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IN VITRO COMPARATIVE STUDY OF THE AMOUNT OF APICALLY EXTRUDED DEBRIS DURING ROOT CANAL PREPARATION USING ONE SHAPE, TWO SHAPE AND REVO-S NITI ROTARY FILE SYSTEMS

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ABSTRACT

Aim: To compare the amount of apically debris extruded following root canal preparation with One Shape, Two Shape and Revo-S NiTi rotary file systems.

Materials and Methods: Forty five extracted mandibular human first molars were selected nearly 20 to 22 mm of length average. The access cavities were prepared and the MB canals were localized and explored with a size 10 K-type file. The distal roots of all teeth were amputated to the cervical level and their orifices were sealed with glass ionomer filling material. The teeth were radiographed with a file in MB canal, and the canals with a curvature degree 10 to 20 were included in this study. Apically extruded debris was collected in pre-weighted collector tubes by 10^{-4} precision microbalance. The teeth with the collector tubes were randomly assigned to three groups, fifteen for each. Group I, MB canals were prepared by using One Shape, Group II, MB canals were prepared by using Two Shape and Group III, MB canals were prepared by using Revo-S NiTi rotary files to the tip sizes 25 and taper of 0.06. Irrigation was performed with bi-distilled water in exactly the same manner for all the specimens with 27-G irrigation needle. All tubes were put in a receptor and were taken to an incubator where they were stored at 37^{o}C for 21 days until the debris was dry. The tubes were then reweighted using the same analytical balance. The difference between pre-weighted tubes and the weight after preparation were tabulated and compared statistically.

Results: The lowest amount of apically extruded debris was found in Two Shape group followed by One Shape group, and the highest amount was found in Revo-S group. Comparison between the mean values of the three groups revealed a statistical significant difference at 5%.Comparison between the Two Shape group and One Shape group revealed a statistical significant difference at 5%. Comparison between the Two Shape group and Revo-S group revealed also a statistical a significant difference at 5%. But no statistical significant difference revealed when comparing the One Shape and Revo-S groups at 5% level of significance.

Conclusion: The Two Shape showed significantly the lowest amount of apical debris extrusion followed by One Shape and the highest amount showed by Revo-S.

KEYWORDS: One Shape file, Two Shape file, Revo-S file, Apical debris extrusion

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INTRODUCTION

Instrumentation, disinfection and obturation are the main steps in successful endodontics. The removal of the vital and necrotic remnants of pulp tissue and its debris, microorganisms and microbial toxins from the root canal system is the main goal of the chemo-mechanical preparation which is achieved by instrumentation and irrigation [1]. Although the working length is controlled by several methods, the dentinal debris, pulp tissue fragments, necrotic tissue, microorganisms, and the intracanal irrigant may be extruded from the apical foramen into the periradicular region [2]. The extruded material act as antigens resulted in the formation of an antigen-antibody complex, which could lead to a severe inflammatory response and postoperative flare-ups [3-5]. Therefore, minimal amount of apically extruded material should minimize postoperative reactions.

Vande Visse JE and Brilliant (1975) [6] have shown that, no significant extrusion of debris was observed in the absence of an irrigant. All preparation techniques and instruments have been reported to be associated with extrusion of infected debris, even when preparation is maintained short of the apical terminus and they are the first to quantify the amount of debris apically extruded during instrumentation. Martin and Cunningham (1982) [7] reported that less debris was extruded when the intra-canal preparation was accomplished with ultrasonic instrument.

Engine-driven instruments with their rotational movement produce less extruded debris than hand filing techniques using the push-pull motion and they have a tendency to pull debris in their flutes [7–10]. It is proven that no instrumentation technique can eliminate the extrusion of debris [11-13]. Apical debris extrusion has been demonstrated to vary based on kinematics, number of files used, taper, cross section, and cutting efficacy [14].

Nickel-titanium hand files are likely to reduce the extrusion of debris from the apical end than stainless steel files due to their more elasticity, the ductility, higher resistance to torsional fracture [15]. Nickel-titanium rotaries have been shown to prepare the root canal rapidly, and maintain the canal shape to the working length with few aberrations during preparation. They are available in various designs that differ in tip and taper design, rake angles, helical angles, pitch, and presence of radial lands [16]. Special design of nickel–titanium files with crown-down technique has been associated with the least amount of debris extrusion [17].

