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Quantitative evaluation of apical extruded debris during root canal instrumentation with 2 rotary and 2 reciprocating file systems. An in-vitro comparative study.

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Abstract:

Aim: An in-vitro quantitative evaluation of apically extruded debris during root canal instrumentation with 2 different rotary and 2 different reciprocating file systems.

Materials & Method: 80 extracted human permanent mandibular single rooted premolar teeth were collected and randomly divided into four groups (n=20) based on type of files used for root canal instrumentation. Group 1: ProTaper Next and Group 2: Neoendo Flex rotary file systems, Group 3: WaveOneGold and Group 4:Reciproc Blue reciprocating file systems. Each tooth was inserted into empty eppendorf tubes till the cervical line. Distilled water was used as irrigant during canal instrumentation and apical extruded debris during instrumentation was collected into eppendorf tubes. These tubes were then incubated at 70°C for 5 days to dessicate the distilled water used. The dry apical extruded debris from each sample was weighed using Analytical Digital weighing microbalance with the accuracy of 0.0001gm. Statistical plan: One way ANOVA and Tukey's Post-hoc tests were used.

Results: One way ANOVA showed statistically significant difference in apical extruded debris between the four groups as $P \leq 0.05$. Group 1(PTN file system) showed the least apical extruded debris with Mean±SD 0.15±0.05 µgm (microgram) compared to Group 2 (Neoendo Flex file system) with 0.41±0.08 µgm. Both Group C (WaveOne Gold) and Group D (Reciproc Blue) reciprocating files showed greatest apical extruded debris with 0.79±0.1 and 0.81±0.14 µgms respectively.

Conclusion: Both the rotary file systems (ProTaper Next and Neoendo Flex) showed less apical extruded debris compared to reciprocating file systems (WaveOne Gold and Reciproc Blue) used during root canal instrumentation. However, ProTaper Next rotary file system showed the least apical extruded debris compared to other file systems used.

Keywords: Apical extruded debris, Canal instrumentation, Eppendorf tubes, Rotary files, Reciprocating files.

Introduction:

Root canal preparation is one of the most important steps in endodontic treatment. For successful endodontic treatment, vital and necrotic pulp tissue, microorganisms and dentinal debris should be removed from the root canal system.[1] However, they extrude from the root canal out the apical foramen into the periapical tissues during root canal instrumentation, as it was first confirmed by Chapman CE et al.[2] For successful shaping and cleaning of root canals require appropriately designed endodontic files for shaping and the use of root canal irrigants to thoroughly remove the debris, Vande Visse JE et al[3] showed that the use of any fluids as root canal irrigants made root canal instrumentation easier, but pushed the debris more easily into the periapical tissues through the apical foramen causing inflammation and infection of periapical tissues, post-operative pain, swelling and failure of root canal therapy. However, root canal irrigation is a key factor in chemo-mechanical preparation and eliminating it from the endodontic treatment protocol causes failure of root canal treatment. So instead of removing it, a modification in root canal instrumentation technique is a more precise option to reduce extrusion of debris apically.[4] Apical extrusion of debris was proven to be an unavoidable occurrence during root canal instrumentation since the methodology for measuring the amount of extruded debris was introduced by Myers GL and Montgomery S in 1991.[5]

Due to availability of various endodontic files, researchers have been trying to determine the factors influencing the incidence and severity of apical extrusion; shape, size and cross-section of endodontic files, propelling mechanism, metallurgy and eventually movement kinematics. The rationale behind conducting this research study was that, along with advances in instrument design and manufacturing,

it seems that movement kinematics plays a role in the severity of apical extrusion of debris from the root canal.[6] So, four popular endodontic file systems that use rotary or reciprocating motion, were chosen in our study. ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is a M-Wire based Nickel-Titanium (Ni-Ti) alloy rotary file system produced by heat treatment, variable taper, off-centered rectangular cross-sectional design to enhance its flexibility, fatigue resistance, an offset design maximizes the augering of debris out of the canal compared to a file with centered mass and axis of rotation, it consists of 5 files namely X1,X2,X3,X4,X5.[7] Neoendo Flex (Orikam Healthcare Private limited, India) is a rotary file system made with proprietary heat treatment, has triangular cross-sectional design and is available in various size and taper; 17/4%, 0/4%, 25/4%, 20/6%, 25/6% with non-cutting safety tip.[8]

