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ORIGINAL ARTICLE

Apical extrusion of debris during the preparation of oval root canals: a comparative study between a full-sequence SAF system and a rotary file system supplemented by XP-endo finisher file

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Abstract

Objectives The purpose of this study was to assess the amount of apically extruded debris during the preparation of oval canals with either a rotary file system supplemented by the XP-endo Finisher file or a full-sequence self-adjusting file (SAF) system.

Materials and methods Sixty mandibular incisors were randomly assigned to two groups: group A: stage 1—glide path preparation with Pre-SAF instruments. Stage 2—cleaning and shaping with SAF. Group B: stage 1—glide path preparation with ProGlider file. Stage 2—cleaning and shaping with ProTaper Next system. Stage 3—Final cleaning with XP-endo Finisher file. The debris extruded during each of the stages was collected, and the debris weights were compared between the groups and between the stages within the groups using *t* tests with a significance level set at $P < 0.05$.

Results The complete procedure for group B resulted in significantly more extruded debris compared to group A. There was no significant difference between the stages in group A, while there was a significant difference between stage 2 and stages 1 and 3 in group B, but no significant difference between stages 1 and 3.

Conclusions Both instrumentation protocols resulted in extruded debris. Rotary file followed by XP-endo Finisher file extruded significantly more debris than a full-sequence SAF system. Each stage, in either procedure, had its own contribution to the extrusion of debris.

Clinical relevance Final preparation with XP-endo Finisher file contributes to the total amount of extruded debris, but the clinical relevance of the relative difference in the amount of apically extruded debris remains unclear.

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Keywords Debris extrusion · Oval canals · Pre-SAF · Self-adjusting file · XP-endo Finisher file

Introduction

During mechanical preparation, dentin chips, pulpal tissue remnants, irrigant solutions, and microorganisms may often be transported via the apical foramen into periapical tissues [1, 2]. Such debris extrusion might cause postoperative inflammation, flare-ups and/or delayed apical healing [3]. Current studies indicate that all preparation techniques and instruments cause some extrusion of debris [4–6]. However, the amount of extruded debris may differ according to the preparation technique and file system design [4, 7–10].

Oval root canal systems may impair proper cleaning and shaping when using rotary or reciprocating file systems [11–13]. Until recently, only the self-adjusting file (SAF) system (ReDent Nova, Ra'anana, Israel) was specifically designed to address the challenge of oval-shaped root canals. SAF is a coreless, hollow, compressible nickel-titanium (NiTi) instrument designed to adapt itself to the walls of root canals with any cross section [12]. It is claimed to circumvent many of the limitations of rotary and reciprocating nickel-titanium (NiTi) instruments when used in oval canals. It should be noted that SAF has no penetration abilities; thus, according to the manufacturer, it requires pre-establishment of a #20/.04 glide path, using Pre-SAF rotary instruments (ReDent Nova). Therefore, the term "full-sequence SAF system" refers, in this study, to a procedure that includes both the Pre-SAF glide path files and the SAF files, as the rotary Pre-

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SAF files might contribute to the total amount of extruded debris.

Several studies evaluated debris extrusion associated with the SAF system [14–16]. However, none evaluated, up to date, the SAF full-sequence protocol, which includes glide path preparation with Pre-SAF instruments, as currently recommended by the manufacturer.

Recently, a new file, the XP-endo Finisher file (#25/.00) (FKG Dentaire, La Chaux de Fonds, Switzerland), was introduced as a complementary *universal* instrument that can be used following root canal preparation with *any file system* of diameter ISO 25 or more, for cleaning highly complex morphologies and difficult-to-reach areas, such as oval canals [17, 18]. It has the capacity to greatly expand when rotating, up to a diameter of 6 mm, and clean the canal with minimal impact on the dentin of the canal walls [17, 18]. A recent study by Leoni et al. [18], showed that XP-endo Finisher file was associated with greater mean percentage reductions of accumulated hard-tissue debris from the mesial root canal system of mandibular first molars compared with modified SAF system protocol. Thus, it is possible to assume that XP-endo Finisher file mechanical preparation may have an impact on debris extrusion during root canal treatment.

To the best of our knowledge, no study has evaluated, so far, the extent of apical extrusion of debris by the XP-endo Finisher file.

The aim of the present study was to assess the amount of apical extrusion of debris when preparing oval root canals with either the full-sequence SAF system or a rotary file system supplemented by the XP-endo Finisher file.