Revo-S rotary system (Micro Mega, Besancon, France) supplied in three instruments Shaper and Cleaner used in continuous clockwise rotation. SC 1 (tip size 25, 0.06 taper and 21 mm length) with an asymmetrical cross section, utilized to widen the coronal two thirds of the canal, SC 2 (tip size 25, 0.04 taper and 25 mm length) with a symmetrical cross section used to the full working length allowing better penetration and Shaper Universal (SU) (tip size 25, 0.06 taper and 25 mm length) with an asymmetrical cross section. The canal axis has three cutting edges located on three different radiuses. Smaller cross-section allows more flexibility and the asymmetrical cross-sectional design initiates a snake like movement inside the root canal that produces less stress on the instrument and increases the available volume for upward debris elimination. The system has additional 0.06 tapered instruments for apical shaping and finishing (AS) at tip sizes 30, 35 and 40 [18].

One Shape rotary NiTi file (Micro Mega Besancon, France) is a single-file system (tip size 25, 0.06 taper and 25 mm length), used in continuous clockwise rotation. It has a variable pitch and a noncutting safety tip [19]. The producers of One Shape try to increase their flexibility and to reduce instrument screwing effects using a variable cross-section along the blade of the instrument. One Shape files have 3 different cross-section zones: the first zone presents a variable 3-cutting-edge design, the second, progressively changes from 3 to 2 cutting edges and the last (coronal) is provided with 2 cutting edges. Barkouky et al. (2016) [20] found that One shape file (single file) extruded significantly less amount of debris and irrigants than Revo S system (multiple files).

Recently, Two Shape rotary NiTi file system (Micro Mega, Besancon, France) is a new T wire technology. It is supplied in two files, TS1 (tip size 25, 0.04 taper and 25 mm length) and TS2 (tip size 25, 0.06 taper and 25 mm length) for root canal shaping in continuous rotation, integrating heat treatment and a new cross section which will optimize cleaning. It has an asymmetrical cross section for better negotiation of curvatures, preservation of the elasticity of NiTi, better resistance to cyclic fatigue, and more flexibility. The two Shape sequence allows a better removal of suspended debris, respects the original root canal anatomy and gives more efficient cleaning of the root canal walls.

The present study was conducted to compare the amount of debris extruded apically following root canal preparation with One Shape (one file), Two Shape (two files) and Revo-S (three files) NiTi rotary file systems.

MATERIALS AND METHODS

Forty five extracted human mandibular first molars due to periodontal disease with fully formed apices and average length from 20 to 22 mm were selected for this study. They were obtained from the tooth bank of Pharos University and stored in saline until use. Teeth with open immature apices, calcification, resorption, anomalies, caries or previous root canal treatment were excluded.

Samples preparation

All teeth were cleaned of external debris and soft-tissue remnants. The access cavities were prepared, and the MB canals were localized and explored with a size 10 K-type file (Dentsply / Maillefer, Ballaigues, Switzerland). The mesio-buccal cusp tip in all teeth was flattened by an air motor hand piece and a diamond bur (Dentsply/ Maillefer, Tulsa, USA) to secure the reference point and standardize the working length (WL) of all teeth. A size 10 K-type file was passively advanced into the mesio-buccal canal for every tooth until the tip of the instrument penetrated and adjusted to the apical foramen and this measurement was recorded. The working length was calculated by subtracting 1 mm from this measurement and recorded for every tooth. Only the teeth in which size 10 K-file could be barely seen through the apex of the MB canal and size 15 K-file that snugly fits at the working length were included in the study.

The distal roots of all teeth were amputated to the cervical level and their orifices were sealed with glass ionomer filling material (Medifil, Promedica, Germany) and were radiographed from buccal and mesial directions to confirm the patency of mesio-buccal canal from its orifice to the separated apical foramen (Figure 1).

All teeth with a size 10 K-type file in MB canal was radiographed and only a curvature degree of the canal from 10 to 20 estimated according to the Schneider method [21] were included in this study (Figure 2).

