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The Effect of Cross-Section of Three Different Files on Apical Debris and Irrigant Solution Extrusion Using Full File Sequences: An In Vitro Study

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Abstract

Objective: The aim of the study was to evaluate the cross-sectional geometry of heat-treated endodontic rotary files upon debris ejection through apex and the quantity of irrigants expelled when employing a complete sequence file system.

Methods: Sixty extracted human maxillary first premolars were included and randomly classified into three categories (n = 20) according to the file employed during the preparation of canal. The groups were Group 1: EdgeFile X7, Group 2: Komet FQ, and Group 3: Fanta AF F One. The modified Myers along with Montgomery experiment protocol was employed to measure the mean weight of upward extruded irrigants and detritus in grams. The comparison of irrigants and debris extrusion was performed utilizing analyses of variances (ANOVA). Significant level has been established at 0.05.

Results: Apical ejection of material was prevalent throughout every one of analyzed files. Quantity of debris extruded during canal shaping did not show any significant variation among the examined files, The Fanta AF F One group exhibited the greatest mean of extrusion irrigant.

Conclusion: Each evaluated endodontic rotary devices produced comparable apical debris ejection among the groups. The Fanta AF F One group extruded the most irrigant.

Keywords: Cross-Section, Instrumentation, Sodium Hypochlorite, Premolar, Flexibility

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Introduction

The eradication of bacteria from root canals becomes crucial for the effective completion of endodontic therapy. Endodontic files and irrigants are employed during chemo-mechanical preparation to eliminate both inorganic and organic tissues that contains microorganisms with metabolites from them within the root canal [1].

Even minimal quantities of apical extrusion could contribute to perioperative inflammatory processes, induce discomfort, and impede recovery. Regardless of whether the preparation reaches the apical endpoint, all instrumentation approaches release debris into the surrounding periradicular tissues [2]. The silent chronic periradicular lesions in infected teeth reflect the delicate balance between the host's defense mechanisms in the surrounding tissues and the aggressive actions of infectious endodontic bacteria. If bacteria are expelled into the tissues surrounding the root, the host encounters a situation during the chemo-mechanical preparation where the exposure to irritants exceeds previous levels [3,4]. However, the amount of debris released varies depending on the instruments used, file designs, and motion kinematics.

The total amount of debris produced following canal straightening has been compared in numerous studies using various file systems and techniques [5,6]. None of the file systems in these experiments demonstrated the ability to perform root canal procedures without causing debris extrusion [7,8]. In contrast to rotary nickel-titanium (NiTi) systems, manual preparation results in greater apical extrusion [9-11].

The EdgeFile X7 Edge Endo; Albuquerque, New Mexico, USA) features a variable helical angle and a consistent taper of 0.04 and 0.06, respectively, with a parabolic cross-section. It is made from fire-treated NiTi alloy, undergoing heating and cooling cycles to enhance its mechanical properties [12]. Conversely, the Fanta AF F-One file is characterized by its unique cross-sectional design, featuring a planar side-cut with two active cutting points and a non-cutting tip. It is manufactured using control memory wire treated with titanium oxide, improving its hardness, flexibility, and resistance to fracture (Shanghai Fanta catalog 2018–2019). The Komet FQ is a rotary endodontic file system manufactured by Komet USA LLC (Rock Hill, South Carolina, USA), developed to provide efficiency, flexibility, and durability through heat treatment.

Its Double-S cross-section and variably tapered core effectively remove apical debris, reducing the time needed for root canal preparation. This instrument's innovative file core offers a variable taper and a large chip space designed for instruments with a 0.06 taper [13]. This technology provides a variety of files that are customizable to specific cases while preserving the natural canal anatomy. The heat-treated NiTi file is less prone to fracture due to its enhanced resistance to cyclic fatigue [14,15].

