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Original Article

Dentistry Section

Apical Extrusion of Debris in Mesiobuccal Root of Maxillary Molars with Five Rotary File Systems

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ABSTRACT

Introduction: Flare-ups in endodontics are multifactorial and may cause severe discomfort to the patient. Apical extrusion while preparing root canal space in any form such as debris, bacteria or irrigants has been found to be associated with many flare-up events and may even lead to treatment failure.

Aim: To quantitatively evaluate apically extruded debris with five rotary instrumentation systems in mesiobuccal root of maxillary molars.

Materials and Methods: A total of 120 human maxillary first molars extracted between January and March of 2017 in oral and maxillofacial surgery department at Drs. Sudha and Nageswara Rao Siddhartha Institute of Dental Sciences, Gannavaram, Andhra Pradesh, India, were included in the current study. Only the Molars with a three rooted pattern were selected and mesiobuccal root was used to evaluate apical extrusion. An experimental apparatus for evaluation of extruded debris as previously described by Myers and Montgomery was fabricated. All samples were divided into six groups (n=20 each) and instrumentation was done with five rotary file systems (K3XF, ProTaper NEXT, HyFlex CM, Revo-S, and FLEXICON) and HAND K FILES which served as control. The weight of the micro tubes in the apparatus before and after the instrumentation was calculated using an electronic weighing balance with a minimum sensitivity of 10^{-4} and weights were compared to quantify the apical extrusion. Statistical analysis was analysed with the ANOVA and multiple comparison (Post-hoc-Dunnett and Tukey) tests.

Results: It was found that all the instrumentation systems showed a considerable amount of apical debris extrusion. HAND K FILES were associated with most debris extrusion compared to all rotary files ($p<0.01$). FLEXICON file system showed lowest debris extrusion among all experimental groups. However, there was no statistically significant difference between K3XF and FLEXICON file systems ($p=0.312$).

Conclusion: The rotary systems extruded less debris compared to HAND K FILES. However, it was observed that there was no statistically significant difference between apical extrusion of K3XF and HyFlex CM, K3XF and FLEXICON X7, HYFLEX CM and Revo-S file systems. Among all the rotary groups, FLEXICON X7 and ProTaper NEXT files showed lowest and highest apical extrusion respectively. Design of rotary endodontic instruments may have a greater impact on their innate apical extrusion potentials.

Keywords: Design of rotary files, Endodontic flare-ups, Flexicon X7, Maxillary molars, ProTaper NEXT

INTRODUCTION

Endodontic therapy enjoys a higher success rate in recent times with innovations in cleaning and shaping systems. The principle behind these systems is that Ni-Ti rotary instruments help in easier, faster and efficient cleaning and shaping. However, many instrumentation related factors might cause post-treatment complications, were not eliminated completely even in these rotary file systems and apical extrusion is one of them. Apical extrusion is considered as an important factor responsible for flare-up and post-operative pain or even failure of endodontic healing [1,2]. An update on apical extrusion potentials of recently introduced rotary systems with newer Ni-Ti technologies is much needed for better endodontic therapy. Among many rotary files that were introduced recently, K3XF (Sybron Endo, Kerr Dental, USA), PROTAPER NEXT (Dentsply, Tulsa Dental Products, Tulsa, OK, USA), HYFLEX CM (Coltene/WhaledentInc; USA), Revo-S (Micro-Mega, Sanavis Group, USA) and Flexicon (Edgeendo, Canada) have demonstrated improved mechanical properties and shaping abilities [3-7].

PROTAPER NEXT file system (DentsplyMaillefer, Ballaigues, Switzerland) introduced in the year 2013 is the next generation of Protaper universal files and 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. A newer NiTi technology known as M-wire was employed for PROTAPER NEXTfiles which increased flexibility and offered greater resistance to cyclic fatigue of the instruments [8].

K3XF files (Sybron endo), introduced as successors of K3 files in the year 2011are made of R-phase nickel-titanium alloy which increased cyclic fatigue and flexibility. Improvements in cross-sectional design such as third radial land and reduced radial land with blade support in combination with newer revolutionary R-phase NiTi technology ensured better performance of these files [9].

