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Measuring the Amount of Apically Extruded Debris of Endosequence ESR, R-Motion, F6 SkyTaper and Endosequence CM Files in Curved Canals: An in Vitro Study

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Abstract

Aim of the study: Assessing the relationship between Endosequence ESR, R-motion, F6 sky taper and Endosequence CM files use in curved canals and the quantity of apically extruded debris.

Materials and methods: 60 curved mesial roots of lower molars with 20-30 degree curvature were selected for this study, The samples were then divided randomly into four groups ($n = 15$)-Group I: EndoSequence ESR, Group II: R-motion (RM), Group III: F6 SkyTaper and Group IV: EndoSequence CM. This research followed the protocol devised by Myers and Montgomery, wherein debris were collected in vials and weighed before and after instrumentation using a 0.00001-sensitive balance. The instrumentation of all groups was terminated at master apical file #25. Irrigation with 10 ml of deionized water was administered using a needle with a side vent. The collected debris weight was calculated by deducting each vial's pre-instrumentation weight from its post-instrumentation weight. The analysis of variance (ANOVA) and the honestly significant difference (HSD) tests were used to assess the statistical significance of the variation in debris levels across the groups under investigation, using a significance level of 0.05.

Results: The results revealed that all tested groups had produced apical debris in different amounts.

Conclusions: Under the purview of the present investigation, apical debris was produced in all tested groups. The EndoSequence CM produced less amount of debris than other tested groups. While the RM and F6 SkyTaper produced a comparable amount of apical debris. The EndoSequence ESR produced the most amount of apical debris.

Keywords: debris extrusion, EndoSequence, R-motion, F6 SkyTaper .

1. Introduction

Flare-up condition, which can result in the failure of an endodontic treatment, are often caused by the debris extruded from the root tip during the shaping and cleaning of root canals. (Yılmaz and Özyürek, 2017; Siqueira et al., 2019). Pulp tissue fragments, dentinal chips, bacterial waste products, and irrigation solutions can all be forced through the apical foramen and into the periapical tissue during instrumentation (Yılmaz and Özbay, 2021).

A number of tooth-related factors affect the prevalence of debris apical extrusion, including tooth type, root curvature, and apical foramen size (Arias et al., 2013). Other factors include the instruments used, which includes the instrumentation method, motion, the number of files being used, instrument alloy and design (Mustafa et al., 2021).

New advances in endodontic instrumentation attempted to improve instrument properties (Arias & Peters, 2022). An important clinical indicator for evaluating the efficacy of instrumentation methods and currently available instruments is the amount of debris that is extruded from the apex (Tanalp, 2022). Amongst the new advertised single-file systems which outlined in the literature with different motions are EndoSequence ESR, R-Motion, F6 SkyTaper and EndoSequence CM file systems.

Endosequence ESR (Brasseler USA ESR™ Endosequence®) it is a single file system that utilizes the latest NiTi technology and has progressive rectangular cross section , non-cutting tip , alternating contact point and Reverse-cutting flute design (BRASSLER, 2018).

The R-Motion (RM) instrument, developed by FKG Dentaire in La-Chaux-de-Fonds, Switzerland, features a spherical tip and a rounded triangular cross-section. These design elements, along with a thin core, enable the instrument to efficiently remove material from the canal walls. Additionally, this design provides increased space for the file to navigate through the varying anatomical features of the canal (de Carvalho et al., 2022).

F6 Sky Taper file (komet, USA) made from NiTi with special heat treatment. Rotary preparation with one taper. Efficient double-S cross-section, sharp cutting edge, large space for dentin chips removal and small core for thorough cleaning and excellent preservation of the course of the canal (Komet, 2018).

Endosequence CM rotary file (Brasseler USA cm™ Endosequence®) an efficient, safe file with a short learning curve and triangular cross section. This instrument uses alternating contact points (ACP) along its cutting length in its file design. Utilizing ACP reduces torque requirements while maintaining file centering in the canal (BRASSLER, 2020).