The present research sought to investigate the impact of three heat-treated endodontic rotary files (EdgeFile X7, Komet FQ, and Fanta AF F One) on the volume of irrigant extruded and the apical extrusion of debris when employing a complete sequence file system. Considering the file's cross-section and design, the null hypothesis posits no significant debris and irrigation extrusion differences among the different file systems. This aligns with the manufacturers' claims that these files have the same taper but differ in cross-section and design.

Material and Methods

Data collection

A total of sixty human maxillary first premolars were recently obtained from various specialized dental offices in Iraq between the end of 2022 until May 2023. We included teeth extracted for orthodontic reasons with no fractures or cracks. The exclusion criteria were teeth with restorations or caries, teeth that had undergone previous endodontic treatment, and teeth with calcification, root resorption, or curved canals. The selection of palatal root canal from teeth with class VI vertucci classification was based on the following specified criteria: patent canal and apical foramen, root length of 15 mm, straight and conical roots with less than 15% curvature, absence of cracks, apical resorption or fractured apex, a mature centrally located apical foramen, and an apical foramen allowing passage of a size 15 K-file tip.

The sample size was determined utilizing G*Power (version 3.1.9.6) with an impact size of 0.4, the level of significant (α) equal 0.05, and a test statistic of 80%. The overall sample size comprised 60 specimens. Ethical approval was secured by the ethical committee at Anbar University, Iraq (Registration no. 163).

Teeth preparation

After meticulous selection, calculus, bone, as well as soft periodontal tissue was excised from the teeth extracted utilizing a cumin scaling. Teeth was immersed in a 6% NaOCl solution for one hour [16].

Each root apex was examined under 20x magnification using a stereomicroscope (MEIJI Techno, Japan) to allow for careful inspection of the roots and apices. After this, a regular saline solution was used to store the samples until needed [17]. The tooth length was marked at 15 mm using a marker pen, and the crowns were removed using a diamond disc with copious water irrigation to facilitate the cutting process. This ensured uniform tooth lengths, eliminated variables, and provided a consistent reference point [18]. The sample length was verified using a digital caliper. Pulpal tissues have been excised with a size 10 spiked broach, and the integrity of the canal along with the exact position of the apical foramen was assessed with K files sizes 10 and 15, advancing the file when it was observable at the foramen at the apical end. 1 mm was deducted off of the root's length to determine the precise working length [17,19].

The sixty extracted human maxillary first premolars were then randomly classified at three categories (n = 20) according to the files utilized for canal preparation. These categories were: Category 1: EdgeFile X7, Category 2: Komet FQ, and Category 3: Fanta AF F One.

Canal preparation

These procedures followed in the research were carried out following each system's manufacturer's instructions. A master apical file (MAF) was utilized in the preparation of each sample canal tip sizing of #25. A disposable 5 mL plastic syringe with an Irriflex irrigation needle (Produits Dentaires SA, Vevey, Switzerland) was used.

The rubber stopper of the files was set to the determined working length (14 mm), and the files were attached to the handpiece. Instrumentation was executed in a crown to down manner via a soft pecking action. Each file was utilized until it became loose, after which 1 mL of distilled water per minute was employed for irrigating the canals using a disposable Irriflex irrigate needle, then passively added through the root canals in both back and forth action, halting 2 mm shorter for apical foramen while avoiding contact with the canal walls. The canals were subsequently recapitulated utilizing K file with a tip size of 15. This identical technique was executed for each consecutive file until the 25/06 file attained its optimal length as well as became loose. The canal was re-irrigated with 1 mL of D.W per minute and reiterated. Each file was sanitized with the gauze along with alcohol following extraction. The X-Smart Plus (Dentsply Sirona, Ballaigues, Switzerland) was employed to utilize the instruments consecutively, adhering to the company's specifications, at a constant speed of 300 rpm and a torque of 2.5 N/cm to standardize the parameters.

- Category 1: Rotary Edge X7 file (Edge Endo; Albuquerque, New Mexico, United States) started with the 17/04 file, followed by 17/06, 20/06, and finished with 25/06.