The null hypothesis of the present study was that the apical extrusion of debris in oval canals would not differ between a full-sequence SAF system and rotary file system supplemented by the XP-endo Finisher file.

Materials and methods

The study was designed to measure and compare the total extrusion of debris when using either full-sequence SAF system, i.e., Pre-SAF files and the SAF (group A), or a rotary file system, supplemented by the XP-endo finisher file (group B).

Specimen preparation

Sixty mandibular incisors were selected from a random collection of recently extracted teeth. All teeth were radiographed in bucco-lingual and mesio-distal projections. Inclusion criteria stipulated that the tooth should be straight, 18–20 mm long, have a fully formed apex, no caries, no coronal restorations or signs of resorption, and include a single straight ($r < 5°$) oval-shaped root canal with a long:short canal diameter ratio of ≥2.5 at 5 mm from the apex [19, 20].

Standard endodontic access cavities were prepared, and a size 10 K-file (Mani, Takanezawa, Japan) was introduced into the canal until it was visible at the apical foramen. The working length (WL) was established 1 mm short of this length. To ensure standardization and avoid teeth with large canals, a size 15 K-file was introduced into each canal, and roots in which the file progressed freely to the apical foramen were excluded. To further enhance standardization and obtain a reference point, the crown of each tooth was ground, using a high-speed diamond bur, and the WL length of all teeth was standardized to 17 mm.

Debris collection setup

The debris collection setup was based, with slight modifications, on previous work of Myers and Montgomery [21], Koçak et al. [22], Kirchhoff et al. [14], and Topçuoğlu et al. [23].

One hundred fifty Eppendorf tubes were pre-weighed to 10^{-4} g precision using a microbalance (Sartoriusintec, Hamburg, Germany). Three consecutive weight measurements were taken for each tube, and their mean value was recorded. Sixty Eppendorf tubes were then allocated to group A and 90 to group B (see below).

A hole was created in the center of the cap of a scintillation glass vial, and the tooth was inserted, apex down, up to the cemento-enamel junction and secured in place with Filtek Supreme flowable composite (3 M/ESPE, St Paul, MN, USA). A 25-gauge needle was also placed and secured in the vial cap to equalize the air pressure inside and outside the vial.

A small "socket" was created on the bottom of the glass vial, using silicon impression material (Coltene/Whaledent, Langenau, Germany) which was later used to hold and stabilize each Eppendorf tube when the caps were fitted onto the vials. This was done so that the apical end of the root was positioned inside the pre-positioned Eppendorf tube. The teeth with their vials were then randomly divided (www.randomizer.org) into two groups (A and B, $n = 30$) according to the instrumentation protocol to be used for preparing the oval-shaped root canals. The vials were covered by a rubber dam to prevent the operator from viewing debris extrusion during tooth preparation. The entire apparatus was handled by the outer vial alone.

Root canal instrumentation

Group A: full-sequence SAF system Instrumentation was conducted in two stages, and debris collection was performed separately for each tooth, and for each stage.

Stage A1: glide path preparation A glide path was prepared according to the manufacturer's instructions. The Pre-SAF OS

(ReDent Nova) was used to funnel the coronal 3 mm of the canals, which was followed by the Pre-SAF1 (#15/.02) and Pre-SAF 2 (#20/.04) instruments using 2–3 gentle strokes up to WL. Patency was confirmed with size 10 K-file. The Pre-SAF OS and Pre-SAF2 instruments were used with the endodontic motor (X-Smart Plus, Dentsply Maillefer) at 600 rpm and 1.5 Ncm and the Pre-SAF 1 at 600 rpm and 1 Ncm. The canals were rinsed repeatedly, after each instrument, with 2 ml of distilled water using a syringe and 30-G needle (NaviTip; Ultradent, South Jordan, UT, USA) with a total of 6 mL and with a flow rate of approximately 4 mL/min.

Stage A2: SAF instrumentation The SAF (1.5 mm in diameter and 25 mm long) was passively introduced into the canal to the WL, and it was activated in the canal for 4 min using an RDT3 hand piece head, at a frequency of 5000 in-and-out vibrations/min and an amplitude of 0.4 mm (ReDent Nova). A pecking motion was applied by the operator to the WL according to the manufacturer's instructions. Irrigation was performed with distilled water, which was continuously provided using a VATEA peristaltic pump (ReDent Nova), at a flow rate of 4 mL/min, with a total of 16 mL. At the end of the preparation, patency was confirmed with size 10 K-file followed by a final flush with 2 mL distilled water using a syringe and 30-G needle at a flow rate of approximately 4 mL/min.

