ORIGINAL RESEARCH

Assessment of Apical Extrusion of Debris during Root Canal Preparation with Different Ni–Ti File Systems: An *In Vitro* Study

Abhinav K Singh[1], Suvarna Chandrakant Chavan[2], Anvi Shah[3], Rashmita Parida[4], Nisarga Kansar[5], Sheela Poojary[6]

Abstract

Aim and objective: The aim of this study was to evaluate the apical extrusion of debris during root canal preparation with the use of different Nickel–Titanium (Ni–Ti) file systems.

Materials and methods: Totally 60 single-rooted human mandibular premolar teeth with fully formed roots were chosen for the study. The coronal access cavity and all other preparations were done with the use of an access cavity kit and then 60 samples were randomly separated into three investigational groups ($n = 20$); group I: self-adjusting file, group II: WaveOne Gold, and group III: Mtwo rotary system. After instrumentation, the teeth were taken out from the tube and the root surface–adherent debris was collected by washing off the apical area of the tooth with distilled water (1 ml) into a centrifuge tube. The centrifuge tube was kept for 5 days in an incubator at 70°C to permit evaporation of the moisture prior to weighing the dry debris with the aid of an electrical analytical balance.

Results: The highest quantity of debris extruded was by the Mtwo rotary system (0.0394 ± 0.880) followed by WaveOne Gold (0.0247 ± 1.030) and self-adjusting file (0.0198 ± 0.102). A statistically significant difference ($p < 0.001$) was found between the various file systems.

Conclusion: After considering the drawbacks of this study, apical debris extrusion could be found with all three groups. However, the self-adjusting file demonstrated a significantly reduced quantity of apical debris extrusion compared to the Mtwo rotary system and WaveOne Gold.

Clinical significance: The chief step during the procedure of root canal treatment is the preparation of the infected root canals biomechanically. This preparation may lead to forcing the apical debris into the periapical space through the apical foramen, resulting in host-initiated immunological response which leads to postoperative discomfort and pain. This consequently leads to selection of a specific rotary system for endodontic treatment.

Keywords: Apical extrusion, Debris, Instrumentation, Ni–Ti file.

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Introduction

The important goal of root canal treatment is to complete the removal of bacteria from the root canals. The biomechanical preparation helps achieve this goal. During the process of preparation of root canal, tissue remnants, debris, and microbes could be extruded past the apical foramen, leading to periapical tissue inflammation, pain after the procedure, and interruption of apical wound healing.[1]

The apical extrusion of bacteria and/or debris usually occurs during every root canal preparation technique; nonetheless, the quantity of extruded material differs from each instrumentation technique and file system used. And, the debris or irritants which have extruded apically may result in recurrence of infection and pain after the operative procedure. Several conditions, such as design and speed of instruments, type of irrigants used, etc., contribute to the apical extrusion.[2]

Formerly, hand files made up of stainless steel were widely used for cleaning as well as shaping. Due to faults associated with iatrogenic causes (canal transportation, ledging, apical extrusion, zipping, and blockage) resulting from these files, there has been an extensive quest for advanced materials, special techniques, and innovative instruments which help to obtain a clean sterile canal without debris and to reduce or avoid apical extrusion. Every system has its own merits and demerits.[3]

The use of innovative metallurgy and nickel–titanium (Ni–Ti) instruments which are motor driven has led to an improvement in cleaning as well as shaping of the root canals. The usage of new generation root canal shaping instruments, such as WaveOne Gold file system, is fabricated with a reverse helix cutting, functions in a 150° anticlockwise direction, and unlocks in a clockwise path at

[1]Department of Conservative Dentistry and Endodontics, Buddha Institute of Dental Sciences and Hospital, Patna, Bihar, India

[2]Department of Conservative Dentistry and Endodontics, Subbaiah Institute of Dental Sciences, Shivamogga, Karnataka, India

[3]Department of Pedodontics and Preventive Dentistry, Ahmedabad Dental College and Hospital, Ahmedabad, Gujarat, India

