Original Article

Quantitative evaluation of the apically extruded debris from root canals prepared by single-file rotary and reciprocating file systems: An *in vitro* study

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Abstract

Aim: The aim is to investigate and compare the amount of apically extruded debris after root canal preparation using single rotary and reciprocating file system.

Materials and Methods: Forty single-rooted human mandibular premolars with straight canals were randomly assigned to four groups ($n = 10$). The root canals were instrumented according to the manufacturers' instructions using single-rotary file systems Hyflex EDM (HEDM) , One Shape (OS) and single-reciprocating file systems Wave OneGold (WOG) and OneRECI (OR). The apically extruded debris was collected in preweighed glass vials using the Myers and Montgomery method. After drying, the mean weight of the extruded debris was assessed using a microbalance.

Results and Conclusions: Multiple comparison between groups demonstrated that the mean weight of apically extruded debris in the HEDM group was significantly less compared to all other study groups, and the differences were statistically significant ($P < 0.001$). Under the condition of this study, all file systems caused apical debris extrusion. The mean apically extruded debris was significantly least in HEDM, followed by WOG, OneRECI and highest in the OS group.

Keywords: Apical debris extrusion; controlled memory files; nickel–titanium; reciprocating; single-file system

INTRODUCTION

Debris of pulpal tissue remnants, irrigants, microorganisms, and dentinal chips can be extruded through the apex to periapical tissue during the chemomechanical preparation in root canal treatment.[1,2]

A number of influencing factors that determines the amount of extruded debris from root canal includes morphological factor of tooth anatomy such as canal curvature, working length and mechanical aspects, such as instrument techniques , motion kinematics, and design of instruments.[3] Even though instrumentation techniques force intracanal content through periapical tissues , the amount of debris extrusion may differ according to the various preparation techniques and the design of the file systems.[4,5] Even though instrumentation techniques force intracanal content through periapical tissues, the amount of debris extrusion may differ according to the various preparation techniques and the design of the file systems.[4,5]

Research on the apical extrusion of debris has shown that push-pull motion typically results in a higher amount of debris than rotation motion. This has led to the hypothesis that engine-driven instruments produce less debris than hand-filing techniques, as they have a tendency to pull debris in the flutes of the instrument.[6]

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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.[5]

HyFlex EDM (HEDM; Coltene/Whaledent, Altstatten, Switzerland) and One Shape (OS; Micro Mega, Besancon, France) are single-file systems with continuous rotation motion.

Compared to noncontrolled memory NiTi instruments, these instruments are more resistant to cyclic fatigue because of this CM characteristic, which also gives the files exceptional flexibility.

HEDM files are manufactured using a unique process called electrodischarge machining technology. Spark erosion is used in this technique to increase cutting efficiency and fracture resistance. It has a variable taper and cross-section along its shaft with a 0.25-mm apical diameter. Throughout the entire working part of the file, there are three different horizontal cross-sections: a quadratic cross-section in the apical region, a trapezoidal cross-section in the middle region, and an almost triangular cross-section in the coronal region.[7] This unique combination of flexibility and fracture resistance reduces the number of files required for cleaning and shaping during root canal treatment to preserve the root canal anatomy.[8]

One Shape (OS, Micro-Mega) uses traditional austenite NiTi. One Shape file (OS, Micro-Mega) uses traditional austenite NiTi. It has a tip size of 25, a constant taper of 0.06, and is characterized by different cross-sectional designs over the entire length of the working part. In the tip region, the cross section represents three cutting edges while in the middle of the cross-sectional design it changes from a three-cutting-edge design to two cutting edges.[9]

With M-wire technology, reciprocating file systems were created as a single-file system that cuts and moves into the root canal by a reciprocating motion. With M-wire technology, reciprocating file systems were created as a single file system that cuts and moves into the root canal by a reciprocating motion. These files demonstrated less incidence of dentinal damage and are resistant to file separation.[10]

WaveOne Gold (Dentsply Malliefer, Switzerland) and One RECI (Micromega, Besancon, France) are single reciprocating file systems.

