EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 937:944, January, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 20-11-2023 • Accept Date : 12-12-2023 • Available online: 10-01-2024 • DOI : 10.21608/EDJ.2023.249982.2790

IMPACT OF DIFFERENT KINEMATICS ON DEBRIS EXTRUSION USING TWO DIFFERENT FULL SEQUENCES ROTARY NITI FILES: AN IN VITRO STUDY

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ABSTRACT

Aim: Compared the effect of continuous rotation and optimum torque reverse on the amount of apically extruded debris using EdgeFile X7 and Endostar E3 Azure files.

Materials and Methods: Forty extracted mandibular premolars with single straight canals were chosen. Canals were divided into two equal groups (n=20) according to kinematics; Group (I): continuous rotation, Group (II): optimum torque reverse. Each group was further subdivided into two equal subgroups (n=10) according to the type of rotary file system employed in root canal preparation: Sub-group A: Endostar E3 Azure files, Sub-group B: EdgeFile X7. Canals were prepared and extruded debris from each sample was collected in pre-weighted Eppendorf tubes and dried. The weight of debris was assessed by an analytical microbalance. Data were statistically analyzed by two-way ANOVA test.

Results: According to motion kinematic; with continuous rotation EdgeFile X7 had higher value than Endostar E3 Azur while with Optimum torque reverse motion, Endostar E3 Azur had higher value with no statistically significant differences. According to file used, EdgeFile X7 showed higher significant value with continuous rotation than with optimum torque reverse. While Endostar E3 Azur showed a higher value with continuous rotation than with optimum torque reverse with no statistically significant difference. In comparing file motion in relation to the file type used; continuous rotation has a significant higher mean value than optimum torque reverse.

Conclusion: Kinematics has an impact on the amount of extruded debris regarding the type of rotary files used.

KEYWORDS: Apical extruded debris, continuous rotation, optimum torque reverse, EdgeFile X7 Endostar E3 Azure files.

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INTRODUCTION

Cleaning and shaping the pulp space is a challenging procedure of root canal therapy. It involves shaping for the cleaning root canal system with the help of intracanal irrigants to allow maximum disinfection.[1] Despite the introduction of various methodologies of shaping the root canals, debris extrusion remains a definite etiology of post-treatment periodontitis and patient discomfort.[2,3] This is an undesirable outcome for the patient and the practitioner (Silva et al. 2014).[4] Therefore, strategies to reduce this occurrence are always being under research. The amount of extruded dentin debris is considered the main parameter assessing the success of the instrumentation technique and the instrument used (Parirokh et al. 2012).[5]

Optimum Torque Reverse (OTR) is a motion kinematic developed in 2015,[9] this new motion was presented to add the advantages of reciprocation to continuous rotation in canal negotiation. OTR motion allows less fatigue stresses applied on the file reducing the risk of fracture while minimizing the reduction in cutting efficiency. It allows the rotary file to rotate in a clockwise rotation freely until it meets resistance torque; then, the file will reciprocate with dissimilar angles 180° CW and 90° CCW until the torque drops to the predetermined level.[10]

Manufacturers developed heat treatment cycles in order to enhance the mechanical properties of the NiTi alloy and upgrade it to a higher fatigue-resistant instrument with a super flexible state. One example of a particularly cutting-edge technology is the NiTi Endostar E3 Azure files (Poldent, Warsaw, Poland). This file system has a modified S-shaped cross-section, variable pitch, and safe cutting tip with sizes ranging from 20-45 and a constant taper of 4, 6, and 8%. The manufacturer claims that this system underwent complicated heating-cooling cycles that formed a blue-tinted titanium oxide layer on the instrument's surface.[6,7] EdgeFile X7 (Edge Endo; Albuquerque, New Mexico, United States) has a constant 0.04 and 0.06 taper with a triangular cross-section, and variable helical angle with sizes ranging from 17-45. It is a FireWire NiTi heat-treated alloy, made by heat and cooling cycles to enhance its mechanical properties.[8]

This study was conducted to compare the effect of different kinematics; continuous rotation (CR) and optimum torque reverse (OTR) with two different full sequences rotary NiTi files Endostar E3 Azure files and EdgeFile X7 on the amount of apically extruded debris.