- Category 2: Rotary Komet FQ file (Komet USA LLC, Rock Hill, South Carolina, USA) started with the 15/03 file, followed by 20/06, and finished with 25/06.

- Category 3: Rotary AF F One file (Fanta Dental; Shanghai, China) started with the 16/04 file, followed by 20/04, and finished with 25/06.

Irrigation protocol

The irrigation protocol for each group utilized a 30-gauge Irriflex irrigating needles (Produits Dentaires SA, Vevey, Switzerland) to deliver an overall of 9 ml of distilled water, comprising 4 ml throughout instruments as well as 3 ml for the last flushing, inserted passively 2 mm from the foramen at the apical end [20]. After instrumentation, 2 ml of distilled water was administered to a root's exterior using a 25-gauge vented needle tip to extract any debris adhering to the root's apical region, and this subsequently transferred to a glass vial for collection. After each file was used, the irrigation procedure was repeated, maintaining a flow rate of 1 ml per minute.

Debris collection

Sixty glass vials with rubber stoppers were employed in the present research to gather the apical extrusion debris and irrigants during instruments. Each vial was labeled according to the file system used for each group. Following the labeling process and prior to instrumentation, the vials' weight was determined using a precise electronic equilibrium with a sensitivity of 0.0001 g. Each vial had been weighed excluding the rubber cap. The methodology for gathering apical extrusion debris has been changed from a prior study [21] and included the following steps:

The glass vials were prepared by removing the vial labels and cleaning any remnants of glue that might have melted and evaporated during the drying process, as this could affect the results; The middle of the rubber cap affixed every vial was punctured with a hot tool [20,22]. The root was inserted during the opening, leaving the inner third visible above the rubber cap. Upon positioning the tooth-cap assembly on the vial, the apical segment from the tooth become suspending within the glass vial, that functioned to be the receptacle for expelled debris as well as irrigants [23], as shown in Figure 1a. To prevent contamination of the glass vial's exterior from coronally extruded debris and irrigants, the vial was covered with a rubber dam secured with dental floss. This contamination could potentially affect the results [23]. The root surface was filled with a flowable composite to improve sealing and prevent the irrigation solution from leaking out of the root canals. To equalize the pressure both within and outside the vial, which could influence the findings, a needle of 25 gauge was introduced through the rubber cap into vial along the root surface of the samples [18], as shown in Figure 1b. Instruments was executed in accordance with the manufacture's guidelines.

Following this, three main groups (n = 20) were randomly selected among the teeth and their vial. The mass of debris extrusion and the amount of irrigant expelled were assessed based

Figure 1. a) The root was punched through the central rubber cap of the vial. **b)** A sealing material was applied around the visible coronal third of the root to prevent debris leakage.

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on the instrumentation technique utilized for the preparation of the palate roots canals in maxillary initial premolars. The same operator performed all weighing and instrumentation procedures to ensure standardization. Each file was disposed of after completing the treatment of a single canal.

Debris collection

After completing the root canal instrumentation, the floss ligation was removed, and the root-cap assembly was separated from the glass vial. Next, to collect any adhered debris, 2 ml of deionized water was applied to the exterior of root apex within the glass vials.

The vial was weighed under the same conditions as during the pre-instrumentation procedure to prevent any errors in the results before the desiccation process for estimating the amount of irrigation extruded.

Desiccation procedure

After two hours of heating at 100°C in a hot air oven, with checks every 30 minutes to ensure dryness, the sample vials were removed [24].

After cooling, the vials were weighed on an electronic balance (Kern ABS 120-4, Germany) with a precision of 0.0001 g, following the same procedure as pre-instrumentation weights to avoid errors. The average of three measurements of weight was computed to ascertain the post-instrumentation weight. While debris weight for every sample has been established by subtracting the pre-weight values from the post-weight of the vials for all sample utilized [25].

Statistical analysis

Utilizing a statistically significant threshold of P = 0.05, the gathered data underwent additional analysis through one-way ANOVA to assess the amount of debris and the volume of irrigant extrusion apical across the various groups.