WaveOne (Dentsply Malliefer , Switzerland) files have been upgraded and are now called as WOG files. WOG file has a tip diameter of 25 and a taper of 0.07 . It has a parallelogram cross-section with 2 cutting edges. It also features the off-center design and is manufactured with advanced gold heat treatment technique.[6]

OneReci is a single reciprocation file system with an asymmetric cross-sectional design, S-shape toward the shank and are made from wire with a diameter of 1 mm. They also undergo a heat treatment (C-wire).[11] According to the manufacturer, One RECI FILE respects the root canal anatomy using a least intrusive and focused preparation technique.[8]

According to a comprehensive literature review, no studies have compared the amounts of debris extruded from the apex using single rotary file systems (Hyflex EDM and One Shape) and single reciprocating file systems (WaveOne Gold and OneRECI).

The aim of the present study was to compare the amount of apically extruded debris using single rotary file system Hyflex EDM and One Shape with single reciprocating file system WaveOne Gold and OneRECI.

MATERIALS AND METHODS

The research protocol of this experimental study was approved by the institution's Ethics Committee Board (VIDS-IEC/PG/APP/2023/51). Forty extracted human mandibular premolars [Figure 1a] with mature apices and straight, single root canals with root curvature <50 according to Schneider (1971) were included in this study. The teeth were verified radiographically to confirm a single canal without calcification. Soft tissue and calculus were moved mechanically from the root surfaces with a periodontal scaler.

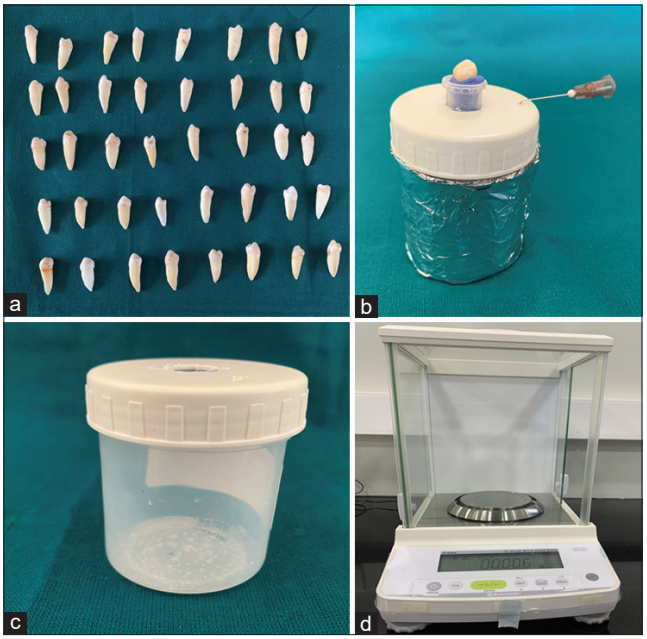

Figure 1: (a) 40 extracted mandibular premolars (b) Experimental setup wrapped with aluminium foil to avoid bias (c) Collection of Apical extruded debris in experimental setup after instrumentation (d) Electronic analytical balance measuring the weight of apically extruded debris

Teeth were divided into four groups of 10 teeth, based on the distance between the cementoenamel junction and the apex, which was measured using a digital caliper.

Endodontic access cavities were prepared using diamond burs with a high-speed handpiece under water cooling. After the preparation of the access cavity, canal patency was established with a size 10K-file. The initial instrument (size 15) was measured at the apical foramen, and its length was subtracted by 1 mm to determine the working length (WL). 2 ml of Bi-distilled water was used as an irrigant after each instrument or after three pecks using the reciprocating files.

The irrigation needle (Double side vented 26ga , RC Twents, PRIME dental Products , India) was placed into the canal without resistance ,1mm short of the working length.