WaveOne Gold (WOG; Dentsply Sirona, Ballaigues, Switzerland) and Reciproc Blue (VDW, Munich, Germany) are two newer reciprocating file systems manufactured with M (Memory)-Wire based Ni-Ti alloy in an innovative thermal treatment process. Both these file systems have left-handed angulation of the blades, thus engaging and cutting the root canal dentin in the CounterClockWise (CCW) direction. Whereas the ClockWise direction (CW) allows the file to disengage and safely progress along the canal path, thus reducing the screwing-in effect into root canal dentin, preventing file fracture.[9] WOG file uses the same reciprocating kinematics as its predecessor WaveOne file (Dentsply Sirona, Ballaigues, Switzerland). WOG files are available in 4 sizes; 20: small, 25: primary, 35: medium, 45: large. They have a parallelogram-shaped cross-sectional design with rounded tip allowing alternate one point contact between the file and walls of root canal.[10] Reciproc Blue is the newer version of Reciproc file system (VDW, Munich, Germany). It is a single file system commonly using one of the three files (R25, R40, R50) for complete root canal instrumentation and have S-shaped cross-sectional design.[9]

The present study intends to focus on the quantitative evaluation of apically extruded debris during root canal instrumentation with the rotary and reciprocating file systems. The null hypothesis in our study was that there will be no significant difference in the amount of apical extruded debris among the 2 rotary and 2 reciprocating file systems used for root canal instrumentation.

Materials and method:

Eighty freshly extracted human mandibular single rooted premolar teeth were collected in Triveni Institute of Dental Sciences, Hospital and Research centre, Bilaspur. India. Inclusion criteria; Non-carious, non-fractured, non-restored, single rooted, matured teeth with closed root apices. Teeth were examined with stereomicroscope at 10X magnification to verify the presence of a single apical foramen. Teeth were radiographically examined bucco-lingually and mesio-distally for the confirmation of single root canal, absence of calcifications, resorptive defects and other anatomical anamolies and only the teeth with the degree of root canal curvature $<5^0$ as assessed following Schneider's criteria[11] were included. Teeth extracted for orthodontic purpose or periodontally compromised were included in our study. Exclusion criteria; Carious, fractured, restored, open root apices, multi-rooted and multiple canal teeth. All specimens were cleaned off superficial debris, calculus, residual tissue tags using ultrasonic instruments and disinfected by immersing in 3% sodium hypochlorite solution for 5 days, washed with running tap water and stored in 0.5% thymol at room temperature until used.

Conventional endodontic access cavity preparations were made in all teeth using Endo access bur no. 2 (Dentsply Maillefer, Switzerland) in a high speed conta-angled airoter handpiece (NSK, Japan), canal orifices were located and pulp tissue was extirpated with barbed broaches (Dentsply Maillefer, Switzerland). The cuspal tips of all teeth were flattened using SF-11 dental bur (Mani, Japan) attached to high speed conta-angled airoter handpiece to obtain stable reference point and to standardize length of all teeth to 18mm. An ISO no.10 K(Kerr)-file(Mani INC, Japan) was placed into the root canal to establish the patency till the apical foramen and the working length was determined by subtracting

0.5mm from the length achieved with the tip of the trial file just visible at the apical foramen of each root canal.

All teeth (n=80) were then randomly divided into four groups with 20 specimens per group, using Random sequence generator (Random.org, Dublin, Ireland) software based on the type of rotary and reciprocating file systems used for root canal instrumentation. The experimental model for quantitative measurement of the amount of apically extruded debris was then prepared following the methodology described by Myers GL and Montgomery S.[5] To prevent any inter-operator variability, a single operator carried out the entire experimental model setup. Each empty Eppendorf tube (Merck KGaA, Darmstadt, Germany) (Figure no. 1) was weighed 3 times consecutively using Analytical Digital weighing balance (Sartorius, Nona Technologies Pvt. Ltd, Bengaluru) and the mean values were recorded for the experimental procedure.

Figure no. 1: Eppendorf tube

A hole was made into the rubber stopper of each eppendorf tube by placing a heated stainless steel ball-burnisher hand instrument (API, AshooSons, New Delhi, India) and the tooth to be instrumented was then inserted apically into the tube upto the level of cementoenamel junction. The tooth-rubber stopper interface was further secured with Addition-Silicone based impression material (Affinis Putty, Coltene/Whaledent AG, Altstatten, Switzerland) to obtain a stable and tight contact. A 24-gauge dispensing needle (Dispovan, HMD, Delhi, India) was then inserted through the stopper into the eppendorf tube in order to equalize the pressure inside and outside of the tube.[5]Each eppendorf tube was then placed into a Glass vial (IndoSurgicals Pvt. Ltd, New Delhi, India). All the glass vials were fully covered with aluminium foils in order to blind the operator against viewing the amount of apically extruded debris during root canal instrumentation, thus preventing any bias.[12] (Figure no. 2 and Figure no. 3)