Group B: multi-instrument rotary file system, followed by the XP-endo finisher file Instrumentation was conducted in three stages, and debris collection was separately performed for each stage.

The ProGlider file (Dentsply Maillefer, Ballaigues, Switzerland) and ProTaper Next instruments (Dentsply Maillefer) were chosen as a representative multi-instrument rotary file system, which was followed by the XP-endo Finisher file.

Stage B1: glide path preparation A glide path was created using ProGlider file, according to the manufacturer's instructions. The file was used with an endodontic motor (X-Smart Plus) at 300 rpm and 2 Ncm. Patency was confirmed with a size 10 K-file.

The specimens were rinsed with a total of 6 mL distilled water using a syringe and 30-G needle with 2 mL applied after each pecking motion, at a flow rate of approximately 4 mL/min.

Stage B2: ProTaper Next instrumentation Following the glide path preparation, the specimens were instrumented with ProTaper Next instruments, according to the manufacturer's instructions, using a gentle brushing motion up to WL. The instruments were used with an endodontic motor (X-Smart Plus) at 300 rpm and 2 Ncm, and the instrumentation sequence consisted of X1 (#17/.04), X2 (#25/.06) and X3 (#30/.07). The root canal instrumentation with each instrument was completed when the file reached working length. Patency was confirmed with a size 10 K-file. After using the X2 file, a size 25 K-file did not bind at WL. The X3 file was used, and the canals were finally gauged with a size 30 K-file and binding was confirmed at WL [24]. The specimens were rinsed repeatedly with 4 mL of distilled water following each instrument, using a syringe and 30-G needle, with a total of 12 mL, at a flow rate of approximately 4 mL/min.

Stage B3: XP-endo Finisher file The 17-mm length to WL was pre-marked on the XP-endo Finisher file and verified using the instrument's special plastic tube to adjust the rubber stopper, while the file was cooled down inside the tube with a cold spray (ROEKO Endo-Frost, Coltène/Whaledent, Germany). The specimens were rinsed with 4 mL of distilled water using a syringe and 30-G needle with a flow rate of approximately 4 mL/min. Prior to irrigation, the distilled water was warmed to 37 °C to allow the XP-endo Finisher file to optimally work during the austenite phase [17, 18]. The file was used with an endodontic motor (X-Smart Plus) at 800 rpm and 1 Ncm, according to the manufacturer's instructions, to achieve final canal cleaning. Prior to irrigation, the distilled water was warmed to 37 °C. The XP-endo finisher was then inserted to WL, the canal access cavity was filled with the warmed irrigant and the instrument operated in the canal for 60 s using slow and gentle 7–8-mm lengthwise in-and-out movements, making sure that the file was always within WL. This was followed by a final flush with 2 mL of distilled water with a flow rate of approximately 4 mL/min.

Debris collection

Following each stage, the Eppendorf tube was removed from the vial to be replaced by a new one. The debris adhering to the apical root surface was collected by washing the root surface with 1 ml distilled water into the Eppendorf tube. A new Eppendorf tube was assigned to each tooth and each instrumentation stage. This process resulted in 60 tubes for group A and 90 tubes in group B. The Eppendorf tubes were then stored in an incubator at 70 °C for 5 days to evaporate all moisture content before weighing the dry debris. Three consecutive weights were obtained for each tube, and mean value was calculated and recorded. The weight of the dried debris was calculated by subtracting the weight of the empty tube from the weight of the tube containing the debris.

To avoid variation and eliminate biases, the same trained endodontist operator cleaned, shaped, and irrigated all samples.

Statistical analysis

Normal distribution of the weights was verified using the D'Agostino-Pearson normality test. The amount of extruded debris collected at each stage was summed up to provide the total amount of debris for a given tooth. The mean debris weights were compared between the two groups (A and B) using the *t* test and between the stages within groups by the paired *t* test; the significance level was set at $P < 0.05$. All statistical analyses were performed using SPSS version 18.0 for Windows (SPSS Inc., Chicago, IL). The relative contribution of each stage to the total extruded debris of a given group was calculated and expressed as the percent.

Results

In group A, the mean weight of the extruded debris was 0.772 ± 0. 565 mg and 0.625 ± 0.357 mg during the glide path and SAF preparations, respectively. Stages A1 and A2 contributed 55 and 45% of the total extruded debris, respectively, and there was no significant difference between these two stages ($P < 0.210$) (Fig. 1).