Results

Table 1 presents the average weight for apical extrusion debris following instrumentation with various Ni-Ti file systems. No significance variations were identified among tested categories having the highest mean recorded in Edge X7 (0.0494 g), while the Komet group (0.0286 g) demonstrated the lowest mean value. The average values for extrusion debris (g) across the various categories are illustrated in a bar chart, as depicted in Figure 2.

Table 1. Mean and standard deviation of the extrusion debris (g) across several categories.

		N	Mean	Standard Deviation	Minimum	Maximum
DEBRIS	g1	20	0.0286	0.0091	0.0126	0.0424
	g2	20	0.0494	0.0561	0.0259	0.2856
	g3	20	0.0331	0.0105	0.0163	0.0560
	Total	60	0.0370	0.0340	0.0126	0.2856
IRRIGATION	g1	20	2.3442	0.4831	1.3206	3.1095
	g2	20	2.5253	0.8973	1.2952	4.3203
	g3	20	3.0183	0.8221	1.5473	4.2554
	Total	60	2.6293	0.7966	1.2952	4.3203

g1: Komet FQ, g2: Edge X7, and g3: Fanta AF F ONE

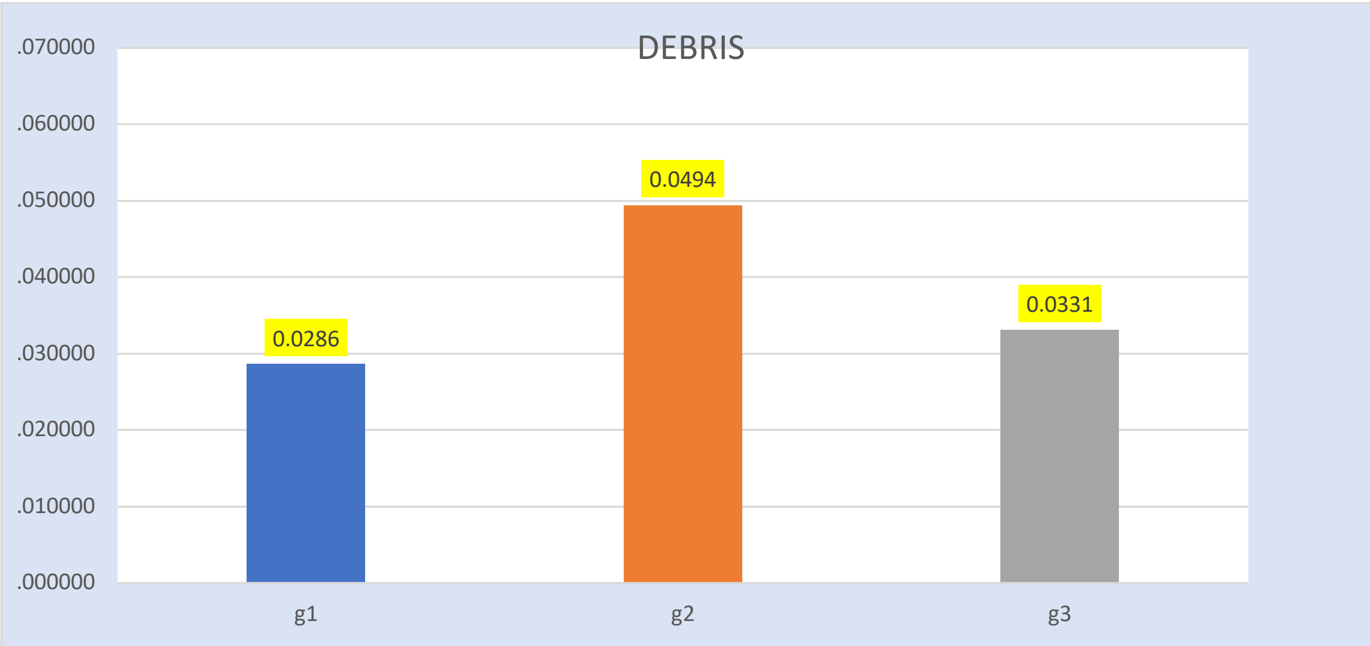

Figure 2. A bar chart illustrating the mean extrusion debris (g) for several categories.