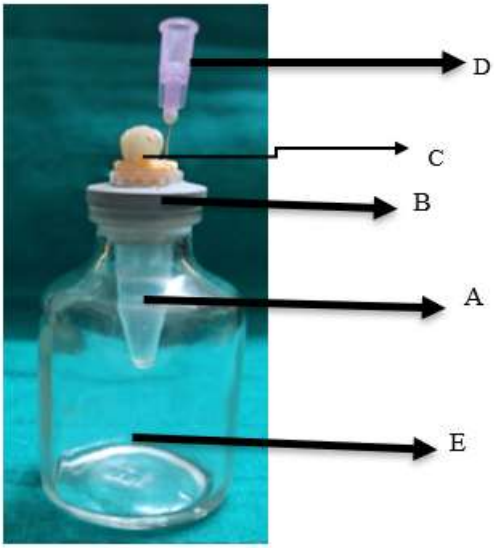


Figure no.2: The Experimental model used in our study. (A) Eppendorf tube used to collect apical extrusion of canal debris. (B) Rubber stopper. (C) Tooth secured through rubber stopper into eppendorf tube. (D) 24-Gauge needle inserted into eppendorf tube. (E) Glass vial.

Figure no.3: The Experimental model used in our study - Glass vial fully covered with aluminium foil.

Root canals of all teeth were then instrumented by one endodontist in the following manner: Group 1 (n=20); ProTaper Next rotary files (Figure no. 4) were used for root canal instrumentation upto their pre-determined working length in the file sequence; X1(size 17, 4% taper) and X2(size 25, 6% taper) attached to torque-controlled Endomotor handpiece (Canal Pro CL2, Coltene Endo, Coltene/Whaledent, Germany) at 300RPM (Revolutions Per Minute) following manufacturer instructions.
Group 2 (n=20); Neoendo Flex rotary files (Figure no. 5) were used for root canal instrumentation upto their pre-determined working length in the file sequence; 17/4%, 20/4%, 25/4%, 20/6%, 25/6% size and taper attached to torque-controlled Endomotor handpiece (Canal Pro CL2, Coltene Endo, Coltene/Whaledent, Germany) at 350rpm following manufacturer instructions.
Group 3 (n=20); WaveOne Gold reciprocating file; Medium file with size and taper 35/6% (Figure no. 6) were used for root canal instrumentation upto their pre-determined working length attached to torque-controlled Endomotor handpiece (Canal Pro CL2, Coltene Endo, Coltene/Whaledent, Germany) at 350rpm following manufacturer instructions.

Group 4 (n=20); Reciproc Blue reciprocating file R25/8% size and taper (Figure no. 7) were used for root canal instrumentation upto their pre-determined working length attached to torque-controlled Endomotor handpiece (Canal Pro CL2, Coltene Endo, Coltene/Whaledent, Germany) at 300rpm following manufacturer instructions.

Figure no.4: ProTaper Next Rotary files

Figure no.5: Neoendo Flex Rotary files

Figure no.6: WaveOne Gold Reciprocating files

Figure no.7: Reciproc Blue Reciprocating files

In each specimen, 2ml of distilled water (Sadbhavna Chemicals, Gujarat, India) was used as root canal irrigant with the aid of Max-i-Probe (Dentsply Maileffer, Switzerland) side-vented, closed-end endodontic irrigation needle during canal instrumentation irrespective to type of file system used. All files were used following their manufacturer's instructions regarding speed, torque and motion. To prevent any inter-operator variability, a single endodontist performed root canal instrumentation in all specimens. One set of files (Rotary, Reciprocating) were used for instrumentation of five root canals and were then discarded followed by the use of new set of respective files.

After completion of instrumentation, the experimental model was dismounted. The extruded debris adherent to the external surface of root apex in each specimen was washed with 1ml of distilled water, collected into the eppendorf tubes.[1,5] All eppendorf tubes were then stored in an incubator (HMG House, Palghar, India) at 70°C for 5 days to allow the distilled water to evaporate before weighing the dry debris.[13] Each eppendorf tube was weighed 3 times consecutively and the mean value was recorded. The quantitative evaluation in the net weight of dry debris was then determined by subtracting the original weight of the empty eppendorf tube from the gross weight[12] using Analytical Digital weighing balance (Figure no. 8) with accuracy of 0.0001gm. The net weight of the collected dry debris in each tube of all specimens was recorded, tabulated and sent for statistical analysis.