Finally, according to the best of author's knowlegment there are no studies considering the amount of extruded debris using EndoSequence ESR and EndoSequence CM and very limited studies on R-Motion and F6 SkyTaper file systems. The current study aimed to compare and quantify and the debris extruded apically produced by multiple NiTi rotary systems (Endosequence ESR reciprocating file, R-motion reciprocating file, F6 sky taper rotary file and Endosequence CM rotary file) in curved canals.

2. Materials and Methods

2.1. Sample Selection and preparation

Before any samples were collected, the present research was authorised by the Ethics Committee of the Mustansririyah University (Reference number: REC126 30/March/2023). Sixty freshly extracted mandibular molars with patient's age range from 30-45. The mesial root of teeth had been selected for this study according to specific criteria which include mature root apex, curved root with 20-30 degree root curvature, Root devoid of any resorption, cracks, fracture or previous root canal treatment.

After extraction, cleaning of the external surfaces of all selected teeth from soft periodontal tissue, calculus, and bone fragments using a periodontal cumine was done (Hussein and Hameed, 2013), followed by immersion in 5.25% NaOCl (AQUA, Turkey) for 30 minutes for the purpose of disinfection, followed by washing under tap water. The root surfaces were then inspected with a light cure device (Eightteeth, china) and a magnifying eye lens (Zumax, china) for any visible fractures or cracks (Zarrabi et al, 2006a; Hamouda et al, 2011). Until time of use, teeth were kept in distilled water (changed daily) (Boijink et al., 2018).

Pre-operative X-rays were taken after the teeth were established in wax block, using hyperlight G portable x-ray device and nanopix sensor (Eightteeth, china) in standardized manner with constant position of the radiation source and the tooth and distance between the tooth and radiation source was 12 cm. This radiograph used for calculating root curvature by Schneider's method by determining 3 points with 2 lines adjoining these points and calculating the angle (Schneider, 1971). Samples with visible canals on pre-operative X-ray with curvatures between ٢0° and ٣0° were used. Ic measure program were used to measure the the angle effectively. After that the crown of the tooth was sectioned to a length of 12 mm with a special disc bur under abundant water to create an unvarying length. Then, the mesial root were separated from distal root and when the mesial root contain two canals with separated foramens one of the canals was blocked with flowable composite but when two canals meet with single foramen the root was discarded, finally the mesial root were measured using digital caliper to ensure the appropriate length. The canals' apical patency was next verified by inserting a #10 hand K-file into the channel and working it forward until it's visible at the apical foramen. After adjustment of the silicon stopper, the file was removed and the working length was obtained by subtracting 1mm from the length of the root which is to get the working length.

60 glass vial were used to collect the debris, each vial was weighed pre-

operatively. The roots, except the coronal section, were inserted into the hole cut in the rubber stopper and the vials were placed inside the glass container for ease of handling and to prevent environmental debris from accumulating during operation. subsequently the pre-weighed collecting glass vial was secured to the stopper/root complex, rubber dam sheet was utilized to cover the outside surface of the container, and ligatured ligature elastic was secured around the container. The pressure on both the inner and outer sides of the vial were then brought to the same level by inserting a needle (gauge-25) through the rubber dam and stopper next to the root fig. (1)

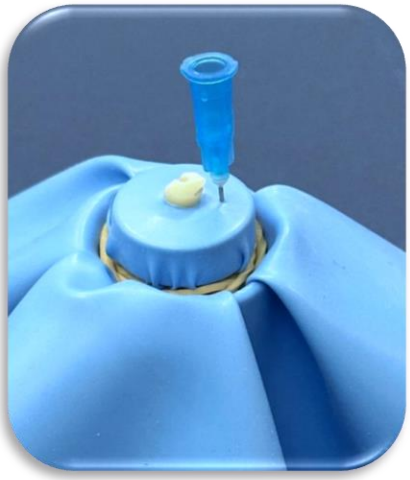

Figure 1: Coating the vial with rubber dam and insertion of ventilating needle through stopper and the root inside the rubber stoper.

2.2. Instrumentation

All systems in this investigation were set up in accordance with their respective manufacturers' recommended sequences. K-file #15 was used as a manual gliding path for all samples once canal patency was established with K-file #10. All canals prepared to MAF # 25/06 with X-Smart IQ endo motor (Dentsply-Maillefer, Ballaigues, Switzerland).