Significant changes in extruded irrigants were noted in the Fanta AF category relative to the other examined categories, as illustrated in Table 2.

The minimal value of extrusion irrigating was seen in the Komet FQ group, as illustrated in Figure 3.

Table 2. Correlation of mean debris weight (g) and mean irrigant volume (mL) among categories.

Dependent Variable			Mean Difference (I-J)	P-value
DEBRIS	g1	g2	-0.0207	0.054
		g3	-0.0044	0.674
	g2	g1	0.0207	0.054
		g3	0.0163	0.128
	g3	g1	0.0044	0.674
		g2	-0.0163	0.128
IRRIGATION	g1	g2	-0.1811	0.452
		g3	-0.6740	0.007
	g2	g1	0.1811	0.452
		g3	-0.4929	0.044
	g3	g1	0.6740	0.007
		g2	0.4929	0.044

g1: Komet FQ, g2: Edge X7, and g3: Fanta AF FONE

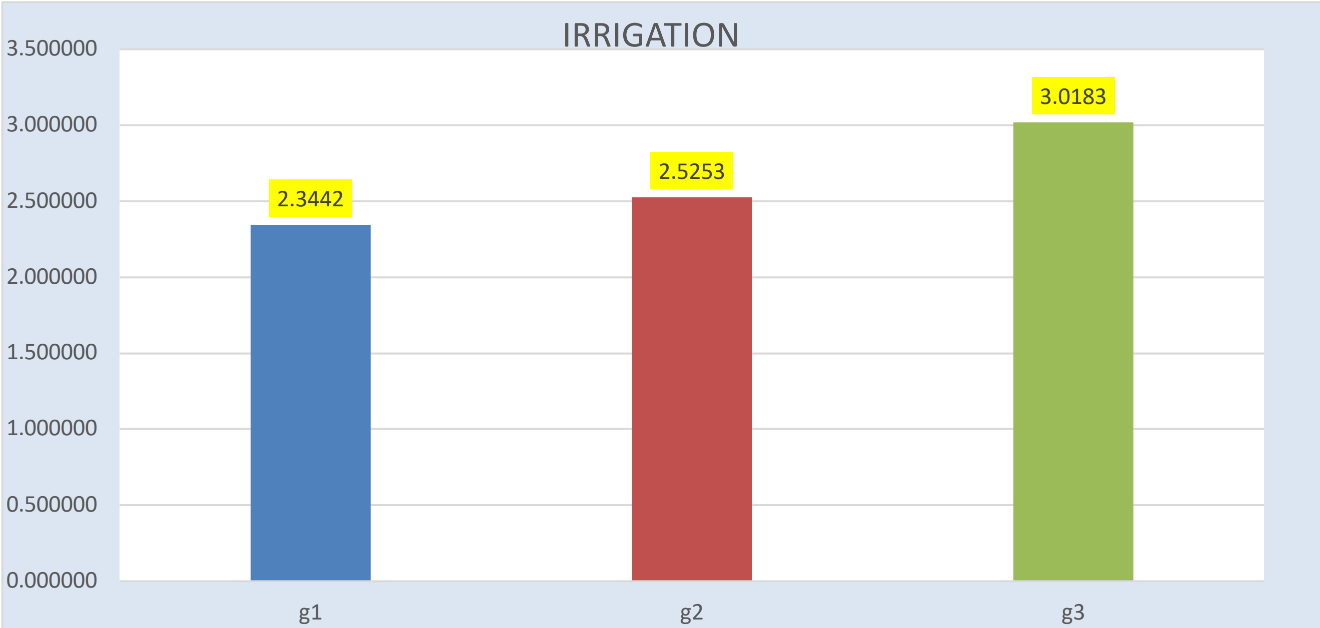

Figure 3. A bar chart showing the average extruded irrigant (ml) in different groups.