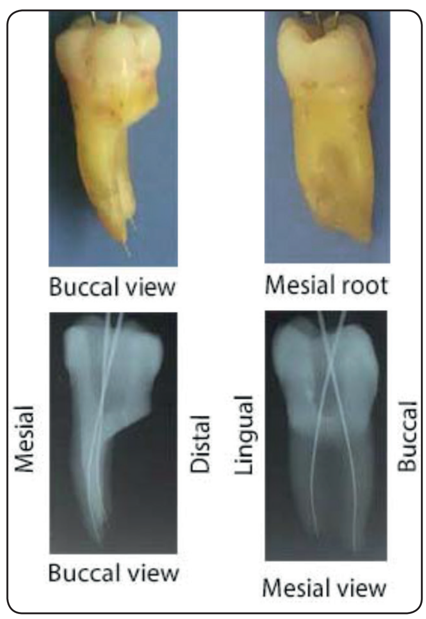

Fig. (1) Mandibular first molar with amputated distal root from buccal and mesial views and radiographs

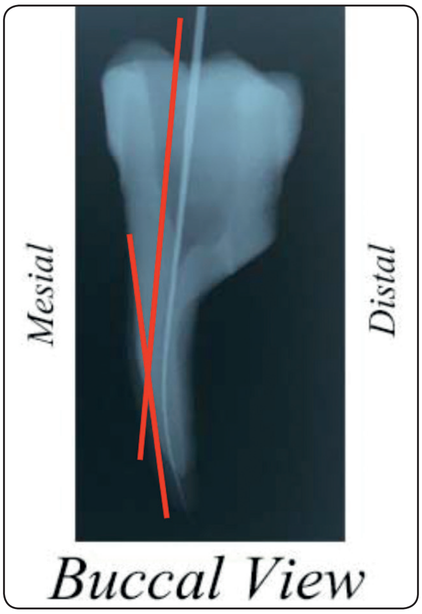

Fig. (2) A size 10 K-type file in MB canal represent a curvature degree of the canal from 10 to 20 estimated according to the Schneider method.

Fig. (3) Electronic weighting balance to 10-4

Two coats of transparent nail varnish were applied to the external surface of the mesial roots in order to prevent debris extrusion through lateral canals.

Sample fixation and debris collection

Each tooth was assessed for weighting of debris extruded apically by using an apparatus as described by Myers & Montgomery [15]. All collector tubes were coded, pre-weighted by 10^{-4} electronic balance (Radwag, AS 220/C/1, Poland) and were recorded (Figure 3).

The mesial roots of teeth were fixed through a hole into rubber sealed tubes by impression material before canal preparation. The rubber seal with the tooth was then fitted into the mouth of each tube which acted as a collecting container for apical debris evacuated through the foramen of each root. The rubber seal of every tube was vented with a 27-gauge needle to equalize the air pressure between inside and outside the tube (Figure 4).

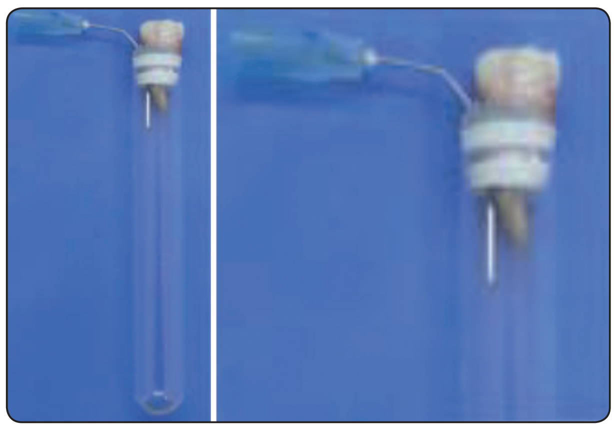

Fig. (4) Collector tube with the tooth sample sealed with butty rubber base impression material and 27-gauge needle

Canal Preparation

The glide path was created for every MB canal with NiTi G-Files (Micro-Mega, Sanavis group, France) to ensure more safety during the use of the first NiTi rotary files. Manual glide path with standard stainless steel size 10 K-file firstly established followed by NiTi G1 (tip size 12 and taper of 0.03) and NiTi G2 (tip size 17 and taper of 0.03) to the working length. The teeth with the collector tubes were randomly assigned to three groups, fifteen for each according to the type of NiTi rotary files for mesio-buccal canal preparation.