Hyflex files (Coltene Whaledent.), a new revolution in rotary endodontics (2012) are machined from a wire (termed CM wire) with double fluting, symmetrical cross-section, variable pitch, non-cutting tip, negative rake angle. Hyflex files by the virtue of their NiTi technology have shape memory and thus have an excellent canal centering ability enabling possibility to negotiate even canals with a greater curvature [10].

Revo-S NiTi instrument system (Micro-Mega, Besancon, France), was introduced as an asymmetric cross-section which has more flexibility and less stress. A customised three instrument preparation technique including both symmetric and asymmetric instruments facilitated penetration by the snake-like movements and offered a root canal shaping adapted to the biologic and ergonomic imperatives with improved debris elimination [11].

Recently in the year 2015, FLEXICON X7 (Edgeendo, Canada) files that are made of an annealed heat treated NiTi alloy brand named Fire Wire TM, have been introduced. According to the manufacturer, Fire Wire Ni–Ti yields performance enhancing durability that provides incredible flexibility so that X7 files enhance and expedite the endodontic treatment [12].

To date, there appear to be very few studies which evaluated the apical extrusion potential of these file systems and thus the present study was aimed at comparative evaluation of apically extruded debris with these five rotary instrumentation systems.

MATERIALS AND METHODS

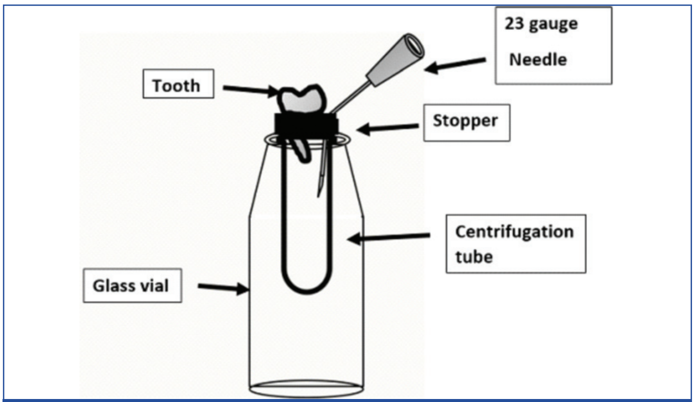
An in vitro experimental study was conducted on 120 mesiobuccal roots of human maxillary first molars, which were extracted due to periodontal considerations between January and March 2017. The study was performed in the Department of Conservative Dentistry and Endodontics, Drs. Sudha and Nageswara Rao Siddhartha Institute of Dental Sciences, Gannavaram, Andhra Pradesh, India, after obtaining an Institutional Ethical Clearance (OC No./ IEC/02/2014). The sample size was calculated using Raosoft online sample size calculator and the power of study set was 80% [13]. The criteria for teeth selection included the presence of a distinct three rooted pattern with canal curvature of mesiobuccal root between 10° to 20°, the absence of root fractures and cracks under stereo microscope at 4X magnification; absence of internal and external resorption or calcification and completely formed apex. Each tooth was radiographed in buccolingual and mesiodistal directions to categorise them and detect any possible obstructions. The teeth in which the apical minor constriction was gauged larger than 20 size hand file and a second mesiobuccal canal were excluded from the study. After a thorough screening, a total of 120 teeth were considered for inclusion in the study.

Preparation of Specimens

Access cavities were prepared using endo access and endo-Z burs (Dentsplymailefer, Tulsa). After access cavity preparation, distobuccal and palatal roots were amputated with a diamond disc (Wuxi xiangsheng industrial and trading co) mounted on a micromotor (Hero dental products, India). The canal orifices of amputated roots were sealed with Glass Ionomer cement (GC FUJI IX). Later the entire root surface of mesiobuccal root was coated with three coats of nail varnish to prevent microleakage through accessory canals and other discontinuities in the cementum. A 10 size K-File (Mani inc, Tochigi, Japan.) was passed 1 mm beyond the apical foramen through nail varnish to ensure uniform apical patency for all the experimental samples. The working length was determined simultaneously while creating apical patency by keeping the tip of instrument 0.5 mm short of the apex which was further confirmed by taking a radiograph.