[4]Sure Smile Dental Clinic, Jabalpur, Madhya Pradesh, India

[5]Department of Pedodontics and Preventive Dentistry, Subbaiah Institute of Dental Sciences, Shivamogga, Karnataka, India

[6]Department of Oral Pathology and Microbiology, Educare Institute of Dental Sciences, Malappuram, Kerala, India

Corresponding Author: Abhinav K Singh, Department of Conservative Dentistry and Endodontics, Buddha Institute of Dental Sciences and Hospital, Patna, Bihar, India, Phone: +91 9576969374, e-mail: akspat01@gmail.com

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30°, and the total movement is 120° cutting cycle, so post-three cycles the instrument would have completed a 360° reverse spin.[4]

Two sharp cutting edges and an s-shaped cross section are present in Mtwo instruments. The Mtwo is fabricated with least radial contact and deep and large flutes for constant evacuation of dentinal chips in an upward direction. The design of this instrument allows flexibility without hindering the strength of the instrument.[5] The self-adjusting file (SAF) is a hollow file fabricated as a thin-walled, compressible, sharp cylinder made up of a slim Ni–Ti lattice. When introduced into the root canal, it adjusts itself to the shape of the canal, both along the boundary of the cross section and the lengthways.[6] Consideration has been coordinated toward the wide quest for innovative materials, instruments, and strategies to get a clean debris-free canal and to limit or prevent apical extrusion. With this extent of enhanced technology, the efficiency of several file systems can be analyzed and the quantity of intracanal bacteria extruded apically can be measured accurately. Thus, this study was performed to assess the extent of debris extrusion apically during the preparation of root canals with various Ni–Ti file systems.

Materials and Methods

Selection and Preparation of Samples

The present study was conducted in the department of conservative dentistry and endodontics and ethical approval was obtained from Buddha Institute of Dental Sciences and Hospital, Patna. Totally, 60 single-rooted human premolar teeth with fully formed roots from the mandibular arch which were extracted for orthodontic reasons were used for this study. The debridement procedure was performed initially to eliminate the soft tissue remnants and calculi present on the outer tooth surface using a periodontal curette. Teeth with a clear single root canal, no caries, and completely formed apices were involved in this study. Teeth that had fractures, root caries, resorption, calcifications, and complex root canal morphology were not involved in this study.

An access cavity was opened coronally with the use of an access cavity kit (Endo-Z Access Kit, Dentsply Tulsa). Barbed broaches were used to remove the pulp tissues. A 20 K-file was used to gain the patency of the canal. Each canal's working length (WL) was established 1 mm short of the size of the 20 K-file's length which was seen at the apical foramen. After this, all 60 teeth were randomly separated into three investigational groups [each group had 20 samples] for different methods of instrumentation.

Group I: Self-adjusting File

The SAF system (ReDent Nova, Ra'anana, Israel) was used to prepare 20 teeth. A handpiece head of RDT3 NX (ReDent Nova) with an endodontic motor from EndoMate (NSK) that generated 5000 vibrations in a minute with 0.4-mm amplitude was used for the intracanal use of SAF (1.5-mm diameter and 25-mm length). The SAF was used with distilled water irrigation for 4 min at 1 ml/min flow rate.

Group II: WaveOne Gold

Countering motion back and forth was used with a reciprocating WaveOne Gold file. As per the instructions provided by the manufacturer, 0.07 tapered reciprocating WaveOne Gold file (Dentsply Maillefer, Ballaigues, Switzerland) was used slowly with an in-and-out pecking motion. The instrument flutes were cleaned subsequent to every three pecks. As the primary size of all the canals was equivalent to size 20, there was no glide path created prior to instrumentation. The instruments were used at the highest torque level of 2.5 N/cm at 350 RPM speed.

Group III: Mtwo Rotary System

With the Mtwo rotary system (VDW, Munich, Germany) to clean twenty canals, 21-mm files were used. For the single-length technique, all the instruments were used for the complete length of the root canal. The instrumentation order was 10/0.04, 15/0.05, 20/0.06, and 25/0.06.