Group I

The fifteen MB canals of this group were prepared by using One Shape NiTi rotary file (Micro-Mega, Cedex, Besancon, France) with tip size 25 and taper of 0.06. The system consists of one sterile single file for root canal shaping with variable pitch and non-working (safety) tip in rotational motion. The speed for its use is 300 rpm in a slow in-and-out pecking motion with amplitude of about 3 mm as manufactures recommended. The flutes of the instruments were cleaned after three in-and-out movements (pecks) and were inserted as deeply as possible into the canal without binding to the working length.

Group II

The fifteen MB canals of this group were prepared by using Two Shape NiTi rotary files (Micro-Mega, Cedex, Besancon, France) supplied in two files, TS1 with tip size 25 and taper of 0.04 followed by TS2 with tip size 25 and taper of 0.06 with rotational motion. The speed for its use was 300 rpm in a progressive movement of every file in three up-and-down movements with upward circumferential brushing movement when feeling the resistance as manufactures recommended. Remove the file from the root canal, clean the grooves and irrigate the root canal. Then continue the progressive downward movement to reach the working length.

Group III

The fifteen MB canals of this group were prepared by using Revo-S NiTi rotary files (Micro-Mega, Cedex, Besancon, France) supplied in three files. SC1 with tip size 25, 0.06 taper and 21 mm length utilized to widen the coronal two thirds of the canal. SC2 with tip size 25 and taper of 0.04 and 25 mm length, it has three identical edges that balance the forces and guide the instrument up to the apical region of the canal. SU with tip size 25 and taper of 0.06 and 25 mm length for apical shaping and finishing. The speed for its use is 300 rpm as manufactures recommended.

After every file motion in the three groups, the files were with-drawn from the canals, the flutes were cleaned, and the root canals were irrigated by 2 mL bi-distilled water. Irrigation was performed in exactly the same manner for all the specimens with 27-G irrigation needle. Canal patency was checked with a size10 K-file (Dentsply Maillefer) between every file used 1 mm beyond the apical foramen. All instruments were discarded after being used in 5 MB canals, and all canals were prepared by the same operator.

Sample incubation and re-weighting

After instrumentation was completed, the rubber seal, needle and the tooth were separated from the tubes. The debris adhering to the root surface was collected by washing the root with one ml of bi-distilled water in the tubes. All tubes were putted in a receptor and were taken to an incubator (FormaSeries II water jacketed CO2 incubator, Thermo electron corporation, USA) where they were stored at 37°C for 21 days until the debris was dry [22]. The tubes were then weighted using the same analytical balance to obtain the final weight of the tubes, including the extruded debris. The weight of the empty tubes was subtracted from the weight of the tubes containing the debris, and the dry weight of the extruded debris was calculated for each tube in each group and tabulated.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median. Significance of the obtained results was judged at the 5% level.

RESULTS

Data regarding the weight of debris extruded during root canal preparation with different NiTi rotary file systems (One Shape, Two Shape and Revo-S groups) are presented as minimum and maximum, mean ± standard deviation and median in (table1).

The mean values ± standard deviations were 0.85 ± 0.41, 0.43 ± 0.26 and 1.02 ± 0.31 for One Shape, Two Shape and Revo-S groups respectively which revealed that, the lowest amount of apically extruded debris was found in Two Shape group followed by One Shape group, and the highest amount was found in Revo-S group (table1).

Comparison between the mean values of apically extruded debris of the three groups revealed a statistical significant difference at 5% level of significance. Comparison between the mean values of apically extruded debris of the Two Shape group and One Shape group revealed a statistical significant difference at 5% level of significance. Comparison between the mean values of apically extruded debris of the Two Shape group and Revo-S group revealed also a statistical a significant difference at 5% level of significance. But no statistical significant difference revealed when comparing the One Shape and Revo-S groups at 5% level of significance (table 1) (figure 5).