For all groups, irrigation protocol were 10-ml of distilled water as total volume which is divided with a 5-ml during instrumentation and 3-ml after instrumentation by using a disposable side vented 30-gauge navi tip needle which was inserted passively 2mm from the working length. As soon as the instrumentation was finished, the root’s external surface was irrigated with 2-ml of distilled water using 25-gauge tip vented needle to collect any adhering debris on the apical part of the root into the collecting glass vial.

2.2.1. Group I: EndoSequence ESR

Instrumentation with EndoSequence ESR system was done in crown-down technique with reciprocating motion range (150 CCW-30 CW) at 350 rpm. The ESR #25 Primary File was used with 1 Rhythm Motion to 5mm for removing of coronal and mid-root dentin then the ESR #25 Primary File were used with 2 rhythm motions until WL is achieved.

2.2.2. Group II: R-Motion

Instrumentation with R-motion reciprocation files system was done with the reciprocating motion (150 CCW-30 CW) (de Carvalho et al., 2022). R-motion file #25/06 was used to full working length while applying very light apical pressure through gentle 3 mm strokes and permitting the file to reach the working length passively.

2.2.3 Group III: F6 SkyTaper

Instrumentation with F6 sky taper system was done in crown-down technique at a 300 rpm speed with a full-rotating motion and a 2.2 ncm torque. F6 sky taper file #25/06 was used with 1 stroke Motion to 5mm for removing of coronal and mid-root dentin then F6 sky taper file #25/06 was used to full working length while applying very light apical pressure through gentle 3 mm strokes and permitting the file to reach the working length passively.

2.2.4. Group IV: EndoSequence CM

Instrumentation with Endosequence CM rotary files system was in crown-down technique at a 500 rpm speed with a full-rotating motion and a 2.3 ncm torque. Endosequence CM file #25/06 was used with 1 stroke Motion to 5mm for removing of coronal and mid-root dentin then Endosequence CM file #25/06 was used to full working length with 2 rhythm motions until WL is achieved.

2.3. Collection and weighing of Apically extruded debris

After the root canals were instrumented and irrigated, the needle and ligature elastic were removed, and the rubber-stopper/root assembly was detached from the collecting glass vials. Then, 2.0 mL of distilled water was used to flush the root tip and gather any remaining material into the vial (Koçak et al., 2015). Subsequently, the vials with the collected samples were placed for 3 hours at 110°C in a hot air oven and were inspected every 30 mintes up until they achieved dryness (Bürklein et al., 2016). then, To ensure that the collecting vials were thoroughly dry and to absorb any lingering moisture, they were taken out of the oven and placed in a desiccator with calcium chloride for 24 hours (Hussein and Al-Zaka, 2014; Sowjanya et al., 2022).

After that, each vial was removed from the desiccator and re-weighed using the same electronic balance (accuracy of 0.00001 g) to obtain the vial’s total weight (extruded debris weight included). Weighing of each vial was repeated three times a day for three days and the mean value had been calculated, these 3 consecutive measurements showed difference only in the last digit by 1–2 (< 0.00002g.); The aforementioned figure denotes the weight after the instrumentation process. By deducting the pre-instrumentation weight from the post-instrumentation weight of each collecting vial, the weight of the extruded debris was then determined (Myers and Montgomery, 1991; Parirokh et al., 2012; Al-Saffar and Al-Gharrawi, 2023).

2.4. Statistical Analysis

IBM SPSS Statistics 26 was used to analyze debris weight data (SPSS, Chicago, IL, USA). Minimum, Maximum, Mean, standard deviation, and standard error were calculated using the previously mentioned program. The Shapiro-Wilk test revealed a normal distribution between groups. Thus, ANOVA test was used to find any significance difference among groups. Also, The Tukey honestly significant difference (Tukey HSD) was performed for multiple comparisons between groups. The threshold for statistical significance was established at 0.05, with P values beyond this threshold considered to indicate non-significance. Significance was attributed to P values that were equal to or less than 0.05.