In group B, the mean weight of the collected extruded debris was 0.480 ± 0.401 mg and 1.022 ± 0.636 mg during the glide path and ProTaper Next preparations, respectively, and 0.752 ± 0.672 mg during the supplementary cleaning step with the XP-endo Finisher file. Stages B1–3 contributed 21, 45, and 34% to the total extruded debris, respectively (Fig. 1). There was a significant difference between the debris extrusion during stage B2 compared to stages B1, B2, and B3 ($P = 0.010$ and $P = 0.045$), and there was no significant difference between stages B1 and B3 ($P = 0.083$).

The total mean weight of the extruded debris from group A was 1.397 ± 0.685 mg, while that from group B was 2.254 ± 1.272 mg. The two groups significantly differed from each other ($P = 0.002$). The complete procedure in group B resulted in 62% more extruded debris than the complete procedure in group A. Additionally, there was a significant difference in the amount of extruded debris during the glide path preparation stage between the groups ($P = 0.024$). ProGlider file extruded significantly less debris than the Pre-SAF instrument sequence.

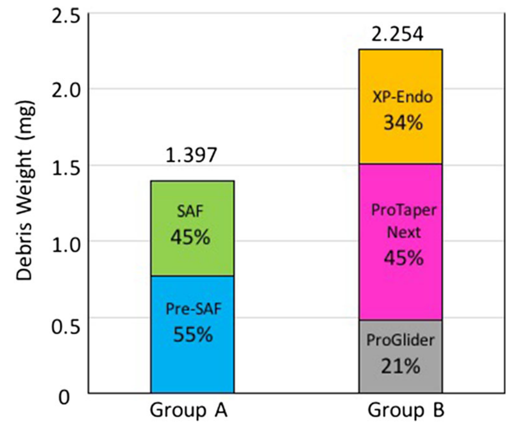

Fig. 1 Apical extrusion of debris by full-sequence SAF system vs. rotary file system supplemented by the XP-endo finisher. Total debris extrusion of group B was 62% higher than that of group A ($p < 0.05$). The relative contribution of each stage in groups A and B is expressed as the percentage of the total debris extrusion for that group

Discussion

This ex vivo study was performed to quantify the amount of debris extruded during cleaning and shaping of oval-shaped root canals, when using two types of instruments specially designed to address the challenge of complex root canal morphologies, such as oval canals: XP-endo Finisher file, which was introduced as a universal supplementary file to be used following *any rotary file system* [25], and the SAF system.

The ProTaper Next system was selected as a representing rotary file system to be used with the new XP-endo Finisher file, as it was previously reported to extrude less debris than other rotary or reciprocating file systems [26–28]. The SAF system was previously reported to have a minimal extrusion of debris compared to rotary and reciprocating systems [15, 16]. Nevertheless, it should be noted that previous "debris extrusion" studies tested the SAF system without the stage of glide path preparation.

Glide path preparation is an essential preliminary stage in many instrumentation protocols. It is aimed to create a smooth radicular tunnel from the coronal orifice of the canal to its physiologic terminus to minimize the incidence of procedural errors and to reduce the amount of apically extruded debris [23]. In the case of the SAF system, this preliminary stage is of most importance, as the SAF is not a penetrating tool and should be allowed to be passively inserted to WL before its activation [29]. Therefore, the essential preliminary stage of glide path preparation should not be ignored when evaluating the total amount of apically extruded debris when using any given procedure, including the SAF. As mentioned above, previous studies evaluating the amount of extruded debris by the SAF system did not address this issue. The glide path preparation was defined in these studies as part of the "specimens' preparation" stage before the experimental stage and prior to the collection of extruded debris [14, 15]. Thus, the experimental design of these studies revealed only limited information about the total amount of extruded debris by the tested procedure [14, 15]. In the present study, the amounts of extruded debris by the ProGlider file (group B) and Pre-SAF instruments (group A) were included in the experimental stage and measured. Each of the glide path files was used as recommended by the manufacturers of the ProTaper Next instruments and SAF, respectively [30, 31].

It should be clarified, that the study was not designed to compare product lines of three different manufacturers, as commonly done. It was designed specifically to test the new technology of the XP-endo Finisher file, which was specially designed to overcome the challenges that rotary files encounter in oval canals, and compare it to an existing technology designed for this purpose, the SAF system.