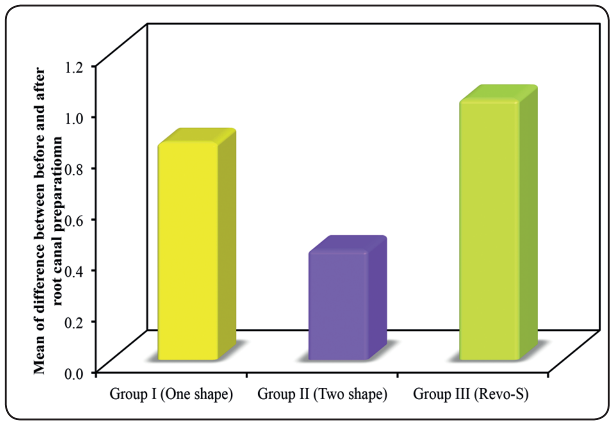

Fig. (5): Comparison between One Shape (group I), Two Shape (group II) and Revo-S (group III) file systems regarding the amount of apically extruded debris during root canal preparation.

TABLE (1): Comparison between One Shape (group I), Two Shape (group II) and Revo-S (group III) file systems regarding the amount of apically extruded debris during root canal preparation.

Difference	Group I One Shape (n = 15)	Group II Two Shape (n = 15)	Group III Revo-S (n = 15)	F	p
Min. – Max.	0.16 – 1.47	0.18 – 1.07	0.45 – 1.44	8.389*	0.001*
Mean ± SD.	0.85 ± 0.41	0.43 ± 0.26	1.02 ± 0.31		
Median	0.89	0.35	1.01		
Sig. bet. grps.	p_1=0.008*, p_2=0.270, P_3<0.001*,				

F,p: F and p values for **ANOVA test***, Sig. bet. grps was done using* **Post Hoc Test (LSD)**

p_1: p value for comparing between group I and group II

p_2: p value for comparing between group I and group III

p_3: p value for comparing between group II and group III

****: Statistically significant at p ≤ 0.05***

DISCUSSION

This study was conducted to compare the mean values of apically extruded debris after root canal instrumentation using three different NiTi rotary systems (One Shape, Two Shape and Revo-S) ended by master apical instruments standardized at ISO size 25 in all the groups. Various cross-sectional designs in the three systems play a different roles in coronal debris removal and therefore affect the amount of apically extruded debris. One Shape files (single file) have 3 different cross-section zones: the first zone presents a variable 3-cutting-edge design, the second, progressively changes from 3 to 2 cutting edges and the last (coronal) is provided with 2 cutting edges. Two Shape files (Two files) are T wire Technology with asymmetrical cross section and their sequence allows a better removal of suspended debris, respects the original root canal anatomy and gives more efficient cleaning of the root canal walls. But, Revo-S files (three files) have a small asymmetrical cross-sectional design that initiates a snake like movement inside the root canal that increases the available volume for upward debris elimination.

The instrumentation process in the present study utilized the crown down technique as this technique decreases the amount of debris extrusion periapically [15,23].

The mesio-buccal canal of the first mandibular molar with separate apical foramen and minimal root curvature was used in this study to avoid complications likely to arise during instrumentation of severely curved roots [24]. The diameters of the apical foramen of all samples were standardized as the greater in young patients may have a greater probability of flare-ups due to greater apical extrusion. However, Fairbourn et al. (1987) [25], Mc Kendry (1990) [4], and Al-Omari and Dummer (1995) [26] found no significant correlation between apical diameter and amount of extruded debris.

Almost all instrumentation techniques produce apical debris extrusion to some extent and lead to Inter-appointment flare-ups and postoperative pain [4,27]. The canal preparation with rotary nickel-titanium systems remains significantly more centered in the root canal with less transport of materials than earlier systems [28].

During root canal instrumentation many factors may affect the amount of extruded intra canal debris such as instrumentation technique, instrument type and size and preparation endpoint [27,29]. Also, the type of irrigant plays an important role on the amount of apically extruded debris and irrigant. In our study, Bi-distilled water was used as an irrigation solution as done by Al-Omari et al (1995) [25] and Beeson et al (1998) [30] to avoid any possible weight increase due to crystallization of sodium hypochlorite after drying.

In the present study, the needle of irrigation (27-gauge) was lied passively in the canal, never wedged in the canal, with up and down motion, and the solution was introduced slowly to minimize forcing the debris with irrigant out of the canal as Boutsioukis et al (2010) [31] did. The depth of needle tip was two mm short of the working length or slightly coronal to that point when resistance is encountered before the needle tip reaches the desirable distance as recommended by Retamozo et al (2010) [32]. The same needle penetration depth was used in the three groups of teeth to provide more standardization of the methodology.