MATERIALS AND METHODS

Specimen Selection;

Ethical approval was obtained from the ethical committee, Faculty of Dentistry, Egyptian Russian University, Egypt (Registration no 15). Forty extracted intact human single-canaled with straight mandibular premolars were utilized in the study. They were extracted for orthodontic or periodontic reasons. Radiographic analysis was used to confirm canal patency. Sample teeth were thoroughly cleaned, scaled and immersed in 5.25% sodium hypochlorite solution for thirty minutes to remove any soft tissues or organic debris on the root surfaces. Teeth were kept in a container filled with 0.9% normal saline solution until the time of use. Access cavities were prepared by a diamond bur (Dentsply, Maillefer, Ballaigus, Sweitzerland) at high-speed handpiece. Debridement of the canals was made by K-type file sizes 10 and 15. Then K file size 20 (MANI, INC., Industrial Park, Utsunomiya, Tochigi, Japan) was fitted at the apexes to ensure apical size standardization. K-file no#15 was used to ensure apical patency and the working length was recorded by subtracting 1 mm from this length. To have a standardized root length of 15 mm, teeth were decoronated using a diamond cylindrical stone set on a high-speed hand piece under water coolant, to avoid variance and biases, all of the samples were cleaned, shaped, and irrigated by the same operator.

Debris Collection

To assess apically extruded debris, Myers & Montgomery's experimental debris extrusion model was used.[11] Eppendorf tubes' caps were taken off. All tubes were given numbers and weighed with an Adam analytical balance (Equipment Co. Ltd, MK10 0BD, UK) to 10^{-4} g. Three measurements were taken for each tube, and the primary weight (W1) was calculated using the mean value. Round holes were drilled through the Eppendorf tube caps using a heated tool, and teeth were then introduced through the cap up to the cemento-enamel junction. Inserting a 27-gauge needle through the side of the plastic cap was made to compensate for the difference in air pressure between the inner and outer tubes. The tooth was attached to the cap with cyanoacrylate glue (Pattex Super Glue; Türk Henkel, Inc., Istanbul, Turkey) to avoid leakage. The assembly was then placed into an opaque vial to save the operator's eyes away from the tubes' interiors.

Allocation of Groups

Based on a prototype endodontic motor (Wismy, Bomedent Changzhou, Jiangsu, China) Motion Kinematics was set to rotate in either (CR) only or continuous rotation with (OTR) during root canal instrumentation. Samples were divided into two equal experimental groups **(n = 20)**.

- **Group I:** files were activated in continuous rotation (CR) mode; the programmed handpiece was used to move in pecking motion, with rotational speed set according to the manufacturer instructions and recommendations of the used rotary files.
- **Group II:** files were activated in optimum-torque-reverse (OTR) mode; the motion was programmed in the motor to oscillate 180° clockwise rotation and 90° counterclockwise at a trigger torque of 1 Ncm.

In accordance with the selected rotary file system during mechanical preparation, each group was further subdivided into two equal subgroups **(n=10)**, as follows:

Sub-group A: Canals were prepared using Endostar E3 Azure files. Speed and torque for each file were set at: 2.4 N cm for (30/08) rotary file for coronal third flaring. The middle third preparation was made by (25/06) at 2.1 N.cm. Recapitulation was done by manual K file 15 to working length followed by (25/04) for apical preparation at full working length then apical shaping was enlarged to sizes (30/04) and (35/04).

Sub-group B: Canals were prepared using the EdgeFile X7, and coronal flaring was prepared by Edge taper platinum file SX (19/progressive taper ending at 12%) with speed of 300 rpm and 4 Ncm torque. Middle one-third was prepared by file size (25/06), then apical preparation was prepared by file 25/04) with recapitulation by file 15 K, then canal diameter was finished to (30/04), and (35/0.4) Files were operated at 300 rpm /2 Ncm.