The debris collection apparatus was made according to the design described by Myers and Montogomery.[12] Each individual tooth was held in an Eppendorf tube using putty material, which was fixed in the experimental set up. It was noted that no possible contact was made between the tube and the experimental set up. And it was vented with a 25G needle to equalize the pressure inside and outside. Subsequently, the experimental set up was covered with aluminium foil for blinding to avoid bias [Figure 1b].

Each instrument was used in a slow in-and-out motion for a maximum of three times per instrument according to the manufacturer's instructions. The preparation sequences were as follows:

- Group 1: HyflexEDM file (25/∼) was used in a rotational speed of 500 rpm and the torque was adjusted to 2.5 Ncm
- Group 2: One Shape file (25/0.06) was used in a rotational speed of 400 rpm and the torque was adjusted to 4 Ncm
- Group 3: WaveOne GOLD (25/0.07) was used in a reciprocating motion at a speed of 300 rpm and the torque was adjusted to 2.5 Ncm
- Group 4: One RECI (25/0.06) was used in reciprocating motion at a speed of 300 rpm and the torque was adjusted to 2.5 Ncm.

For each file, the individual torque limit and rotational speed were programmed in XMart Plus endomotor, while HyflexEDM and One Shape were used in a rotary motion and WaveOne GOLD and OneRECI were used in reciprocating motion.

Each instrument was used only once to prepare the root canal. The instrument was removed once it had freely rotated and reached the end of the canal. At this point, the instrumentation was judged to be complete for all the single-file systems.

All root canal preparations were completed by one operator and the assessment of debris was carried out by a second examiner who was blinded with respect to all experimental groups.

Each tooth was secured to the receptor tube, it was fixed in the experimental set up and held the extruded debris and the irrigant (bi-distilled water). The root apex was suspended within the receptor tube.

Collection of debris and storage: After the completion of instrumentation, each tooth was separated from the receptor tube and the debris adhering to the root surface was collected by washing the root with 2 ml of bi-distilled water into the experimental set up.

The receptor tubes were stored in an incubator at 70°C for 5 days to evaporate moisture before weighing the dry debris [Figure 1c]. An electronic balance (Matrix Labs Healthcare Solution, India) with an accuracy of 0.00001 g was used to weigh the container containing the debris and the mean value was calculated [Figure 1d]. By subtracting the weight of the empty container from the weight of the same containing debris, the dry weight of the extruded debris was determined.

Statistical analysis

The amount of extruded debris was analyzed statistically using the analysis of variance and Tukey's post hoc test at a significance level of $P < 0.05$.

RESULTS

The mean weight of apically extruded debris for the HyflexEDM group was 0.186 ± 0.030, One shape group was 0.431 ± 0.019, WaveOne GOLD group was 0.310 ± 0.016, and OneReci group was 0.404 ± 0.020. This difference in the mean weight of apically extruded debris between four groups was statistically significant at $P < 0.001$ [Table 1].

Multiple comparison between groups demonstrated that the mean weight of apically extruded debris in the HyflexEDM group was significantly less compared to all other study groups and the differences were statistically significant at $P < 0.001$.

Table 1 : Comparison of mean weight of apically extruded debris (/105) values between groups using One Way ANOVA Test

Groups	*n*	Mean	SD	Min	Max	*P*
Hyflex EDM	10	0.186	0.303	0.12	0.22	<0.001*
One Shape.	10	0.431	0.019	0.40	0.46	
WaveOne GOLD	10	0.310	0.016	0.29	0.34	
One RECI	10	0.404	0.020	0.37	0.43	

SD:Standard Deviation. *Level of significance : <0.05

This was then followed by the WaveOneGOLD group, which showed significantly lesser mean weight of apically extruded debris as compared to One Shape and OneRECI groups and the differences were statistically significant at $P < 0.001$, respectively.

This was later followed by the OneRECI group showing significantly lesser mean weight of apically extruded debris as compared to the One Shape group and the differences were statistically significant at $P = 0.04$ [Figure 2 and Table 2].