Figure no.8: Analytical Digital weighing balance (Sartorius, Nona Technologies Pvt. Ltd, Bengaluru)

Results:

The tabulated readings of the weight of apically extruded debris of all specimens were statistically analysed with computer software; Statistical Package for Social Sciences (SPSS) version 24, using Analysis of variance (One Way ANOVA) and Tukey-Post hoc test. Analysis of Variance tests the equality of three or more means at one time by using variances. One way ANOVA showed statistically significant difference in the mean values of the weight of apically extruded debris between the four

groups as P≤0.05. It was found that Group 1(PTN rotary file system) showed the least apical extruded debris with the Mean and Standard Deviation(SD) of net weight 0.15±0.05 µgm (microgram) compared to Group 2 (Neoendo Flex rotary file system) with 0.41±0.08 µgm. Both Group C (WaveOne Gold) and Group D (Reciproc Blue) reciprocating files showed greatest apical extruded debris with the Mean±SD 0.79±0.1 and 0.81±0.14 µgms respectively (Table no. 1) and (Graph no. 1).

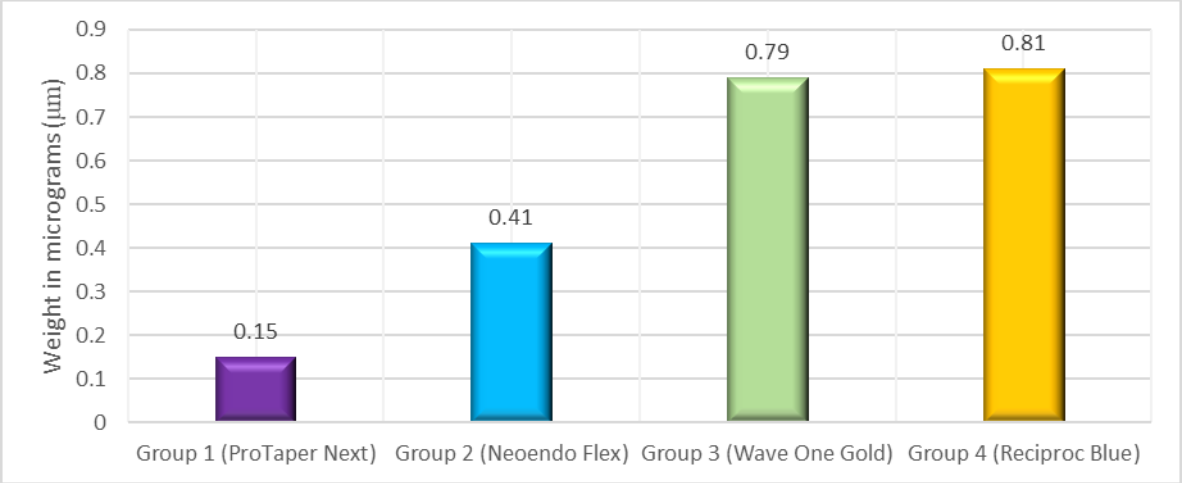
Groups	**No. of specimens**	**Mean ± SD**	**P value**
Group 1 (ProTaper Next Rotary file)	20	0.15 ± 0.05	**≤0.01 (HS)**
Group 2 (Neoendo Flex Rotary file)	20	0.41 ± 0.08	
Group 3 (WaveOne Gold Reciprocating file)	20	0.79 ± 0.1	
Group 4 (Reciproc Blue Reciprocating file)	20	0.81 ± 0.14	

Table no. 1: OneWay ANOVA test
P: Probability, SD: Standard Deviation, HS: Highly Significant

To find exactly where the statistically significant difference exists, Tukey-Post hoc test was done for inter-group comparison between the four groups (Table no. 2). Statistically highly significant difference (P≤0.05) was seen in the amount of extruded debris between Group 1 and Group 2, Group 1 and Group 3, Group 1 and Group 4, Group 2 and Group 3, Group 2 and Group 4. However, no statistically significant difference (P>0.05) was seen in the amount of extruded debris between Group 3 and Group 4.