Cleaning and shaping of all samples were made by the same operator to eliminate any bias. The pecking motion of three pecks (in-and-out) movements with 3 mm stroke amplitude was performed along the canal (cervical, middle, and apical) until the WL was reached (1 mm short of the apical foramen). The file was removed, when it reached the working length and rotated freely. All samples were carefully irrigated with 10 mL of 2.5% sodium hypochlorite (NaOCl) (Clorox, HC Egyptian Company, Cairo, Egypt) at room temperature during the instrumentation process using a side-vented 27-G needle (Endo-Eze Irrigator, Ultradent Products, South Jordan, UT, USA). The needle tip was passively placed into the canal 2 mm away from the apical foramen, with no dentin wall binding. A final flush was made with 3.0 mL of 17% EDTA (BSA Sakurai, Nagoya, Japan), 3.0 mL 2.5% NaOCl, and 2.0 mL saline for 1 min each, and dried with paper points (META Biomed CO., LTD, Korea). Dentinal debris extrusion was weighted by another researcher who was blinded to the group task.

Tube covers and teeth were removed when the root canal instrumentation was finished. The apices of the teeth were flushed with 1 mL of distilled water to include the debris that deposited at the apical region of the roots. Tubes were placed in an incubator at 70°C for five days to enable irrigant evaporation, then three weight measurements were recorded using the same methodology and equipment. Mean post-preparation weight values were calculated and subtracted by preoperative weight values to obtain the weight of the extruded debris.

RESULTS

Descriptive statistics for weight of extruded debris (mg) values were presented in table (1, 2 and 3) and in figures (1 and 2).

According to motion kinematic table (1) fig (1), Regarding continuous rotation only, EdgeFile X7 (1.90±0.90) (mg) had higher value of extruded debris than Endostar E3 Azur (1.26±0.93) (mg), yet the differences were not statistically significant (p=0.052). However, for Optimum torque reverse, Endostar E3 Azur (1.05±0.34) (mg) had higher mean value than Edge (0.98±0.44) (mg) but also the differences were not statistically significant (p=0.835).

According to file used table (2) fig (2), EdgeFile X7 showed higher significant value of extruded debris with continuous rotation (1.90±0.90) (mg) than with optimum torque reverse (0.98±0.44) (mg) (p=0.006). While Endostar E3 Azur showed a higher value with continuous rotation (1.26±0.93) (mg) than with optimum torque reverse (1.05±0.34) but the differences were not statistically significant (p=0.500).

Comparing the files motion in relation to the file type used in table (3) Two-way ANOVA test results; only file motion has an impact on the amount of extruded debris as continuous rotation has a significant higher value than optimum torque reverse (p=0.016). In contrast, the type of file used has no an impact (p=0.212).

TABLE (1) Comparison between the mean values of weight of extruded debris (mg) using both files in same kinematics.

File	Motion	Mean	95% CI		SD	Min.	Max.
			Lower	Upper			
Edge	**CR**	1.90	1.34	2.46	0.90	0.20	2.96
	OTR	0.98	0.71	1.26	0.44	0.40	1.80
Azur	**CR**	1.26	0.69	1.84	0.93	0.20	2.80
	OTR	1.05	0.84	1.26	0.34	0.40	1.48

CI= confidence interval for the mean; SD=standard deviation; Min=minimum; Max=Maximum.

TABLE (2) Two-way ANOVA test results

Parameter	Sum of squares	df	Mean square	f-value	p-value
File Type	0.80	1	0.80	**1.61**	**0.212**
Motion	3.19	1	3.19	**6.41**	**0.016***
File Type * Motion	1.22	1	1.22	**2.46**	**0.126**
Error	17.90	36	0.50		

****Significant (p<0.05), df= degree of freedom.***

TABLE (3) Comparisons between the mean values of weight of extruded debris (mg) in each file with different kinematics.

