the instrument were cleaned.

Group II: Using manufacturer's instructions, ProTaper Universal instruments were used in a gentle in-and-out motion. The order in which instrumentation was performed as follows: SX at two-thirds of the WL; S1 and S2 at WL -1 mm; and then F1 (20.07) and F2 (25.08) at the WL. The finishing instrument was removed once it had negotiated to the end of the canal and had rotated freely.

Group III: The sequence for instrumentation with ProTaper Next files was as follows: X1 (17.04) and X2 (25.06) (full working length) at a rotational speed of 300 rpm and 200 g/cm torque. Each file was used in a brushing motion. 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.

Bidistilled water of 2 mL was used as an irrigant after each instrument or after 3 pecks of using the reciprocating files (as recommended by the manufacturers). A 30-gauge side-vented irrigation needle (Maxi-Probe; Dentsply-Rinn, Elgin, IL, USA) was placed as deep as possible into the canal without resistance but not deeper as the predetermined WL -1 mm.

The preweighed Eppendorf tube was used to collect the extruded debris and the irrigant (bidistilled water), which was attached to the lower edge of an individual rubber plug prepared for each tooth according to the method described by Myers and Montgomery.¹³ All the Eppendorf tubes were preweighed by using an electronic balance with an accuracy of 0.00001 g (Mettler Toledo, Bradford, USA). A total of 60 Eppendorf tubes were used for collecting debris from all the samples and the root apex was suspended within the receptor tube. To avoid contact with the collecting vial, a second bottle was used to hold the device during instrumentation. The amount of extruded material is extremely

low; the contact of moist or greasy fingertips may alter the weight of extruded debris significantly.¹⁴ The bottle was vented with a 24-gauge needle alongside the rubber plug to equalize the pressure. Each tooth was separated from the receptor tube after the completion of instrumentation, and the root was washed with 1 mL of bidistilled water to collect the debris adhering to the root surface into the receptor tube. Then, in an incubator, the receptor tubes were stored at 70°C for 5 days to evaporate the moisture. Later the dry debris was weighed using the same weighing machine. The dry weight of extruded debris was calculated by subtracting the weight of the empty tube from the weight of the tube containing debris as described by Bürklein et al.¹⁵

RESULTS

The results indicate that all the tested instruments caused a measurable extrusion of the debris at the apex. The mean debris extrusion by WaveOne reciprocating file was 0.00118 mg, ProTaper Universal was 0.00083 mg, and ProTaper Next was 0.00066 mg (Table 1). The highest mean debris extrusion is shown by WaveOne followed by ProTaper Universal and least by ProTaperNext (Fig. 1). The intergroup comparison is depicted in Table 2, which shows that the reciprocating single-file WaveOne system has produced significantly more debris compared with full-sequence ProTaper Next system ($p < 0.05$). There was no statistically significant difference between ProTaper Universal and ProTaper Next systems ($p > 0.05$), and ProTaper Universal and WaveOne ($p > 0.05$).

DISCUSSION

The debris produced between the instrumentation of the abovementioned files was collected using the Myers and

Table 1: Amount of apically extruded debris in grams

Debris extrusion in grams	WaveOne	ProTaper Universal	ProTaper Next
Mean	0.00118	0.00083	0.00066
Standard deviation	0.00065	0.00054	0.00025
T	8.06	6.94	11.85
D_f	19.00	19.00	19.00
p value	0.000*	0.000*	0.000*

* p value significant at the level <0.05

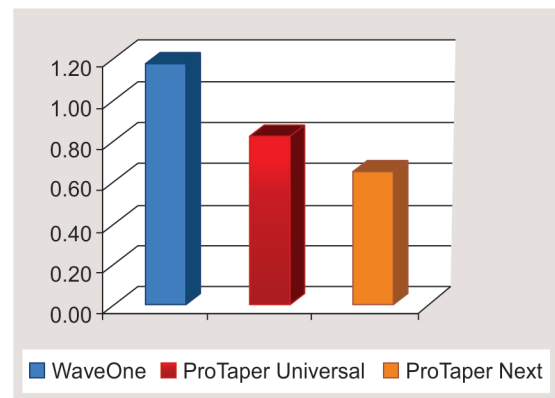


Fig. 1: Mean debris extrusion in milligram

Table 2: Intergroup comparison of apically extruded debris

Comparison between groups	WaveOne		ProTaper Universal		ProTaper Next	
	ProTaper Universal	ProTaper Next	WaveOne	ProTaper Next	WaveOne	ProTaper Universal
Mean difference	0.35	0.51	0.35	0.17	0.51	0.17
Standard error	0.16	0.16	0.16	0.16	0.16	0.16
p value	0.089	0.006*	0.089	0.544	0.006*	0.544