In this study, nail varnish was used to cover the mesial root of the first mandibular molar to prevent the exit of debris and irrigant from accessory canals and direct their extrusion through the apical foramen only this was found to be followed by Ferraz et al (2001) [12], while McKendry (1990) [4] and Tasdemir et al (2010) [33] ignored this point.

In this study instrumentation was confined to 1mm short of the apical foramen as Burklein and Schafer (2012) [34] did because working length 1 mm short of the canal length contributed to significantly less debris extrusion [15,35]. Apical debris extrusion was observed more at 0.5 mm short of the canal length and at a length where the file was observed to just protrude through the apical foramen than canals prepared 1mm short of the apex [7].

The method used to collect the intra-canal materials in this study was the generally accepted method of Myers and Montgomery (1991) [15], which is more standardized and repeatable than other methods. Unlike Liu et al (2013) [36] and Burklein et al (2014) [37], used different techniques to measure the apically extruded debris and irrigant.

In the present study, the three systems showed extrusion of debris which was in agreement with a common finding that all instrumentation techniques produce apical extrusion to a certain extent [12,38-40]. Meanwhile, the Two shape system showed the least amount of extruded debris followed by One shape and the Revo-S showed the highest amount of extruded debris with a significant difference between them.

The results of this study showed that, One shape single-file system extruded less debris than the Revo-S full sequence rotary system with no significant deference. This might be due to the instrument design of the One shape file that has a variable cross-section with three different cross-section zones which might contribute to the better coronal debris elimination. This observation was found to be in agreement with Nayak et al (2014) [41]. While the Revo-S files have an asymmetrical cross-section, the canal axis has three cutting edges located on three different radii.

The instrumentation of the canal with the One shape file 6% taper prepared the entire canal with a single file was done in an incremental crown down preparation of the coronal two thirds first followed by a three mm increase in depth ending by preparation of the entire length of the canal apically. The close and intimate contact of the canal walls with a single file in continuous rotation may have produced a decrease in debris extrusion, meanwhile in the Revo-S system the canals were first prepared by SC1 6% taper that prepared the coronal two thirds followed by SC2 4% taper which prepared the canal to the full working length, enlarging it to some extent before using the SU 6 % taper thus loosing the previously mentioned intimate contact between the file and the canal walls. Also, this result was in accordance to the study conducted by Kucukilmaz et al (2015) [42] who stated that the single file One shape extruded less debris than the full sequence Protaper.

Furthermore, the use of three files in the Revo-S system versus one file in the One shape system may explain why the higher amount of apically extruded debris was found in the Revo-S system than the One shape system. This was found to be in agreement with Tanalp et al (2006) [25] who mentioned that increasing number of instruments may increase the amount of apical debris extrusion and in disagreement with Abozor and Awad (2015) [22] who found that, a new Revo-S NiTi rotary system with an asymmetric cross section, inducing a snake like behavior phenomenon of the instrument along the canal and increases the available volume for upward debris elimination which may contribute to the production of less debris and irrigant extrusion apically. Also, it is in contrast with Vivekanandhan et al (2016) [43] who assume that continuous rotation movement during instrumentation when used with engine driven and balanced force concept results in collection of debris into the flutes and acts like a screw conveyor producing transportation of debris, dentin chips, and its evacuation out of the root canal in a coronal direction resulting in less debris extrusion.

The present study revealed that, the mean values of apically extruded debris of the Two Shape were less than One Shape and Revo-S file systems significantly. These results agree with the product description of Micro-Mega that, Two Shape is a new T wire technology supplied in two shaping instruments in continuous rotation, TS1 and TS2.

It has asymmetrical cross section which reduces the risk of instrument fracture [44] and increases the efficacy of the circumferential brushing movements for efficient selective cleaning [45]. The Two Shape sequence allows a better removal of suspended debris thanks to the secondary cutting edge.

CONCLUSION

Based on the results of this study, it can be concluded that all rotary instruments tested extruded debris apically with different quantities. The Two Shape showed significantly the lowest amount of apical debris extrusion followed by One Shape and the highest amount showed by Revo-S

REFERENCES

1- Shin SJ, Kim HK, Jung IY, Lee CY, Lee SJ, Kim E. Comparison of the cleaning efficacy of a new apical negative pressure irrigating system with conventional irrigation needles in the root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 109(3):479–484.