Motion \ File	Weight of extruded debris (mg) (Mean ±SD) EdgeFile X7	Endostar E3 Azur	f-value	p-value
CR	1.90±0.90	1.26±0.93	**4.03**	**0.052**
OTR	0.98±0.44	1.05±0.34	**0.04**	**0.835**
f-value	**8.40**	**0.47**		
p-value	**0.006***	**0.500**		

Significant (p<0.05).

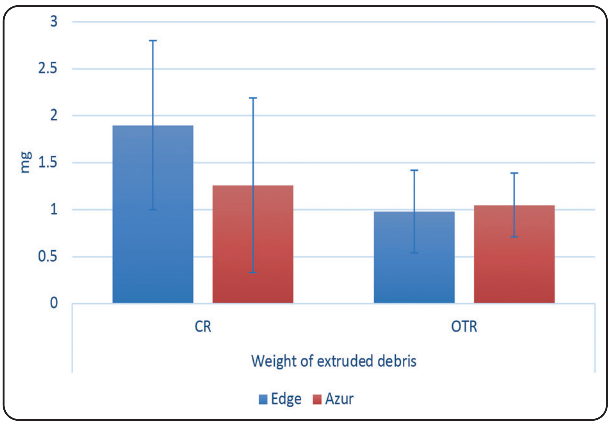

Fig. (1): Bar chart showing mean and standard deviation values of weight of extruded debris (mg) using both files in same kinematics.

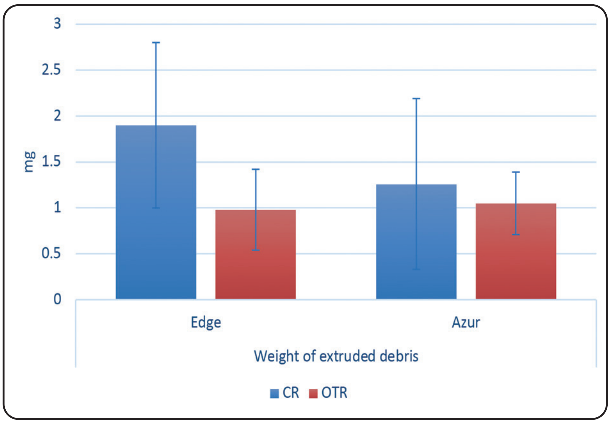

Fig. (2): Bar chart showing mean and standard deviation values of weight of extruded debris (mg) in each file with different kinematics.

DISCUSSION

During the root canal process, there is a tendency for extrusion of intra-canal debris combined with irrigants into the periapical tissues, leading to inflammatory reactions and flare-ups. The primary factor causing periapical periodontitis and postoperative pain is the extruded material, which was referred to as "the worm of necrotic debris".[12,13] Although apical dentin extrusion is inevitable and no instrument has prevented it, attempts were made to minimize its harm by testing new files and instrumentation approaches.[14] Consequently, the calculation of apically extruded dentin debris is of great importance in evaluating the competency of instrument designs and techniques.

Dentinal debris extrusion has been affected by multiple factors such as motion kinematics, the number of files used, and its file design[15]. The present study was designed to evaluate the effect of two different kinematics on irrigant and dentinal debris extrusion when using full-sequence rotary instrumentation systems. Results showed that, all tested samples produced apically extruded dentin debris, corroborating the results of previous researches[3, 4, 5].

Samples were selected to be mandibular premolars with single straight root canals in such research because both instrumentation and debris collection were easier and allowed instrument design evaluation.[16,17] It is crucial to standardize root length among all samples, to exclude canal length on the instrumentation interval or the quantity of extruded dentin debris. The working length was adjusted at the anatomic apex visually at one mm short from the root tip. The closer the working length to the apical foramen, the more debris will extruded (Uezuet al. 2010).[18]

The study followed the method proposed by (Myers and Montgomery 1991) for debris collection and weighing through the apical foramen. This methodology is considered efficient and simple.[19]

In the present study, NaOCl irrigation was used instead of distilled water, although there is a tendency of the extruded NaOCl irrigant outside to form crystals that affect the amount of apically extruded dentin debris.[20] It seemed logical to use the routine irrigant solutions to more accurately reflect the clinical situation this was in agreement (Nevares et al. 2015).[15] Additionally, irrigant extrusion is affected by needle depth inside the root canal. The more coronally positioned the needle inside the root canal the less amount of irrigant extrusion occurs. For standardization purposes in all samples, the needle was placed 2mm shorter than the working length, without binding into the root canal walls to avoid extrusion of the fluid into the periapex.