3. Results

Mean AED was lowest in the EndoSequence CM group, followed by the F6 SkyTaper group, and highest in the EndoSequence ESR group (Table 1). There was a statistically significant split in the test groups, as shown by the ANOVA test. Further, the the Tukey honestly significant difference (Tukey HSD) test showed that the EndoSequence CM system extruded significantly less AED than all tested groups. Likewise, no significant difference between the R-Motion and F6 SkyTaper systems (Table 2).

Table 1. Descriptive Statistics of apically extruded debris for all groups.

Groups	Mean	SD.	SE.	Min.	Max.
(I) EndoSequence ESR	0.0213120	0.00786682	0.00203121	0.01139	0.03404
(II) R-Motion	0.0178633	0.00987065	0.00254859	0.00455	0.03455
(III) F6 SkyTaper	0.0136307	0.00427167	0.00110294	0.00677	0.02107
(IV) EndoSequence CM	0.0072927	0.00481854	0.00124414	0.00083	0.01643

Table 2. Tukey HSD test for multiple comparison between groups.

Multiple Comparisons				
Tukey HSD				
(I) Groups	(J) Groups	Mean Difference (I-J)	P value	
Endosequence ESR	R-Motion	0.00344867	0.546	NS
	F6 SkyTaper	0.00768133	**0.022**	**Sig.**
	EndoSequence CM	0.01401933	**0.000**	**Sig.**
R-Motion	F6 SkyTaper	0.00423267	0.367	NS
	EndoSequence CM	0.01057067	**0.001**	**Sig.**
F6 SkyTaper	EndoSequence CM	0.00633800	**0.004**	**Sig.**

4. Discussion

It's been speculated that post-operative discomfort following root canal instrumentation may be due to the presence of AED (Tanalp and Gung, 2014; Hadi and Hameed, 2017; Zawrzykraj et al., 2022). AED seems to be the most important etiological factor of post-operative pain (Zawrzykraj et al., 2022). Many factors, including the preparation technique, and the files' size, design, count, and kinematics determine the amount of AED occurring from canal preparation (Ustun et al., 2015). So Different rotary and reciprocation instrumentation systems possess different design features were used in this study.

It has been observed that molar teeth are more likely to have post-endodontic discomfort (Arias et al., 2013). Hence the curved mesial roots of lower molars were selected to correlate the results of this study with the flare-up incidence under clinical situations (Mustafa et al., 2021). Moreover the clinicians face many challenges during instrumentation of molar teeth with moderate to severely curved roots (Topcuoglu et al., 2016). So the curved mesial canals of mandibular molar teeth were used.

Capar et al., in 2014 concluded that larger apical foramen tend to extrude more debris. Morover, since different sizes of apical foramen affect the amount of AED; thus, only canal with # 10 file patency was used.

An important factor in how much debris is extruded from a root canal is its curvature. (Karataslioglu et al., 2019). So Prior to the experiment and grouping of the specimens, the canals were measured for their curvature degree (Tanalp and Gung, 2014).

A needle was inserted through the vial top to equalize the internal and exterior pressures, which is remarkable given that no physical barrier was created over the apices of the roots. Because a physical barrier, analogous to the tissues of PDL and bone, might inhibit the AED buildup, this configuration is warranted (Sowjanya et al., 2022).

Sodium hypochlorite as an irrigation solution provide a better tissue dissolving action in root canal treatment but the crystallized solution after the drying procedure would compromise the precise conduction of post-instrumentation weight (Tamilselvi et al., 2020 ; Tanalp, 2022). For this reason distilled water was used as an irrigant with a side vented needle gauge 30.

All samples had the same irrigation depth (2 mm short of the WL) while also avoiding binding. To reduce the potential impact of volume on apically extruded debris, each sample was irrigated with 10 ml of distilled water (Kharouf et al., 2022). All procedures in the current investigation were performed by a single operator in an effort to reduce operator variance (Koçak et al., 2016).

The Myers and Montgomery Methodology was used because of its ability to precisely measure extruded debris with a high-precision electronic balance, as well as because of the flexibility with which it can be modified to mimic real-world clinical settings (Tanalp, 2022).

In the current investigation, care was taken with the delicate electronic balance to prevent interference with the weight conduction process from outside sources (Tanalap. 2022). So the weighting was done at a temperature of 25 ℃ and a range of humidity between (58% - 65%) (Kharouf et al., 2022).