Debris Extrusion Apparatus

The method for the collection of apically extruded debris was adapted from a previous study conducted by Myers GL and Montgomery S (1991) [14]. 120 centrifugation micro tubes (Tarsons, India) were taken and their stoppers were detached. The initial weight of individual tubes was taken using single pan analytical balance with 10^{-4} sensitivity (Shimadzu ATX224). An average of three readings for each sample was considered to avoid numerical error. With the help of a heated instrument, a hole was created in the center of the rubber stopper to fix the tooth. After creating a hole, the root was pushed into the stopper of centrifugation tube up to the cervical area and subsequently sealed with cyanoacrylate glue (Anabond Darien). The stopper was attached to the respective tube and a 23 gauge needle was inserted into it to equalise atmospheric pressure [Table/Fig-1]. This entire assembly was transferred to a transparent glass vial and subsequently, the vial was covered with aluminium foil for the purpose of isolation and blinding to avoid bias.



[Table/Fig-1]: Schematic representation of apparatus used for evaluation of debris extrusion.

GROUPS

All the samples were randomly assigned to six groups containing 20 teeth each, based on the file systems used for root canal preparation as mentioned below.

Group 1: Root canal preparation was done using Hand-K files (Mani inc.).

(This was considered as a control group.)

Group 2: Root canal preparation was done using K3XF files.(Sybron endo.)

Group 3: Root canal preparation was done using PROTAPER NEXTfiles (Dentsply Mailefer.)

Group 4: Root canal preparation was done using HYFLEX CM (Coltene Whaledent.)

Group 5: Root canal preparation was done using Revo-S files (Micro-Mega)

Group 6: Root canal preparation was done using FLEXICON X7 files (Edgeendo, Canada).

All the samples in their respective groups were prepared according to the manufacturer's instructions [Table/Fig-2] [15-20]. Glide path for all the rotary groups was created with a #15 K-File. All the rotary files were used as per manufacturer's specific RPM and torque. Each instrument was used in a short in and out motion for a maximum of four times per instrument. In all the groups except Group-1, a corresponding file with tip diameter #25 with a 6% taper was used as a finishing file while in Group-1 the finishing file was a size #25 k file (Mani Inc.) with 2% taper. The rubber dam was applied on to the tooth to prevent any possible contact of irrigating solution to the exterior of centrifugation tubes while irrigating.

Irrigation Protocol

All the canals were irrigated in between instrumentations and also after completion of instrumentation by using a 30 gauge side vented irrigation needle. A total of 5 mL bidistilled water was used per sample. After completion of instrumentation, stopper was removed and apically extruded debris attached to root tip was washed into Eppendorf tube with 1 mL of bidistilled water.

Drying of Samples

After completion of the root canal instrumentation, stopper assembly was removed from centrifugation tube. In order to facilitate evaporation of the irrigant, all the samples were placed in a hot air oven (BTI, India) at 140°C for five hours.

Measurement of Extruded Debris

After ensuring complete evaporation of the irrigant the final weights of individual tubes were measured using the same analytical balance as before [Table/Fig-3]. An average of three consecutive weights

Group	Mode of preparation	Sequence of instrumentation	Torque (NCM)/RPM
Group1 (control) (HAND K FILES)	Crown down	Coronal flaring with Headstrom files till 16 to 18 mm → coronal flaring size 2,3 & 4 GG drills → creation of apical seat and final apical finishing with size 25 k-file [15]	NIL
Group 2 (K3XF)	Crown down	0.12/#25 (orifice shaping) → 0.10/#25 (1/3rd of working length) → 0.08/#25 (2/3rd of working length) → 0.06/#25 (till working length) [16]	2.8/450
Group 3 (PROTAPER NEXT)	Crown down	SX (orifice shaper) → X1 0.04/#17 (till working length) → X20.06/#25 (till working length) [17]	2/300
Group 4 (HYFLEX CM)	Crown down	0.08/#25 (orifice shaper) → 0.04/#20 (apical enlargement/working length) → 0.04/#25 (apical enlargement/working length) → 0.06/#20 (middle part shaping/working length) → 0.06/#25 (apical finishing/working length) [18]	2.5/500
Group 5 (REVO–S)	Crown down	Endo flare (orifice shaper) → SC1 0.06/#25 (coronal 1/3rd of working length) → SC2 0.04/#25 (apical shaping till working length) → SU 0.06/#25 (apical finishing till working length) [19]	2.5/400
Group 6 (FLEXICON)	Crown down	X7 0.06/#25 (Till resistance is felt) → X7 0.04/#17 (till working length) → 0.06/#20 (till working length) → 0.06/#25 (apical finishing till working length) [20]	2.5/350