The development of new hybrid kinematics like TF Adaptive (TFA), Optimum Torque Reverse (OTR) and Canal Pro Jeni (Jeni) has been recommended to enhance file progression inside the root canals and decrease the incidence of file separation.[21,22] OTR is a new adaptive kinematic recently released, with limited data about apical dentin debris extrusion during mechanical preparation in the literature. In agreement with (Al Omari et al. 2023), results showed that rotary files with OTR motion produced significantly less amount of apically extruded dentin debris than rotary files with continuous rotation p=**0.016**.[23] The nature of OTR motion involves a continuous alternation of angles between a 90° anticlockwise and 180° clockwise spin. This process helps to improve efficiency and reduce apical extrusion by bringing the torque down to the desired level Grande NM and his coworkers stated that adaptive motion induce less pressure movement that extrude less dentinal debris apically.[24]

NiTi (CM-Wire) (Endostar E3 Azure and Edge-File X7) are multiple-files rotary heat-treated alloys used in the study as they possess higher resistance to cyclic fatigue and superior flexibility than conventional NiTi rotary files.[25,26] They have different file geometry and design features that affect mechanical performance such as cutting efficiency, cyclic and torsional fatigue resistance and screw-in force generation.[27,28] Both systems were used in a crown-down manner to gain the advantage of minimized debris extrusion compared to the manual apical coronal instrumentation method. The Edge Taper platinum SX file was meant to be added with Edge as a preflaring file, which corresponds to a preflaring file that is already present in Endostar E3 Azur, in order to standardize the Preflaring phase and a number of instruments that have been used for cleaning and shaping in both systems. According to (Caviedes et al. 2016), a limited number of files used might lead to a reduction in the apically extruded debris.[29]

According to a recent study, Edge files produce more extruded debris than Endostar E3 Azur files, regardless of the motion used. This finding is consistent with previous studies that have identified the effect of the cross-sectional design of the instrument to be the main factor of apical debris.[30] The parabolic cross-section of Edge files makes them highly flexible, while rotary instruments with broad radial lands tend to come into contact with a larger surface area of the canal walls, resulting in a higher chance of extruded debris.[31] On the other hand, Endostar E3 Azur files feature a modified S-shaped cross-section that reduces the core of the file allowing a larger amount of debris removal, greater flexibility and cutting efficiency.[32] This design also reduces the contact point and cutting area of dentin, thereby increasing clearance space and reducing the production of dentin debris. The unique geometric design of each file affects its mechanical properties.

To prevent debris from clogging inside the root canal, it is important to consider the design of rotary NiTi files and the motion used. Different mechanical systems can result in varying amounts of debris being extruded, which may explain the unique reaction of each file.[33] Results found that there was a significant difference in the extruded dentin debris amounts when using EdgeFile X7 with continuous rotation compared to OTR. However, no significant difference was observed when comparing Endostar E3 Azur files in both motions.

This confirms previous research that showed the amount of extruded dentin debris can vary based on the preparation technique and file system used. (Kustarci et al. 2002).[34] Generally, both system files help in decreasing the amount of extruded debris as they possess variable helical angles tending to decrease the screwing effect of the file.[35]

Further investigation is needed to determine the relationship between instrument design and new kinematics on debris extrusion, highlighting the clinical outcomes such as post-operative pain.

CONCLUSIONS

Despite the different kinematics used, all tested file systems resulted in apically extruded debris. However, when comparing the OTR and CR modes, it was observed that the OTR mode produced significantly less amount of extruded debris. This held true for both motions when Edge files were utilized. In the case of Azur files, CR produced less extruded debris than OTR but without discernible variations. Additionally, No significant differences were found between both files in each motion.

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