However all reciprocating and rotary file systems extruded debris apically in different quantities. The findings of this study revealed that the EndoSequence CM system significantly produced the least amount of AED in comparison with the other tested groups.

This may be to attributed to different reasons such as the rotational motion of the file which was supported by previous studies that conclude the rotational motion produced least amount of AED in comparing with the other motions (Bürklein et al, 2014; Toyoğlu & Altunbaş, 2017 ; Predin et al., 2021). Additional cause is the triangular cross section of the file which supported by other studies that showed the triangular cross-sectional design facilitates debris removability thus reduced the amount of apical debris extrusion (Paqué et al., 2005; Xu et al., 2018). Moreover the tip of the file which is non-active at the tip, fully active precisely at 1 mm, the non-active tip produce little amount of AED (Koçak et al., 2015; Pawar et al., 2021). Also the file have no radial land with alternating contact point that improve centering the file within canal

,prevents self-threading “screw in” to canal and enhances debris removal (Sanghvi and Mistry, 2017).

Although F6 Sky file has the same rotational movement of EndoSequence CM file, it showed significantly more AED than it. This may be attributed to double S-shaped across sectional design through the whole length of the file, which gives the instrument sharp cutting blades. This design may give more cutting efficiency with higher tendency to screw-in and push debris beyond the apex (Dagna et al., 2017).

The reason behind the non-significance difference that found between R-Motion and F6 SkyTaper file even it activated with a reciproc motion is due to the R-Motion have newly modified spherical tip. Additionally, a lower quantity of apical debris extrusion may be due to the triangular cross-section design of the blue heat-treated wire, as this shape has been shown to improve debris removability in other research (Paqué et al., 2005; Xu et al., 2018). These features of R-Motion help to reduce the amount of apical debris extrusion which make it comparable with F6 SkyTper that have rotational movement.

Finally the great amount of apical debris were produced by EndoSequence ESR file system, the contributing factors of such results may be the rectangular cross section, reversed cutting edge and smaller chip space. All these features make it have piston like action and push debris apically (Vivekanandhan et al., 2016; Sowjanya., 2022). Moreover, the utilisation of a rectangular cross-sectional form in the file design offers increased contact surface area with the root canal wall during the preparation process. This design also minimises the available space for accumulation and clearance of debris towards the coronal region (Sowjanya., 2022). Moreover the reciprocating motion of this file may tend to produce more debris as supported with previous studies (Toyoğlu & Altunbaş, 2017 ; Predin et al., 2021). Generally, in this study the rotary files (EndoSequence CM and F6SkyTaper) extrude less debris from reciprocating files (EndoSequence ESR and R-Motion) when comparing the mean values of tested groups. According to Sowjanya et al. (year), the reciprocation movement is characterised by a larger cutting angle and a lower releasing angle. During the process of rotation at the release angle, it is seen that the flutes exert a force that causes the debris to be displaced in an apical direction (Sowjanya et al., 2022). The continual rotation of the crown facilitates the coronal transportation of dentin, and a number of authors have speculated that the reciprocal rotation may operate as a mechanical piston, enhancing the transport of debris towards the apex (Bürklein et al., 2014; Uzunoglu et al., 2015).

Unfortunately there are very limited studies on R-Mtion and F6 SkyTaper files and to the best of author’s knowledge, there are no studies in this field regarding EndoSequence ESR and EndoSequence CM files. For this reason, we cannot compare with agreement or disagreement with other studies.

5. Conclusions

Within the limitation of the present in vitro study, the following can be concluded:

1. During root canal preparation both rotary and reciprocation instruments resulted in apical extrusion of debris.
2. Rotary motion systems produced less amount of AED than reciprocation motion systems.
3. The EndoSequence CM rotary system produced least amount of debris than other used systems.
4. The F6 SkyTaper and RM caused a comparable quantity of AED.
5. The EndoSequence ESR reciprocation system produced the most amount of AED.
6. Instruments design showed to be important issues that influence the apical extrusion.

Conflict of Interest

The authors reported that they have no conflicts of interest.

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