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Influence of Kinematics on Apical Debris Extrusion

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Abstract

Introduction: Apical debris extrusion is an undesirable outcome of biomechanical preparation of the root canal which can result in pain and/or swelling due to severe inflammatory response. Until now none of the available instrumentation systems could completely prevent extrusion. The amount of debris extruded depends upon the preparation techniques, the design of file systems and kinematics of endodontic files. Technological advancements in rotary NiTi instruments have led to the development of newer file systems manufactured from special thermal treated alloys with superior designs which works under varying kinematics to overcome the problems associated with older file systems.

Aim: To evaluate the amount of apical debris extrusion with different file systems working under varying kinematics.

Materials and Methods: 24 human premolar teeth having single root canal with <5° curvature were selected for this study. Access openings were done and working length was determined. The samples were then randomly divided into three groups depending upon the file systems used for cleaning and shaping. Group I – Twisted File Adaptive (TFA) (n = 8), Group II – Hyflex EDM (HEDM) (n = 8), and Group III –Wave One Gold (WOG) (n = 8). Cleaning and shaping was completed and the mean weight of the debris collected in preweighed Eppendorf tubes were assessed using an electronic balance and analyzed using One Way Analysis of Variance (ANOVA) test.

Results: All the samples showed apical debris extrusion. TFA showed the least amount of apical debris extrusion. WOG showed better result than HEDM. However no statistically significant differences were recorded among them.

Conclusion: TFA was associated with less debris extrusion compared with WOG and HEDM.

Keywords: Twisted File Adaptive System, Waveone Gold, Hyflex EDM, Kinematics, Apical Debris Extrusion.

Introduction

One of the most important step in ensuring the success of endodontic treatment is cleaning and shaping. [1] During instrumentation vital and necrotic tissues, dentin debris, microbes and irrigants may get extruded periapically leading to undesirable postoperative complications. Factors that control the debris extrusion quantitatively are - the natural physical factors like the anatomy of the apical constriction & dentin hardness, quantity & momentum of flow of the irrigant and the mechanical factors such as the final apical size of the instrument & instrumentation technique. The size of the irrigation needle and its depth of insertion into the canal also influences the debris extrusion. [2]

All instruments and preparation techniques produce some degree of apical extrusions, even when the preparation is maintained short of the apical limit.[3]However, the amount of debris extruded varies according to the preparation techniques, the design of file systems and kinematics of endodontic files.[4,5] The use of motor-driven instruments produced significantly less debris extrusion compared to conventional hand filing techniques.[6]Various studies have shown that balanced force and crown-down techniques produce less debris extrusion. Most NiTi instrumentation systems function in a crown down manner whereas reciprocating systems mimic the balanced force technique. [5] Recently technological advancements have led to the introduction of new NiTi files with superior designs, special thermal treated alloys and kinematics for the preparation of root canals. [7]

The WaveOne Gold (WOG) (Dentsply Tulsa Dental, Tulsa, OK) is a single-file reciprocating system that was manufactured with a proprietary thermal treatment, the gold alloy technology which resulted in improved physical properties. The modified tip diameter, taper, and offset parallelogram cross section provides greater file flexibility compared with that of its predecessor Wave One (WO) reciprocating system (Dentsply Tulsa Dental). [7]

HyFlex EDM (HEDM; Coltene/Whaledent, Altst€atten, Switzerland) is another latest innovation in rotary endodontics which works in a continuous rotary movement. HEDM files are manufactured from controlled memory alloy using electrical discharge machining technology that uses spark erosion to harden the surface of NiTi file which owes to its unmatched flexibility and fracture resistance. The file has 3 different horizontal sections along the working part: triangular cross section at the top, trapezoidal in the middle and quadratic in the apical part which also contributes to its high fracture resistance. [4]

Twisted File Adaptive (TFA) (Axis/SybronEndo Orange, CA, USA) is a novel NiTi file system, which works with the use of a specialized motor (Elements Adaptive motor, SybronEndo) that automatically shifts between continuous rotary or reciprocating movement depending on the frictional intracanal stress and load generated on the instrument. In the presence of minimal load, the file works in continuous rotation and when it engages the dentin and excess load is applied, it changes to a reciprocation mode, with uniquely designed clockwise (CW) and counter-clockwise (CCW) angles, which vary from 600-0° up to 370-50°. [5]The R phase heat treatment, coupled with its twisted file design improves its flexibility and the adaptive technology allows the file to adapt to intracanal torsional forces. [7]

Investigating the movement kinematics of these new NiTi systems are important for understanding how it affects the apical debris extrusion. Hence, the aim of this study was to evaluate the influence of TFA, WOG and HEDM files which works under adaptive, reciprocative and rotary motion respectively on the amount of apically extruded debris.