Collection of Debris

The method used in this study is based on Myers–Montgomery's experimental model.[7] The original weights of the tubes were measured separately by another examiner who was blinded to sample groups with the use of an electrical analytical balance (single pan K-15, K. Roy Instruments Pvt. Ltd., India) which can accurately record 10^{-4} g. After obtaining three successive weights for each tube, the average was calculated. Once every tooth was implanted equal to the cementoenamel junction, a 27-gauge needle was introduced together with a stopper for drainage purposes. Later, each tooth with the stopper and the needle was connected to its Eppendorf tube, and the tubes were attached to the vials. One operator was proficient with the efficient use of each file system and it was this operator who performed the complete instrumentation.

After instrumentation, all the teeth were taken out of the tube and the apical area of the root surface was washed with distilled water (1 ml) to remove the adhering debris and the debris was collected in a centrifuge tube. The centrifuge tube was kept in an incubator for 5 days at 70°C to let the dampness evaporate prior to the use of an electrical analytical balance to weigh the dry debris.

Statistical Analysis

A statistical package for social sciences for Windows 20.0 (SPSS Inc., Chicago, IL) was used to analyze the data. For intergroup comparisons, descriptive data which show mean and standard deviation for all the groups distinctly were used. One-way analysis of variance test was used to analyze the observed data and a *post hoc* Tukey test was used to find the difference between the groups. A 95% confidence interval was estimated and $p < 0.05$ was interpreted as statistically significant.

Results

The weight (mean) of apically extruded debris postinstrumentation with various Ni–Ti file systems is as shown in Table 1. The highest quantity of debris extruded apically by Mtwo rotary system was 0.0394 ± 0.880 followed next by WaveOne Gold (0.0247 ± 1.030) and SAF (0.0198 ± 0.102).

The comparison of weight (mean) of apically extruded debris postinstrumentation with various Ni–Ti file systems is as depicted by Table 2. Mtwo rotary system reported the maximum quantity

Table 1: Evaluation of mean apical extrusion of debris after instrumentation with different Ni–Ti file systems

File systems	*Samples (n)*	*Mean ± SD*	*Std. error*
Group I: self-adjusting file	20	0.0198 ± 0.102	0.0182
Group II: WaveOne Gold	20	0.0247 ± 1.030	0.0077
Group III: Mtwo rotary system	20	0.0394 ± 0.880	0.0124

Table 2: Comparison of mean apical extrusion of debris after instrumentation with different Ni–Ti file systems

File systems	*Mean ± SD*	*Std. error*	*F*	*p-value*
Group I: Self-adjusting file	0.0198 ± 0.102	0.0182	6.210	0.001
Group II: WaveOne Gold	0.0247 ± 1.030	0.0077		
Group III: Mtwo rotary system	0.0394 ± 0.880	0.0124		

Table 3: Multiple comparisons of mean apical extrusion of debris after instrumentation using Tukey *post hoc* test

Groups	*Compared with*	*Mean difference*	*Significance*
Self-adjusting file	WaveOne Gold	−0.0049	0.06
	Mtwo rotary system	−0.0196	**0.001**
WaveOne Gold	Self-adjusting file	0.0049	0.06
	Mtwo rotary system	−0.0147	**0.001**
Mtwo rotary system	Self-adjusting file	0.0196	**0.001**
	WaveOne Gold	0.0147	**0.001**

Bold values are Highly Significant

(0.0394 ± 0.880) of apically extruded debris, while SAF reported the least amount (0.0198 ± 0.102) of apically extruded debris. A statistically significant difference ($p < 0.001$) was found between the different file systems.

Table 3 shows the results of the Tukey test and there was no significant difference between SAF and Mtwo rotary system and Mtwo rotary system and WaveOne Gold in the apical debris extrusion. No statistically significant difference was seen between SAF and WaveOne Gold.