[Table/Fig-2]: Strategy of root canal preparation and sequence of instrumentation in all the study groups [15-20].

was obtained for each tube and amount of extruded debris was calculated by substituting in the following formula and results were subjected to statistical analysis.

Extruded debris=final weight of centrifugation tube-initial weight of centrifugation tube

[Table/Fig-3]: Micro-tubes showing extruded debris after evaporation of irrigating solution.

STATISTICAL ANALYSIS

The results were analysed using SPSS version 22.0. (Statistical Package for Social science, IBM Corporation) software. All the groups were analysed for overall significance values using ANOVA (Analysis of Variance) test (confidence interval was F=65.39) [Table/Fig-4]. whereas, comparison with control group (GROUP-1) and other Intergroup comparisons were done utilising Post-hoc Dunnett's test and Post-Hoc Tukey's tests respectively with a level of significance set at p<0.01 [Table/Fig-5,6].

Group	Apical Extrusion of Debris (mg)						
	N	Minimum extrusion	Maximum extrusion	Mean	SD	Median value	p-value
1 HAND K	20	6.9	59.1	41.3	13.8	42.35	<0.01
2 K3XF	20	.3	13.9	6.1	4.0	5.55	<0.01
3 PTN	20	2.5	40.0	20.4	8.8	19.15	<0.01
4 HYFLEX	20	.7	21.6	8.3	6.2	8.20	<0.01
5 REVO–S	20	3.4	19.3	9.2	4.3	8.25	<0.01
6 FLEXICON	20	1.1	14.8	5.5	3.7	5.1	<0.01

[Table/Fig-4]: The mean values and standard deviation of apically extruded debris of all groups.
Test: ANOVA; F-value=65.39; p<0.01; highly significant

Comparison between groups		p-value
1 HAND K	2 K3XF	<0.01
1 HAND K	3 PTN	<0.01
1 HAND K	4 HYFLEX	<0.01
1 HAND K	5 REVO–S	<0.01
1 HAND K	6 FLEXICON	<0.01

[Table/Fig-5]: Comparison of Control group (Hand-k files) with all other experimental groups using Post-Hoc Dunnett's test with a level of significance set at p<0.01.

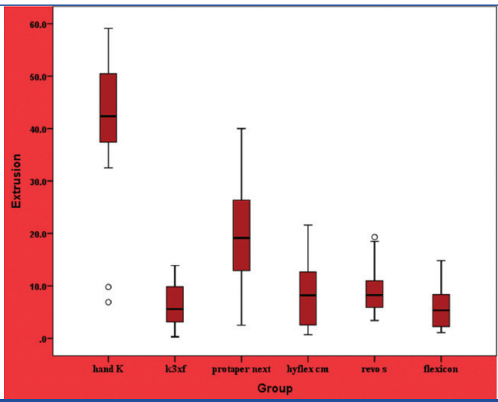
Comparison between groups		p-value
2 K3XF	3 PTN	<0.01
	4 HYFLEX	0.095 NS
	5 REVO–S	0.01
	6 FLEXICON	0.312 NS
3 PTN	4 HYFLEX	<0.01
	5 REVO–S	<0.01
	6 FLEXICON	<0.01
4 HYFLEX	5 REVO–S	0.80 NS
	6 FLEXICON	<0.01
5 REVO–S	6 FLEXICON	0.003

[Table/Fig-6]: Inter-Group Comparison of all groups with rotary systems by using Post-Hoc Tukey's test with a level of significance set at p<0.01.