2- Seltzer S, Naidorf IJ. Flare-ups in Endodontics: I Etiological factors. J Endod. 1985; 11:472–8.

3- Tanlap J, Kaptan F, Sert S, Kayahan B, Bayirl G. Quantitative evaluation of the amount of apically extruded debris using three different rotary instrumentation systems. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006; 101:250–7.

4- McKendry DJ. Comparison of balanced forces, endosonic and step-back filing instrumentation techniques: Quantification of extruded apical debris. J Endod. 1990; 16:24–7.

5- Naidorf IJ. Endodontic flare-ups: Bacteriological and immuno-logical mechanisms. J Endod. 1985; 11:462–4.

6- Vande Visse JE, Brilliant JD. Effect of the irrigation on the production of extruded material at the root apex during instrumentation. J Endod. 1975; 1:243–6.

7- Martin H, Cunningham WT. The effect of endosonic and hand manipulation on amount root canal material extruded. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1982; 53:611–3.

8- Sequiria JF, Rocas IN, Favieria A. Incidence of post operative pain after intracanal procedures based on an antimicrobial strategy. J Endod. 2004; 28:457–60.

9- Gutierrez JH, Brizuela C, Villota E. Human teeth with periapical pathosis after overinstrumentation and overfilling of the canals: A scanning electron microscopic study. Int Endod J. 1999; 32:40–8.

10- Shovelton DS. The presence and distribution of microorganisms within nonvital teeth. Br Dent J. 1964; 117:101–7.

11- Azar NG, Ebrahimi G. Apically-Extruded Debris Using the ProTaper System. Aust Endod J. 2005; 31(1):21–3.

12- Ferraz C, Gomes N, Gomes B, Zaia A, Teixeira F, Souza-Filho F. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. Int Endod J. 2001; 34(5):354–8.

13- Tinaz AC, Alacam T, Uzun O, Maden M, Kayaoglu G. The effect of disruption of apical constriction on periapical extrusion. J Endod. 2005; 31(7):533–5.

14- Tinoco JM, De-Deus G, Tinoco EMB, Saavedra F, Fidel RAS, and Sassone LM, "Apical extrusion of bacteria when using reciprocating single-file and rotary multifile instrumentation systems". International Endodontic Journal, 2014; 47, (6):560–566.

15- Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. J Endod. 1991; 17(6):275–9.

16- Thompson SA, Dummer PM. Shaping ability of ProFile.04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals: Part 1. Int Endod J. 1997; 30:1–7.

17- Ruiz-Hubard EE, Gutmann JL, Wagner MJ. A quantitative assessment of canal debris forced periapically during root canal instrumentation using two different techniques. J Endod 1987; 13:554-8.

18- Yeter KY, Evcil MS, Ayranci LB, Ersoy I. Weight of apically extruded debris following use of two canal instrumentation techniques and two designs of irrigation needles. Int Endod J 2013; 46: 795-799.

19- Burklein S, Tsotsis P, Schafer E. Incidence of dentinal defects after root canal preparation: reciprocating versus rotary instrumentation. J Endod. 2013; 39(4):501-4.

20- Barkouky R M, Moussa S M, Mohy ElDin M H and Leheta N A. Evaluation of apical extrusion of debris and irrigant using two rotary instrumentation systems. Alex. 2016 Dent J; 41: 99-104.

21- Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971 Aug; 32(2):271-5.

22- Abozor B M and Awad N. Apically Extruded Debris and Irrigant Using the Revo-S System. J Interdiscipl Med Dent Sci 2015; 3 (2): 1-4.

23- Ruddle CJ. Single-file shaping technique achieving: a gold medal result. Dent Today 2016 Jan; 98:102-103.

24- Tanalp J, Kaptan F, Sert S, Kayahan B, Bayirl G. Quantitative evaluation of the amount of apically extruded debris using 3 different rotary instrumentation systems. Oral Surg, Oral Med, Oral Pathol, Oral Radiol, and Endod 2006; 101: 250-257.