Discussion

The foundation for endodontic therapy is the triad involving biochemical preparation, control of microbes, and total obturation of the root canal space. As per Baumgartner, Ingle, and Backland, incomplete root canal obturation leads to 60% of endodontic failures, while several factors, such as continuous trauma, fragmented instruments, external root resorption, root perforations, empty root canals, grossly overextended or overfilled root canals, and other negligible causes including unintentional removal of silver points lead to other 40% of endodontic failures.[8]

Diverse rotary instrumentation systems have different properties and shapes that affect the consequence of their actions, and apical extrusion is one such consequence of using rotary instruments. The factors that contribute to apical extrusion include size and type of files, WL, instrumentation techniques, and irrigant solution.[9]

Apical extrusion is defined as a lack of balance between the host defenses and infectious intracanal microbes and this results in an acute inflammatory response, thus warranting restoration of equilibrium. So, lessening the apical extrusion of debris can curtail the postoperative reactions resulting from continuous rotating and reciprocating instruments.[10]

In the present study, mandibular premolars with single canal were used because of the wide frequency between extracted teeth. Additionally, the application of only one kind of tooth can help increase the similarity between the samples. In this study, the reduced quantity of apical extrusion was demonstrated by SAF in comparison with Mtwo rotary system and WaveOne Gold. A study by Hof et al.[11] found similar results and reported that advanced kinematics of SAF for shaping and cleaning uses vibratory movement and removes dentin from the walls of the canal circumferentially, concurrently broadening and irrigating as the configuration of the original canal is maintained with reduced extrusion of debris.

The results obtained by us are in accordance with the study by Ozsu et al.[12] who related SAF with ProTaper Next and WaveOne and found less amount of extrusion of debris apically with SAF. Dietrich et al.,[13] Pawar et al.,[14] and Vyavahare et al.[15] have also reported reduced apical debris extrusion with SAF system in comparison with other rotary file systems.

The highest debris extrusion was recorded with Mtwo rotary system in this study. A study by Abhilasha Dass et al.[5] found similar results and reported an increasing pitch length to the shaft from the tip and a cross section which is an s-shaped positive rake angle with two cutting edges for Mtwo instruments which permits outstanding cut laterally. However, when compared with other file systems, increased apical debris extrusion has been found with Mtwo instruments.

In our study, an experimental model by Myers and Montgomery[7] was used. This system involves the use of a rubber stopper which helps to force and secure the instrumented root, a glass vial to collect the irrigants or extruded debris, and a glass flask within which the vial is kept. There are no apical tissues in this model to perform as an apical extrusion's natural barrier.

A 10-K file was used to maintain the apical patency in all cases to attain apical diameter standardization. It was demonstrated by Tinaz et al.[16] that the debris extrusion increased with increase in the diameter of patency of the apex, whereas Lambrianidis et al.[17] reported that even when constriction of the apex remained intact, the amount of apical extrusion increased.

In order to prevent any differences associated with the quantity of extruded bacteria and apical size enlargement, the apical diameter of all master apical files was maintained at ISO size 20 consistently in all the groups. Thus, the quantity of apically extruded debris from the root canals could be ascribed to the technique and design of the corresponding instrument used in a specific group. An irrigating solution of normal saline was used as it has no consequence on debris.[18]

Even though this study permits file system comparison under indistinguishable environments, there were still some drawbacks. The main demerit of the method is that apical vital tissues could not be imitated. Additionally, this study restricted to the use of the teeth with fully formed root morphology. The results thus obtained should not be applied to teeth with open apex and incompletely formed roots. Moreover, quantifying the quantity of extruded debris with regard to its weight is not sufficient to make an assumption about flare-ups during midtreatment. There could be other conditions, such as intracanal medication, bacterial virulence, extruded irrigant, and the host response that can activate such a flare-up. There is a need for additional investigations to evaluate the extrusion of solid debris along with intracanal irrigants. Further *in vivo* studies are also required to evaluate postinstrumentation pain with these instrumentation systems.

Conclusion

After considering the drawbacks of this study, apical debris extrusion could be found with all three groups. However, the

SAF demonstrated a significantly reduced quantity of apical debris extrusion compared to Mtwo rotary system and WaveOne Gold.

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