RESULTS

Under the experimental conditions of the current in vitro study, the results showed that all instrumentation systems caused apical extrusion of debris. However, highest extrusion was observed in Group-1 (HAND K FILES) and least was observed in case of Group-6 (FLEXICON) [Table/Fig-4]. Mean debris extrusion of Control group was compared with other experimental groups utilising Post-hoc Dennett's test where the values were compared with 5% (0.05) level of significance. This comparison revealed that there was a highly significant difference in extrusion between the control group and all other experimental groups. An Intergroup comparison for experimental groups utilising Post-hoc Tukey's test revealed a statistically significant difference in extrusion between all Groups except between Group-2 (K3XF) and Group-4 (HYFLEX CM), Group-2 (K3XF) and Group-6 (FLEXICON), Group-4 (HyFlex CM) and Group-5 (Revo-S).

Debris extrusion values are represented in the box plot diagram which showed more deviation in extrusion values as observed in Group-1 (Hand-K files) and Group-3 (PTN) followed by Group-4 (Hyflex-CM) and Group-2 (K3XF), whereas least is observed in Group-6 (FLEXICON). Two outliers are seen in Group-1 (Hand-K files) and one outlier is observed in case of Group-5 (Revo-S) [Table/Fig-7].



[Table/Fig-7]: Box-plot diagram representing the distribution of apical extrusion of debris of all groups.

Based on middle quartile values the order of debris extrusion is as follows:

[GROUP-1 (HAND K)] > [GROUP-3 (PTN)] > [GROUP-5 (REVO-S)] > [GROUP-4 (HYFLEX CM)] > [GROUP-2 (K3XF)] > [GROUP-6 (FLEXICON)]

DISCUSSION

During mechanical preparation, dentin chips, remnants of pulpal tissue, irrigating solutions, and microorganisms and their by-products are often transported through the apical foramen and introduced into the periapical tissues causing postoperative inflammation/infection, pain, flare-ups, and consequently, delay apical healing [1,2].

Key factors that are responsible for apical extrusion can be categorised under: i) natural physical factors, such as anatomy of apical constriction, root dentin hardness, quantity and momentum of flow of irrigant in the root canal and the position of the tooth whether in the upper or lower jaw which may be affected by gravity; ii) Mechanical factors, such as the selection of the final apical size of instrument, instrumentation techniques, designs of instruments, rotation speed of the file and movements of the hand of operator during preparation [21]. As most of the natural factors are not under the control of an operator, a balancing approach towards various mechanical factors that might govern and aid in minimising apical extrusion should be considered. Standardisation was achieved by selection of a narrow root, the inclusion of samples with similar initial apical diameter, canal curvature in the range of 10° to 20°, confining apical preparation to 0.25 mm with 6% taper for all samples and a common irrigation system with canal preparation done by a single operator. This leaves us with a conclusion that it is the design of the instrument and instrumentation system that is most responsible for this mode of apical extrusion in the present study.

At present NiTi instruments are available on hand as well as engine driven preparation techniques and are 2-3 times more elastic than stainless steel files due to their very low modulus of elasticity, NiTi files have shown higher resistance to torsional fracture. According to the structural characteristics of these files, their use is likely to reduce the extrusion of debris from the apical end [9]. Manufacturers have designed new nickel-titanium rotary files with different parent metallurgical phases and they differ greatly in their design which may influence the amount of apically extruded debris through the apical foramen.

Maxillary molars were chosen for the current study as the apical diameter of selected mesiobuccal root is small and it helps in achieving reliable results as most of the working part of the file is in contact with canal walls which may not be possible with single-rooted teeth with larger apical diameters and wide canal geometry as previously reported by Kirchhoff AL et al., [22]. Arias A et al., while establishing predictive models to evaluate post-operative pain found that the incidence of more post-operative pain was associated with maxillary molars which can be a complication due to apical extrusion [23].

Generally accepted method of Myers and Montgomery et al., [14] was used to collect the debris extruded apically with minor modifications to make it more simple, practical and affordable. As suggested by Tanalp et al., [24] the usage of Sodium hypochlorite and lubricants like EDTA were avoided in the current study as their extrusion might cause biased weights when measured and irrigation was strictly restricted to 5 mL of bi-distilled water which leaves no residue when it evaporated [25].