Intergroup comparison	**Difference (Mean ± SD)**	**P value**
Group 1 (ProTaper Next Rotary file)	0.26±0.10	<0.01 HS
Group 2 (Neoendo Flex Rotary file)		
Group 3 (WaveOne Gold Reciprocating file)	0.02±0.19	0.61 NS
Group 4 (Reciproc Blue Reciprocating file)		
Group 1 (ProTaper Next Rotary file)	0.64±0.14	<0.01 HS
Group 3 (WaveOne Gold Reciprocating file)		
Group 1 (ProTaper Next Rotary file)	0.66±0.14	<0.01 HS
Group 4 (Reciproc Blue Reciprocating file)		
Group 2 (Neoendo Flex Rotary file)	0.38±0.13	<0.01 HS
Group 3 (WaveOne Gold Reciprocating file)		
Group 2 (Neoendo Flex Rotary file)	0.4±0.16	<0.01 HS
Group 4 (Reciproc Blue Reciprocating file)		

Table no. 2: Tukey-post hoc test for Inter-group comparison
P: Probability, SD: Standard Deviation, HS: Highly Significant, NS: Non-Significant



Graph no. 1: Vertical bar graph - Mean weight of apical extruded debris in micrograms (µgm) among the four groups.

Discussion:

Apical extrusion of root canal debris is clinically relevant, as it can cause post-operative pain and flare-up of an already existing endodontic pathology. It is not only the quality of the debris (virulence of microorganisms and microbial load), but also the quantity of apical debris extruded and the mere presence of foreign body over the root apex could negatively influence the outcome of root canal treatment.[14]

Our study discuss the phenomenon of apical extrusion of canal debris between Endodontic file systems using two different movement kinematics; Rotary files (ProTaper Next, Neoendo Flex) and Reciprocating files (WaveOne Gold, Reciproc Blue). The standard methodology for weighing apical extruded canal debris given by Myers GL and Montgomery S in 1991[5] was followed in our study. This methodology has been used since several years in various research studies for the purpose of measuring the amount of apically extruded canal debris during root canal instrumentation.[15] It was found to be effective, practical, reproducible option for such measurements and also enables comparison with other research studies, thus providing appropriate data for further Meta-analysis between various studies.

However, in the present study we have modified few parameters to enable proper collection of the apical extruded debris for the included file systems during canal instrumentation. The conditions that simulate to the normal clinical instrumentation were practiced in our study.

An ISO no.10 K-file was used to maintain the apical patency of root canals in all specimens to standardize the apical diameter. Tinaz AC et al[16] demonstrated that the debris extrusion increased with increase in the diameter of patency of the root apex. According to the American Association of Endodontists, Apical patency is considered as a way for maintaining the apical portion of the root canal free of debris using a small K-file through the apical foramen.[17] Buchanan defined patency file as a small flexible K-file, which passively moves through the apical constriction of root canal without widening it.[18]

Irrigation method, working length determination and technique of root canal instrumentation, design and kinematics of file systems are the factors contributing to the apical extrusion of debris.[16,19] Altundasar E et al[20] drew attention to the type of root canal irrigation needles used during root canal instrumentation using rotary files and concluded that the use of side-vented, closed-end irrigation needles showed lesser irrigant extrusion compared to conventional irrigation needles, thus in our study we used Max-i-Probe side-vented, closed-end endodontic irrigation needles.

There is no gold standard among Nickel-Titanium rotary and reciprocating file systems with respect to apical debris extrusion. In the present study, all file systems used caused some amount of apical extrusion of canal debris during canal instrumentation. This is found to be in accordance with the apical

extrusion studies reported by Burklein et al[21]and De-Deus et al.[22] Therefore in our study, the null hypothesis that there is no difference in the apical canal debris extrusion between the four file systems used was rejected.

In our study, both the rotary file systems showed less apical debris extrusion compared to reciprocating file systems. However, PTN rotary file system showed the least apical extruded debris (0.15 µgm) compared to Neoendo Flex rotary file (0.41µgm), WaveOne Gold (0.79 µgm) and Reciproc Blue reciprocating files (0.81µgm). PTN files are designed such that the center of mass and/or the center of rotation are offset generating swaggering motion of file serving to minimize the engagement between the file and walls of root canal.[23] Kocak MM et al[24] attributed that off-set rectangular cross-section, the non-uniform and reduced contact points between PTN file and root canal wall also enhances auguring of debris out in coronal direction towards the orifice rather than extruding the debris apically during root canal instrumentation. Neoendo Flex files have a triangular cross-section that makes a three-point contact with the root canal dentin wall during its rotation. This file scrapes dentin, rather than cutting it due to its negative rake angle, thus pushing the debris more coronally towards the orifice.[25] This explains why the apical extruded debris is less with this file system in our study compared to both the reciprocating file systems.