This was why we preferred not to use one of the Race series of instruments (FKG Dentaire) from the same manufacturer of the XP-endo finisher file, neither did we use EndoActivator system (Dentsply Maillefer), from the manufacturer of the ProTaper Next system. The first was avoided since the XP-endo Finisher file was introduced by its manufacturer as *universal finisher file*, and we choose to use a well-known, widely used and widely researched rotary system for the stage of root canal preparation. The second was avoided since the EndoActivator is a sonic activation device intended solely for fluid activation using a polymer tip, and not a NiTi file intended to mechanically clean the dentin walls [25, 32]. Furthermore, it should be noted, that the EndoActivator is also indicated by its manufacturer (Dentsply Maillefer) to be used following any tapered preparation and not solely after the same manufacturer rotary systems [32].

Distilled water was used as an irrigant in the present study, based on previous work of Bürklein and Schäfer [33], to eliminate the potential interference of mineral residue that may accumulate when sodium hypochlorite solution is dried by evaporation. It should not be taken, by no means, as a recommendation to use distilled water as an irrigant in the clinical situation.

The total debris extrusion in group B was significantly higher than that in group A; therefore, the null hypothesis was rejected. A full-sequence SAF system, including the glide path preparation stage, extruded significantly less debris than a sequence of the ProGlider file, ProTaper Next system, and XP-endo Finisher file, when used in oval canals.

It should be noted that the ProTaper Next system, together with its glide path file, extruded an amount of debris that was similar to that of full-sequence SAF system (Fig. 1). However, final preparation with XP-endo Finisher file contributed additional amount of debris, which made the difference between the groups significant (Fig. 1). Nevertheless, the clinical relevance of the relative difference in the amount of apically extruded debris remains unclear [34, 35].

The fact that glide path preparation with the ProGlider file extruded significantly less debris than the Pre-SAF instruments was not surprising because ProGlider file has an apical size #16 with progressive tapers from 4 to 8% over its length, while Pre-SAF1 and Pre-SAF2 have apical sizes of #15 and #20 and 2 and 4% taper, respectively. It is conceivable that a two-file glide path system with bigger sizes and tapers may extrude more debris. However, this does not mean that the ProGlider can be used as part of the SAF sequence because the SAF lacks any penetration capabilities and requires pre-establishment of a #20/.04 glide path to allow it to passively reach the WL [29, 31].

Several studies have shown that rotary files alone are unable to achieve effective and adequate cleaning of oval-shaped root canals [36–39]. This is the reason why the XP-endo Finisher file was recently introduced, to overcome this limitation of rotary and reciprocating files. The manufacturer of the XP-endo Finisher file specifically indicates that this instrument may be used as a *universal complementary stage* after canal preparation with *any* rotary or reciprocating file system, providing that the size of the final file is #25 or larger [25].

The ProTaper Next system was chosen as a representative, widely researched, rotary file system. The canals were prepared up to ISO size 30, which is similar to that expected in the SAF group, in which final apical size was also expected to be approximately size 30 following preparation with SAF 1.5 [31]. The XP-endo Finisher file was added as a supplementary stage to clean difficult-to-reach areas in oval-shaped canals. Such combined procedure is termed “hybrid technique,” aimed to reduce the shortcomings of individual instruments [40].

A recent study by Leoni et al. [18], evaluated the efficacy of SAF and XP-endo Finisher file on reducing hard-tissue debris accumulated within the isthmus of mandibular first molar mesial root canal system. It showed that the XP-endo Finisher file was associated with significantly less hard-tissue debris accumulation in the isthmus [18]. Nevertheless, its cleaning efficacy in oval-shaped canals has not yet been evaluated, and future studies should be conducted to explore this specific issue. The present study indicates that the XP-endo Finisher file, when used as a supplementary stage in cleaning oval canals, contributes to the extent of apical extrusion of debris.

It is important to emphasize that the results obtained in the present ex vivo study may differ if applied in a clinical situation in which the root apex is surrounded by periapical tissue, which may resist debris extrusion to some extent [14, 15]. Also, the clinical relevance of the relative difference in the amount of apically extruded debris remains unclear. Further attempts should be conducted to identify the best sequence for cleaning and shaping oval-shaped root canals, which may eliminate or minimize the level of debris extrusion.

Conclusions

1. Both instrumentation protocols resulted in apical extrusion of debris from oval-shaped root canals.
2. Each stage of both protocols had its own contribution to the apical extrusion of debris.

3. The sequence of rotary instruments, followed by XP-endo Finisher file extruded significantly more debris than the full SAF sequence.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study, formal consent is not required.

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