This infers that the mean Apically Extruded Debris was significantly least in HyflexEDM group, followed by WaveOne GOLD, OneRECI and found to be highest in One Shape group.

DISCUSSION

According to the results of this study, apical debris extrusion occurred regardless of the different file motion used. Hyflex EDM resulted in least amount of debris extrusion as compared to other files used in the study. Numerous studies have reported that rotary NiTi systems are associated with less apical extrusion than manual instrumentation.[4,10] The incidence of apical extrusion of debris is multifactorial, and it can be attributed to tooth-related factors such as the type of tooth, root curvature, apical foramen size, instrument design, irrigation needle type, irrigation methodologies, and patient age.[13,14]

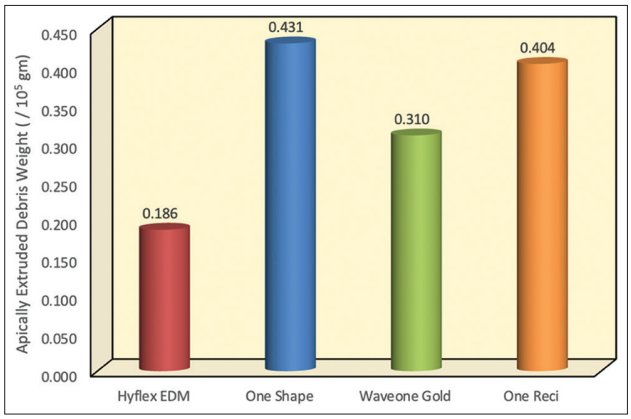

Figure 2: Mean weight of apically extruded debris between different groups. X - axis: Groups. Y- axis: Apically Extruded Debris weight (/10^5 g)

Table 2 : Multiple pairwise comparison of mean difference in apically extruded debris (/105) between groups using Tukey's *post hoc* test

Groups		Mean diff	95% CI of the diff		*P**
			Lower	Upper	
Hyflex EDM	One Shape	-0.245	-0.271	-0.219	<0.001
	WaveOne GOLD	-0.124	-0.150	-0.098	<0.001
	One RECI	-0.218	-0.244	-0.192	<0.001
One Shape	WaveOne GOLD	-0.121	-0.095	-0.147	<0.001
	One RECI	-0.027	-0.001	-0.053	<0.001
WaveOne GOLD	One RECI	-0.094	-0.120	-0.068	<0.001

*Level of significance : $P<0.05$

The characteristics of instrument systems, such as kinematic, cross-section concept, shaping capacity, tip diameter and taper, affect the amount of apically extruded debris.[5,15] Reciprocation motion was first demonstrated by Yared to enhance the NiTi endodontics files mechanical characteristics, which led to the invention of the single-file concept.[13] Preparing the entire canal with only one single-file instead of sequential multifile systems has simplified instrumentation and could be one of the reasons that studies observed more extrusion with the use of multiple file systems compared with single-file system.[16]

A single-file system was utilized to entirely form the root canal. They have advantages such as lower cost, decreased shaping time, allowing the clinician to spend more time on cleaning the canal with more advanced irrigation techniques.[17] In the current study, the performances of 4 NiTi Single-file systems were evaluated in terms of the amount of apically extruded debris with continuous rotary and reciprocating motion.[2,18,19]

To eliminate possible complications such as WL loss or nonstandard preparation and irrigation in curved root canals, single - rooted teeth were used. In this study, the generally accepted method of Myers and Montgomery was used to collect apically extruded debris.[12,20]

Distilled water was used as an irrigation solution to avoid any possible crystallization of sodium hypochlorite.[3] The results of the present study revealed that the HyflexEDM file extruded less amount of debris when compared to One Shape in continuous rotary motion.