*p value significant at the level <0.05

Montgomery method,¹³ which is adopted in most of the studies pertaining to apical extrusion of debris despite some shortcomings. The apical extrusion of debris will not be limited because of the absence of a physical back pressure provided by periapical tissues.^{14,16} This is a possible shortcoming of *in vitro* design as already discussed by Myers and Montgomery. Though alternative methods using floral foam have been suggested to stimulate resistance of periapical tissues,^{17,18} foam when used as a barrier can absorb some irrigant and debris. Therefore, to simulate periapical resistance, no attempt has been made in the present study. The irrigant used in this study was bidistilled water. This was preferred over sodium hypochlorite because sodium hypochlorite if used as an irrigant can result in crystallization during drying process and this may alter the weight of dentin debris and can compromise the reliability of the results.¹⁹ With regard to needle usage, various studies have evaluated the periapical extrusion by different types of irrigation needles. The studies indicated that side-vented needles extruded less irrigant compared with a regular needle.^{17,20} Therefore, in the present study, side-vented needles were used in all the groups to avoid extrusion on irrigation and also to standardize the irrigation protocol.

The result of this study showed that some amount of debris extrusion was caused by all the instruments. Among the three file systems used in this study, WaveOne reciprocating single-file system caused the maximum amount of apically extruded debris, followed by ProTaper Universal and least by ProTaper Next. There were statistically significant differences in the apical debris extrusion between WaveOne and ProTaper Next ($p < 0.05$). The mean debris extrusion by WaveOne reciprocating file was 0.00118 mg and ProTaper Next was 0.00066 mg. The obtained differences may be attributed to factors like kinematics, number of files, instrument cross section, and design. It has been suggested by Burklien et al. that continuous rotation by ProTaper Next acts like a screw conveyor to improve coronal transportation of dentin chips and debris.²¹ Another reason may be the geometry of the rotary file, which allows accumulation of debris into the flute space and forcing them outside toward the orifice, thus avoiding their compaction into the root canal.²² Yet another feature of ProTaper Next is an off-centered rectangular design generating traveling waves of motion along the active part of file and swaggering motion which tends to reduce the contact between file and dentin. These features provide more space for debris to be collected between file and dentin. For the abovementioned reasons, the debris may get pushed up to the coronal aspect by the clockwise rotary action of the file.

Reciprocating motion of WaveOne system results in a 360° counterclockwise rotation after every three oscillations (150° CCW with 30° CW). Summatively, this reciprocating motion is a total reverse of rotary file. Therefore, logically, it can be inferred that rotary movement in counterclockwise direction is liable to pack debris in apical third rather than moving it in coronal direction. Several other studies have also shown that single-file

reciprocating systems WaveOne and Reciproc extruded more debris than multiple-file and single-file rotary systems. This result is in accordance with various other studies.^{15,21-24} The literature also shows that the result was not in agreement with other studies,^{25,26} which stated reciprocating single file systems produced less apical extrusion than full-sequence rotary systems. The difference with the contradicting study by Uzun et al. could be because of the study design. Although apical enlargement was done to size 25, maxillary anterior teeth were selected in their study, whereas in this study, mandibular anterior teeth were selected. Since mandibular incisors have narrower canal, the contact of the instrument with the walls can be expected to be more in comparison to studies done in mandibular premolars extracted for orthodontic reasons where the canal diameter is much wider, and therefore, a difference with the other studies is possible.

The mean debris extrusion for ProTaper Universal was 0.00083, which was an intermediate value between WaveOne and ProTaper Next. But while comparing the amount of apically extruded debris between WaveOne and ProTaper Universal, and ProTaper Next, there was no statistically significant difference between these groups ($p > 0.05$). In the case of ProTaper Universal, debris extrusion was less than WaveOne reciprocating file primarily because of the continuous rotation which may improve coronal transportation of dentin chips and debris by acting like a screw conveyor.

ProTaper Next and ProTaper Universal systems show common design feature as these show presence of progressive and regressive percentage tapers on a single file. However, the debris extrusion by ProTaper Universal was more than ProTaper Next. There is 0.08 taper in ProTaper Universal F2 instrument at the apical 3 mm, whereas there is 0.06 taper in ProTaper Next X2 instrument at the apical 3 mm. The ProTaper Universal instrument has a larger taper at the tip, which might explain the increased amount of debris extrusion with this system. This result is in concordance with various other studies, which also states that ProTaper Next caused least debris extrusion and ProTaper Universal caused more debris extrusion.^{27,28} But the difference was not statistically significant in this present study.

CONCLUSION

Within the limitations of this present *in vitro* study,

- there was debris extrusion by all the three tested systems, namely, WaveOne, ProTaper Universal, and ProTaper Next systems.
- WaveOne instrumentation system extruded the most followed by ProTaper Universal. ProTaper Next instrumentation system extruded the least apical debris extrusion.
- a significant difference between extrusion of WaveOne and ProTaper Next was observed.
- also, there was no significant difference between ProTaper Universal and the other two instruments, namely, ProTaper Next and WaveOne.

CLINICAL SIGNIFICANCE

Endodontic instrumentation causes apical extrusion, which differs with cross section, design, and kinematics. Reciprocating instruments extrude more debris than rotary instruments.

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