In our study compared to PTN and Neoendo Flex rotary file systems, both the reciprocating file systems (WOG and Reciproc Blue) showed greatest apical extruded debris. Both these file systems have left-handed angulation of blades on their files, thus engaging and cutting the root canal dentin in the counter-clockwise (CCW) direction and disengaging from walls of root canal in clockwise direction (CW), where the angle of cutting motion is greater than the angle of disengaging motion.[9,26]

The findings of our study are in concurrence with the studies conducted by Kocak S et al[1], Topcuoglu HS et al[27] and Pawar AM et al[28]. They concluded that root canals instrumented with reciprocating files showed significantly greater amounts of apical extruded debris compared to PTN rotary files. The findings of our study also corroborates with the study by Burklein and Schafer[13] evaluated the amount of apical extruded debris using rotary (Mtwo and ProTaper) and reciprocating (Reciproc and WaveOne) file systems and concluded that rotary file instrumentation showed less apical debris extrusion compared to reciprocating single-file systems.

Apical debris extrusion variability is presumed to be due to differences in the cross-section and cutting blade design of files, taper, tip size, flexibility and movement kinematics of files.[29] Burklein S et al[13] demonstrated a link between the quantity of apical extruded debris and cross-sectional design of files. The Taper of file also influences the extrusion of debris from the canal, Reciproc Blue file having a greater taper compared to WOG file have extruded greater debris.

Ozsu D et al[12] and Silva EJ et al[23] in their previous studies, stated that the number of files used for root canal instrumentation could be a factor that accounts for the greater amount of apical extruded debris. In the present study, the number of files used for canal instrumentation in Group 1 (PTN file system) and Group 2 (Neoendo Flex file system) was three and six files respectively. Whereas, in Group 3 (WOG) and Group 4 (Reciproc Blue) was one file each respectively. The PTN and Neoendo Flex file systems caused less apical debris extrusion compared to WOG and Reciproc Blue files systems. Therefore in the current study, the amount of apical extruded debris can be associated with the number of files used during canal instrumentation.

There is another issue to be taken into consideration when discussing the methodology of our study. Despite the fact that sodium hypochlorite (NaOCl) solution is the most commonly used irrigant during root canal instrumentation in contemporary endodontic therapy. In our study methodology, this solution was not used, as it was found to be not inert upon its contact with the walls of root canal and apart from disinfection, NaOCl dissolves organic debris, dentin and also crystallize.[24,30] So in our study, to avoid any possible weight increase caused by particulate matter of NaOCl crystal formation affecting the measurement of apical extruded debris in the eppendorf tubes, we decided that it would be best to use

a solution that is biologically inert as canal irrigant, thus Distilled water was used. In our study, all samples were incubated at 70°C for 5 days to allow the distilled water to evaporate before weighing the dry debris, Delvarani A et al[31] and Dincer AN et al[32] demonstrated in their studies that evaporation did not affect the weight of extruded debris. To overcome the possibility of data miscalculation, each eppendorf tube with collected debris was weighed three times consecutively in order to prevent any potential errors and quantitatively evaluated to determine the net weight of dry debris in each sample.
Our in-vitro study limitations include; even though all 80 specimens were standardized to a length of 18 mm, they may not fully represent the variability encountered in clinical situations. It was impossible to standardize each individual tooth in terms of root canal dentin hardness and any histological variations. Caution should be exercised when applying the findings of our study to clinical situations. In the in-vitro methodology setup of our study, the root apex is suspended in air, whereas in clinical situations the root apex would be surrounded either by healthy periapical tissues or granulomatous tissue, which would show resistance against debris extrusion to a certain extent.[33] The controlled laboratory setup of our study do not fully account for the myriad of clinical variables such as clinicians skill and intraoral conditions, which can significantly influence the performance of both rotary and reciprocating file systems during root canal instrumentation in clinical practice.

Conclusion:

Rotary file systems (PTN and Neoendo Flex files) showed minimal apical debris extrusion compared to Reciprocating file systems (WOG and Reciproc Blue). In our study, PTN rotary files showed the least apical extruded debris compared to all other file systems used for root canal instrumentation. WaveOne Gold and Reciproc Blue files showed greatest apical extruded debris. Nonetheless, further in-vivo studies are needed to confirm and correlate the findings of our in-vitro study and enhance the applicability of our findings to real-world clinical scenarios.

Conflict of interest: Nil
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