25- Fairbourn DR, McWalter GM, Montgomery S. The effect of four preparation techniques on the amount of apically extruded debris. J Endod 1987; 13:102-8.

26- Al-Omari MA, Dummer PM. Canal blockage and debris extrusion with eight preparation techniques. J Endod 1995; 21:154-8.

27- Kustarci A, Akdemir N, Siso SH, Altunbas D. Apical extrusion of intracanal debris using two engine driven and step-back instrumentation techniques: an in-vitro study. European Journal of Dentistry 2008; 2: 233-239.

28- Lopez FU, Fachin EV, Camargo Fontanella VR, Barletta FB, So MV, Grecca FS. Apical transportation: a comparative evaluation of three root canal instrumentation techniques with three different apical diameters. J Endod. 2008; 34:1545-8.

29- Ghivari SB, Kubasad GC, Chandak MG, Akarte N. Apical extrusion of debris and irrigant using hand and rotary systems: A comparative study. Cons Dent J 2011; 14: 187-190.

30- Beeson TJ, Hartwell GR, Thornton JD, Gunsolley JC. Comparison of debris extruded apically in straight canals: Conventional filing versus Profile 0.04 Taper Series 29. J Endod. 1998; 24:18-22.

31- Boutsioukis C, Verhaagen B, Versluis M, Kastrinakis E, Wesselink PR, van der Sluis LW. Evaluation of irrigant flow in the root canal using different needle types by an unsteady computational fluid dynamics model. J Endod. 2010; 36:875-9.

32- Retamozo B, Johnson N, Aprecio RM, Torabinejad M. Minimum contact time and concentration of sodium hypochlorite required to eliminate Enterococcus faecalis. J Endod. 2010; 36:520-3.

33- Tasdemir T, Er K, Celik D, Aydemir H. An in vitro comparison of apically extruded debris using three rotary nickeltitanium instruments. JDS. 2010; 5:121-5.

34- Burklein S, Schafer E. Apically extruded debris with reciprocating single file and full sequence rotary instrumentation systems. J Endodon. 2012; 38:850-2.

35- Fairboun DR, McWalter GM, Montgomery S. The effect of four preparation techniques on the amount of apically extruded debris. J Endod. 1987; 13:102-8.

36- Liu R, Hou BX, Wesselink PR, Wu MK, Shemesh H. The incidence of root microcracks caused by 3 different single-file systems versus the ProTaper system. J Endod. 2013; 39:1054-6.

37- Bürklein S, Benten S, Schäfer E. Quantitative evaluation of apically extruded debris with different single-file systems: Reciproc, F360, and OneShape versus Mtwo. Int Endod J. 2014; 47:405-9.

38- Reddy SA, Hicks ML. Apical extrusion of debris using two hand and two rotary instrumentation techniques. J Endod. 1998; 24:180-3.

39- Albrecht LJ, Baumgartner JC, Marshall JG. Evaluation of apical debris removal using various sizes and tapers of ProFile GT files. J Endod. 2004; 30:425-8.

40- Adl A, Sahebi S, Moazami F, Niknam M. Comparison of apical debris extrusion using a conventional and two rotary techniques. Iran Endod J. 2009; 4:135-8.

41- Nayak G, Singh I, Shetty SH, Dahiya S. Evaluation of apical extrusion of debris and irrigant using two new reciprocating and one continuous rotation single file system. J Dent (Tehran). 2014; 11:302-9.

42- Kucukyilmaz E, Savas S, Saygili G, Uysal B. Assessment of apically extruded debris and irrigant produced by different nickel-titanium instrument systems. Braz Oral Res. 2015; 29:1-6.

43- Vivekanandhan P, Subbiya A, Mitthra S, Karthick A. Comparison of apical debris extrusion of two rotary systems and one reciprocating system. Cons Dent J 2016; 19(3): 245-249.

44- Capar ID, Ertas H, Arslan H. Comparison of Cyclic Fatigue Resistance of Nickel-Titanium Coronal Flaring Instruments. Aust Endod J. 2015; 41(1):24-8.

45- Alattar S, Nehme W, Diemer F, Naaman A. The Influence of Brushing Motion on the Cutting Behavior of 3 Reciprocating Files in Oval-shaped Canals. Endod J. 2015; 41 (5): 703–709.