Discussion

A primary purpose of roots canals treatment consists of meticulously cleanse the root canal system. During chemo-mechanical preparation, debris including dental chips, necrosis pulpal tissue, germs, and irritants might unintentionally protrude into the periapical tissues, potentially leading to postoperative pain [26]. A variety of factors contributes to the extent of apically extruded of debris, including instrumentation techniques, types and sizes of files, working length, the types of irrigants used, and their activation [27]. The predominant emphasis of research is exclusively on the volume of debris extruded.

The present investigation included both the irrigant and the volume of extrusion debris, as each can contribute to postoperative pain, periapical inflammatory, and perhaps hinder recovery.

The research used the palatal roots for maxillary first premolars because these teeth are commonly extracted for orthodontic purposes. Utilizing one type of tooth can reduce variation between samples. The occurrence of flare-ups after root canals therapy is reported to range from 1.5% to 17%. The expulsion of waste material causes the formation of a complex between antigens and antibodies, resulting in an intense inflammatory response and strong postoperative flare-ups [28].

The extrusion of irrigants, specifically sodium hypochlorite, during root canal procedures can lead to various complications, including discomfort, inflammation, hematoma, ecchymosis, and more severe issues like necrosis and paraesthesia. This phenomenon, occurring during some hours or days post-procedure, is usually referred to as the "interappointment flare-up” [29-31]. This work employed an experimental paradigm, as per Myers and Montgomery, to quantitatively assess the apically extruded of debris with irrigants [21]. In all cases, apical integrity could be preserved with a 10-K file, thereby standardizing the apical diameter. The extrusion of debris escalates with an increase in diameter for the apical integrity. Apical

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extrusion increases even with intact apical constriction [32]. A consistent amount of distilled water was utilized as the irrigate solution in each canal to avert the crystallization of sodium hypochlorite, which could modify the weight of dental debris and jeopardize the findings [33].

Despite the absence of significance variations between tested categories during our investigation, the Edge File X7 category exhibited the highest apically debris extruded. This may be attributed to its parabolic asymmetric triangular cross-section [34]. Hence, altering the shape of the root canal wall using three cutting sites impacts the file's centric ability. Data show that cross-sections with only one cutting edge exhibited a less aggressive mode of action when enlarging canals [35]. There is at least one report [36] that showed a lower percentage of debris associated with Edge File X7 than other files. This discrepancy may be attributed to the type of endodontic movement utilized in their study, which employed reciprocation movement. In contrast, our present study utilized continuous rotational movement, which, when combined with the X7's small parabolic cross-section, results in a screwing effect that may force debris apically.

Regarding the amount of apically extruded irrigants, our study found that the highest degree of irrigant extrusion was recorded in the Fanta AF F One category, with non-significant differences observed between the Komet and Edge files. The design of the Fanta AF F One file, featuring vertical blades, efficiently moves irrigants from the flutes to the relieving area due to its flat-sided design. This design facilitates increased space for the irrigant to advance toward the apical region, possibly resulting in considerable apically extruded from the irrigant.

The limitations for experiment models that may influence the findings encompass the absence of apical backpressure, lack of control over dentin microhardness, sensitive of the balance of analysis, and sample hydrate associated with humidity [18]. The influence of a vital or necrosis pulp, along with the existence of an endodontic lesions, on the apically extruded of debris is still ambiguous.

Conclusion

Examined endodontic rotary files generated apically extruded debris along with irrigants. No substantial variations were seen between the categories for the apical extrusion of debris. Fanta AF F One group documented the maximum volume of extrusion irrigant.

Conflict of interest

The authors report no conflicts of interest.

Author contributions

All authors contributed to designing the study, collecting the data, interpreting the results, writing up the draft of the manuscript, reviewing and finalizing the manuscript.

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