Materials and Methods

Freshly extracted human single rooted premolar teeth with fully formed apices were collected. The teeth were kept in 2.5% sodium hypochlorite (NaOCl) for 2 hours (hrs) and the root surfaces were further cleaned of debris and tissue with periodontal curette and stored in saline solution. Twenty four teeth with single root canal and single apical foramen with <5° root canal curvature were used for this study. Teeth with root canal calcification, internal resorption, and curved root canals were excluded from the study. Buccal cusp tips were ground to ensure a flat coronal reference point and a total tooth length of 16 mm. Coronal access cavity was prepared with high-speed bur, and all the canals were checked for apical patency with a K-File (KF) (015/02) which is barely visible at the tip. Working length (WL) was obtained by subtracting 1mm from the length of the initial instrument (015/02 KF) which was barely visible at apical foramen.

The debris collection apparatus was set up according to an experimental study model described by Myers and Montgomery.[8] Empty Eppendorf tubes were weighed initially in an electronic microbalance (Sartorius cubis, Germany) with an accuracy of 10^{-4}gram (g) after separating the stoppers from it.[9] Three consecutive measurements were taken for each tube, and the mean value was assessed. With the help of a hot instrument a hole was made at the centre of the stopper and tooth was inserted up to the cementoenamel junction (CEJ) on each stopper and sealed by using cyanoacrylate resin. The tubes were vented with a 27-gauge (G) needle alongside the stopper to equalize the pressure. [10] To avoid variation and eliminate bias during instrumentation all the tubes were covered with foil.

The samples were randomly divided into three groups according to the file used for the instrumentation of root canals. Glide path established in all the mounted teeth using K file (015/02).

Group I: TWISTED FILE ADAPTIVE

Canal preparation was done using TFA SM1 (20/.04) and SM2 (25/.06) with the TF Adaptive program Elements Motor (Sybron endo, Glendora, CA, USA.) according to manufacturer's instruction.

Group II: HYFLEX EDM

The HEDM Orifice Opener (25/.12) was used at a rotational speed of 300 rpm (revolutions per minute) and 1.8Ncm (torque) followed by HEDM One file (25/~) was used in gentle in-out motion rotary motion at 500 rpm and at a torque of up to 2.5 Ncm to the working length with Coltene Canal Pro CL2 Endomotor according to the manufacturer's instructions. HEDM One file has a tip size of 25 (0.08) taper which is constant in apical 4mm and reduces progressively upto (0.04) taper in coronal portion.

GROUP III: WAVE ONE GOLD

A Small WOG file (20/.07) followed by apical preparation with Primary WOG file (25/.07) were used in a reciprocating ,slow in-out pecking motion according to manufacturer's instruction with Coltene Canal Pro Cl2 Endomotor.

After each instrumentation 2ml (millilitre) of saline was used as an irrigant. Once instrumentation has been completed each tooth was separated from the Eppendorf tube and debris adhering to the root surfaces was collected by washing with 2ml of saline. A total of 10ml of saline was used for each sample.The receptor tubes were then stored in hot air oven at 140^0C (degree Celsius) for 9hrs in order to evaporate the moisture before weighing the dry debris. [6]

The tubes were weighed again using the same electronic balance to obtain the final weight of the tubes with debris

.Three consecutive measurements were taken for each tube, and the mean value was assessed and the dry weight of extruded debris was calculated by subtracting the weight of the empty tube from the weight of the tube containing debris.[11]

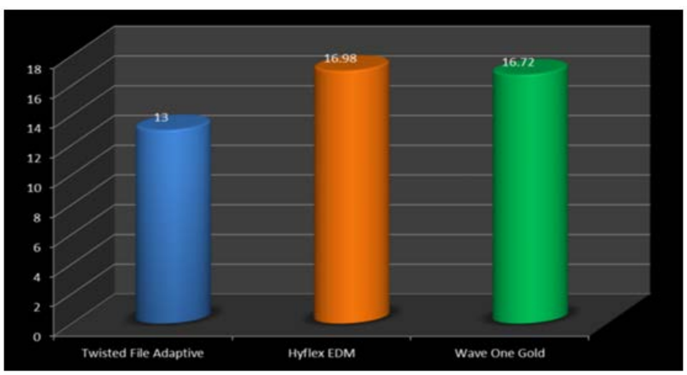
Results

Samples of the entire group showed debris extrusion.

MEAN DIFFERENCE OF THE DRY WEIGHT OF EXTRUDED DEBRIS (10^{-4}g)

GROUPS		MINIMUM	MAXIMUM	MEAN	MEAN DIFFERENCE (POST-PRE)	P VALUE
TFA (I)	Pre	674.13	708.00	688.02	13.00	0.191
	Post	687.36	719.00	701.03		
HEDM (II)	Pre	669.73	707.86	684.90	16.98	
	Post	691.16	725.93	701.88		
WOG (III)	Pre	674.03	701.50	688.55	16.72	
	Post	690.60	720.06	705.27		

Table 1: Comparison of the dry weight of the debris extruded (10^{-4}g) using ANOVA



Graph: 1 Mean distribution of the dry weight of the debris (10^{-4}g) among the groups.