In current study, results suggested that control group i.e., Hand-K files is associated with greater apical extrusion of debris compared to other rotary groups. This observation is in accordance with previous studies [24, 26-29]. Previously Lousi SB et al., suggested that a file without rotatory motion acts like a piston in tube which results in extrusion of a greater amount of debris which could be the reason for this observation whereas, continuous rotation seemed to improve coronal transportation of dentine chips and debris by acting like a screw conveyor [26].

PROTAPER NEXT showed second highest debris extrusion in the current study. The preparation technique associated with these files does not resemble a pure crown down technique as canal preparation till working length is achieved with initial instruments itself. Results in present study are in accordance with Uzunoglu E et al., [30]. It was hypothesised that larger apical taper of instruments working at the apical area (X1 and X2) while using PROTAPER NEXT might be the reason for more extrusion. Though the off-centred design of PROTAPER NEXT was supposed to aid in augering more debris out of the canal, a greater taper of instruments at the apical 3 mm which might remove more dentin and possibly the number of files instrumented till working length which might push more debris apically when the file is moved apically in a linear fashion.

Revo-S system is a unique combination of files with both symmetric and asymmetric cross-section. An asymmetric cross-section helps in more debris elimination in a coronal direction. Though the same feature was incorporated in PROTAPER NEXT system, the differences in the extrusion of debris could be due to differences in the apical taper of both systems and difference in the files that are used till working length. Kocak S et al., demonstrated in a previous study that REVO-S extruded lesser debris compared to ProTaper Which they attributed to an asymmetrical cross section of the instrument design an off-centered design [31].

HYFLEX CMfile system was found to be associated with more debris extrusion next to Revo-S. Elmsallati EA et al., in a previous study showed that the short pitch design extruded less debris than the medium and long ones [21]. Capar ID et al., proposed that the unwinding of the spirals of HyFlex instruments is well known during root canal preparation which results in lengthening pitch and thereby more debris extrusion [32]. The results of the current study are in accordance with Kocak S et al., who hypothesised that physical properties of CM system could be the reason for these observations [31].

K3XF file system has a variable pitch to prevent the screwing-in effect and presence of radial lands to aid in debris elimination, along with increasing variable helical flute angle from tip to handle which helps to dislodge the dentin chips from working area and carried coronally to the orifice. These observations are in accordance with previous studies done by Ghogre P et al., and Zan R et al., [33,34].

FLEXICON X7 file system showed least apical extrusion in the current study. This newer file system has a similar cross-sectional design as K3XF files including radial lands, variable pitch and increasing helical angle which supports efficient removal of debris in coronal direction. However, there is no statistically significant difference between apical extrusion patterns of these two files. To date, there is not enough published data to emphasise the design features of FLEXICON files that could affect the apical extrusion of debris and further research is required in this regard. It is noteworthy that both HYFLEX CMand FLEXICON X7 files belongs to a newer category of files having a property of deformation memory with differences in cross-sectional design.

Differences in the amount of apical extrusion, when compared to previous studies, were due to variations in selected teeth, file systems and irrigation protocols followed. The results of the current study showed significant differences in mean apical extrusion values with different rotary file systems by the virtue of their cross-sectional design. Further, it was also observed that there is no exact correlation between the number of files used and corresponding extruded debris for each system. On the other hand, it is still unclear that whether a specific NiTi technology can directly influence innate apical extrusion potentials of these rotary systems and has to be evaluated in further studies.

LIMITATION

The limitation of the study was the inability to simulate apical resistance to extrusion which exists in the natural tooth due to the presence of periapical tissues. Further studies are required to evaluate apical extrusion patterns of these file systems under the presence of apical resistance.

CONCLUSION

Under the limitations of this in vitro study, FLEXICON X7 and K3XF files extruded less apical debris compared to all other groups. Highest debris extrusion was associated with PROTAPER NEXT files. There is no statistically significant difference in the apical extrusion patterns of Group-2 (K3XF) and Group-4 (HYFLEX CM), Group-2 (K3XF) and Group-6 (FLEXICON), Group-4 (HyFlex CM) and Group-5 (Revo-S) file systems. Knowledge of these factors may help in reduction of apical extrusion while cleaning and shaping which facilitate proper endodontic therapy; prevent flare-ups and help to obtain satisfactory results.

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