The probable reason could be the changing triangular or modified triangular cross-section with three sharp cutting edges in the apical and middle part and an S-shaped design with two cutting edges near the shaft.[6] In a study where apically extruded debris of One Shape file was compared with Neoflix neoniti file showed that One Shape extruded more amount of debris.[17]

In this study, Hyflex EDM file extruded less amount of apical debris as compared to other files used. Earlier, an *in vitro* study was conducted to compare the amount of apically extruded debris using Reciproc Blue, HyFlex EDM, and XP-endo Shaper NiTi files duringIn our study, Hyflex EDM file extruded less amount of apical debris as compared to other files used which is in accordance to a study done earlier using Reciproc Blue, Hyflex EDM, and XP-endo shaper Niti files comparing the amount of apically extruded

debris during root canal instrumentation.[19] Probable reason could be controlled memory property of HEDM file which uses electrical discharge machining technology.

When we compared files in reciprocating motion for apical debris extrusion, it revealed that WaveONE Gold extruded less amount of debris as compared to the OneRECI file. Result of our study is in accordance to a previous study , which concluded that WaveOne Gold file was associated with significantly less apically extruded debris and irrigants during root canal filling material removal in comparison with Reciprc Blue, WaveOne GOLD, R- Endo and Protaper Next systems.[21]

In this study, when single reciprocating files were compared, WaveOne GOLD extruded less amount of apical debris as compared to One RECI. Earlier a study was conducted where amount of apically extruded debris was calculated following root canal preparation using ProTaper Next, Twisted File Adaptive and WaveOne Gold and the study resulted that WOG extruded less debris.[22] The probable reason was the constant helical angle and the additional space around the WOG instrument that might provide space for debris accumulation and the coronal removal of debris.[22]

In our study, WOG file(Reciprocation motion) extruded more amount of debris as compared to HEDM file (Rotary motion). The most likely explanation is that WOG file has two 85° cutting edges and parallelogram cross-sectional shape which improves debris clearance and cutting performance. It combines the metallurgical improvements of gold-wire thermal treatment to increase the elasticity and reciprocating motion.[5,21] One RECI file offers a more uniform cross-section and better cutting efficiency and flexibility. It has undergone a NiTi heat treatment called C Wire, which confers a shape memory effect on the file.[23] Different results from all of the studies on apically extruded debris may be caused by the use of different files and methodologies.

The disparity in extruded material weights reported by various researchers is a glaring example of the difficulties with standardization. The residue that is left over after the evaporation of the liquid is highly dependent on the irrigation method used.[24] Furthermore, studies investigating the extrusion of the canal content using extracted teeth have some limitations as the vital periapical tissues cannot be mimicked in an *in-vitro* study.[5]

Advances in instrument design, such as radial lands, flute depth, different tapers, and cross-sections, and the use of different operational principles may influence the amount of debris extrusion.[4] To standardize the amount of irrigant used during root canal preparation, 2 ml bidistilled water was used. However, as bidistilled water was used as irrigant it might be assumed that this method has no or at least only minimal influence on the results.[3,19,25]

Gravity may also play a crucial role in carrying the irrigant out of the canal along with the debris due to the lack of backpressure, to avoid this bias in our study, mandibular premolars were used.

The limitation of this study is, although we attempted to standardize the length of teeth used in each group, quantity of the irrigant, and the instrumentation process, each tooth has a different dentin thickness as per the aging of the teeth in terms of dentin deposition, which will highly influence the debris extrusion.

Therefore, the results of this study are to be assessed with caution as the clinical scenario could not be replicated truly. Further studies should be done in different combinations of File motion and File designs to compare the apical extrusion of debris.

CONCLUSION

Within the limitations of this *in vitro* study, debris extrusion was noted with all the tested file systems used. However, the amount of apically extruded debris for different files tested was least in the HyflexEDM group, followed by the WaveOne GOLD group, OneRECI, and highest in the One Shape group.

Taking into consideration, the excellent shaping ability of the reciprocating single-file systems, clinical studies are required to assess whether these findings have an impact on the clinical outcome, particularly as the clinical relevance of debris extrusion still remains undetermined.

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Conflicts of interest
There are no conflicts of interest.

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