The results of the present study revealed that the TFA system extruded significantly less debris than the WOG and HEDM systems. WOG showed better result than HEDM. However no statistically significant differences were recorded among them ($P > .05$).

Discussion

During cleaning and shaping of the root canals an inflammatory reaction can be triggered by forcing the contents of the root canals to the periapical region.[4] The debris is the main cause of periodontal ligament inflammation.[12] The debris extrusion is also influenced by the movement kinematics and instrument design.[4] Instruments may vary greatly in their design like radial lands, flute depth, taper, cross-sections (CS) and kinematics which can influence the amount of apically extruded debris through the apical foramen.[13]

There have been several contradictory results on the effect of movement kinematics and debris extrusion. Some studies reported that reciprocating motion produced more debris than continuous rotating motion whereas others have the opposite opinion. These conflicting results can be related to the differences in the experimental set-up, design of instruments and type of teeth used. [6]

Recently, instrument systems operated with adaptive motion were introduced and investigations on their effect on debris extrusion is limited. Hence this present study evaluated the effect of TFA, HEDM and WOG which works under adaptive motion, rotary motion and reciprocating motion respectively on the amount of periapical debris extrusion.

TFA which works under adaptive motion showed the least amount of debris extrusion. This may be attributed to the design of the file and particularly the kinematics. TFA files have a triangular cross-section. The amount of apically extruded debris may differ depending whether adaptive movement is predominant at the beginning of the instrumentation or at the point of root curvature and also the degree of CW and CCW rotation according to the intensity of stress generated on the file during instrumentation. [14]

WOG performed better than the HEDM in this study. WOG has a unique design features like offset parallelogram shaped cross section and are used in brushing motion which decreases the contact area between the file and the canal wall, eliminates undesirable taper lock, and allows the instrument to run more freely. It has a constant helical angle of 24 degrees along the active length of the instrument which reduces the screwing in tendency. The additional space around the instrument also facilitates for improved debris removal. The tip of WOG is ogival, roundly tapered and semi-active, which reduces the mass of the centre of the tip and enables to produce a smooth and reproducible glide path. [15]

This is in accordance with another study where they proved that the reciprocating single-file instruments resulted in less apical extrusion than the rotary full-sequence systems. The reciprocating motion functions by squeezing debris into the flutes and moving it coronally, whereas the rotary instruments are more likely to exert a spiral effect which may push the debris out of the apical foramen. [2]

Some studies reported that there is no difference in the amount of apically extruded debris between rotary and reciprocating instrumentation.[4] Some researchers contradicted by concluding that reciprocating motion appeared to increase transportation of debris towards the apex whereas continuous rotation resulted in coronal transportation of dentine chips and debris by acting like a screw conveyor.[8] Elmsallati et al evaluated the amount of apically extruded debris of the same instruments with short, medium, and long pitch designs and showed that less debris extrusion was seen among the short pitch design group. HEDM file system used in this study have the property of unwinding when there is fatigue. This can be a reason for the increased debris extrusion seen with the HEDM system. [16]

The disparities between the studies can be explained by differences in the experimental set-up, design and type of teeth used. Moreover, the use of instruments with distinct designs and number of files could explain these conflicting results. In this study NaCl (0.9%) solution was used as the root canal irrigant. The NaCl precipitate which accumulated in the tube after drying acted as an indirect measurement of the extruded irrigants and increased the accuracy of the measurements. [2] In clinical situation periapical tissues will act as a natural barrier, which could limit apical debris extrusion. In addition to it, the status of pulp tissue and the presence of periapical lesion also affects apical extrusion of debris. [6] Based on the results of this study, all instrumentation techniques produced debris and irrigant extrusion.

Conclusion

Within the limitations of the present study, it can be concluded that all the file systems, working under Rotary (HEDM), Reciprocating (WOG), Adaptive (TFA) kinematics showed apical debris extrusion .TFA showed the least debris extrusion followed by WOG and HEDM file systems. Hence the instrument design and working principles affects the quantity of apical debris extrusion. As there is less apical debris extrusion and thus less post-operative pain, file systems working under adaptive motion is safe.

Abbreviations

ANOVA	One way Analysis of Variance
BMP	Bio-mechanical preparation
CCW	Counter clock wise
CEJ	Cementoenamel junction
CM	Controlled memory
CS	Cross section
CW	Clock wise
^{0} C	Degrees Celsius
EDM	Electric discharge machining

ga or G	Gauge
g or gm)	Gram
hrs	Hours
HEDM	Hyflex EDM
KF	K-files
mL	Milliliter
NiTi	Nickel-titanium
rpm	Revolutions per minute
NaCl	Saline
NaOCl	Sodium hypochlorite
TFA	Twisted File Adaptive
SM1, SM2	Twisted file adaptive small
Nm	Torque
WO	Wave One
WOG	Waveone Gold
WL	Working length

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