Comparison Of Apical Extrusion Of Debris After Canal Shaping Using Different Rotary Systems: An In-Vitro Study

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ABSTRACT

BACKGROUND :

Chemo-mechanical preparation, a key step in root canal therapy, involves mechanical instrumentation and the use of irrigants. During this process, debris such as pulp tissue, dentin chips, bacteria, and irrigants may be extruded into the periradicular tissues, potentially causing postoperative pain. Accurate working length determination and the choice of instrumentation technique and file system can influence the extent of debris extrusion. Therefore, techniques that minimize apical extrusion are preferred to enhance patient comfort and treatment outcomes.

AIMS AND OBJECTIVES :

The aim of this study was to evaluate the amount of apically extruded debris using different file systems. To compare the amount of apical extrusion of debris after biomechanical preparation using multiple rotating rotary file systems (Hyflex CM and TruNatomy), single rotating rotary file systems (Hyflex EDM and One Shape) and single reciprocating rotary file systems (Reciproc Blue and Wave One Gold

MATERIALS AND METHODS :

Sixty extracted mandibular premolar teeth with single canals and similar lengths were used and divided into six groups – Hyflex CM, TruNatomy, Hyflex EDM, One Shape, Reciproc Blue and Wave One Gold. The initial weight of each Eppendorf tube to be used was calculated using an analytical balance before instrumentation. For all canals apical preparation was done till size 25 except TruNatomy which was prepared till size 26. Distilled water was used as irrigant. After instrumentation, the tubes were then stored for 14 days in an incubator at 37°C. The Eppendorf tubes were weighed again to determine their final weight which contained the extruded debris. The data were statistically analysed using a one-way ANOVA test and Tukey's post hoc test. The level of significance was set at $P<0.05$.

RESULTS :

Among the file systems evaluated, the **TruNatomy (TN)** system resulted in the **lowest amount of apically extruded debris**, with the difference being statistically significant when compared to all other groups. This was followed, in increasing order of extrusion, by **HyFlex CM, OneShape, WaveOne Gold, Reciproc Blue**, and with the **highest amount of debris extrusion observed in the HyFlex EDM** group

CONCLUSION :

Apical debris extrusion is an intrinsic characteristic of all file systems. However, among the systems evaluated in this study, the TruNatomy (TN) file system demonstrated the lowest level of debris extrusion.

CLINICAL RELEVANCE :

Apical debris extrusion can lead to postoperative discomfort, flare-ups, and the potential need for retreatment, all of which may negatively impact the patient's experience and the overall prognosis of endodontic therapy. Ongoing research in this area supports the refinement of clinical protocols, promoting enhanced patient safety and improved treatment outcomes.

KEYWORDS :

Apical debris extrusion(ADE), Rotary files, Hyflex CM(HCM), TruNatomy (TRN), Hyflex EDM(HEDM), One Shape(OS), Reciproc Blue(RCB), Wave One Gold(WOG).

INTRODUCTION

The primary objective of root canal preparation is to eliminate irritants while preserving the health of periapical tissues. Chemo-mechanical preparation, combining mechanical instrumentation and chemical irrigation, is a crucial step in root canal therapy. However, achieving thorough debridement is challenging due to the complex anatomy of the root canal system, which includes isthmuses, accessory canals, fins, and deltas that harbour bacteria, necrotic tissue, and debris. Therefore, chemical irrigation plays a vital role in complementing mechanical cleaning.[1,2]

During instrumentation, pulp tissue, organic and inorganic debris, bacteria and their byproducts, or irrigants may be inadvertently pushed into the periradicular tissues, resulting in apical debris extrusion—a complication that no system can completely prevent. Such extrusion can cause postoperative pain, inflammation, and flare-ups, delaying healing. Nearly half of endodontic patients report postoperative pain, influenced by factors such as age, sex, pulpal status, tooth type, and microbial, chemical, and mechanical conditions.[3-7]

When dentin or pulp tissue—whether contaminated or not—is extruded beyond the apex, it can provoke an immune response. Several studies indicate that antigen-antibody complexes formed from canal antigens can trigger severe inflammation if they enter periapical tissues. Accurate working length determination and careful instrumentation are essential to reduce this risk. The amount of debris extrusion is affected by the instrumentation technique and the type of files used. Nickel–titanium (NiTi) instruments have emerged as preferable options due to advantages like reduced operator fatigue, enhanced safety, and fewer procedural errors.[8-10]

Regardless of technique, debris extrusion remains a leading cause of postoperative discomfort. Thus, methods that minimize extrusion and related symptoms are preferable. Factors affecting debris extrusion can be broadly categorized into physical variables—such as apical anatomy, curvature, root length, and canal complexity—and mechanical variables like the design and movement of instruments. Key instrument characteristics, including cross-sectional design, rake and helical angles, flute spacing, tip configuration, taper, flexibility, alloy composition, and number of files, all influence extrusion levels. The motion kinematics—rotary or reciprocating—also significantly affect debris expulsion, necessitating the evaluation of commonly used systems.[11-13]

Stainless steel hand files, traditionally used for canal preparation, are prone to iatrogenic errors like ledging, zipping, and canal transportation, often resulting in greater apical extrusion. These drawbacks led to the development of advanced NiTi rotary systems. Rotary instruments, in general, have been shown to extrude less debris compared to hand files.[14-15]

Among modern systems, **HyFlex CM** employs a controlled memory alloy offering superior flexibility and fatigue resistance. Its features include a symmetrical cross-section, dual flutes, variable pitch, a non-cutting tip, and a negative rake angle. **TruNatomy**, a more recent innovation, is crafted from thin NiTi wire and designed with a slim core and regressive taper to preserve pericervical dentin while providing effective debridement. It includes shaping files in small, prime, and medium sizes with an off-centered parallelogram cross-section.[16-20]

Single-file systems have gained popularity for their efficient shaping ability, reduced procedure time, and minimized cross-contamination. **HyFlex EDM**, a single-file system, is manufactured using electric discharge machining, giving it a variable cross-section and enhanced fracture resistance. It features a constant 8% apical taper that gradually decreases coronally and a cross-sectional design that transitions from quadratic to trapezoidal to triangular.[21,22]

OneShape, also a single-file rotary system, consists of a 25/.06 NiTi file with three different cross-sections along its length, enhancing its safety, efficiency, and flexibility. **WaveOne Gold** is a reciprocating single-file system made from heat-treated Gold-wire NiTi alloy, offering four sizes and characterized by a parallelogram cross-section, variable taper, and enhanced fatigue resistance. **Reciproc Blue**, an evolution of the Reciproc system, features an S-shaped cross-section and dual cutting edges, with added flexibility from a proprietary blue heat treatment.[23-24]

The impact of motion type on apical extrusion is still debated; while Arslan et al. found less extrusion with reciprocation, Bürklein et al. reported the opposite. Both **WaveOne Gold** and **Reciproc Blue** systems operate in reciprocating motion with alternating clockwise and counterclockwise movements and are intended for single use.[25]

Debris extrusion is inherently multifactorial, and study methodologies vary widely. This study compares the apical debris extrusion produced by multiple rotating systems (**HyFlex CM**, **TruNatomy**), single rotating systems (**HyFlex EDM**, **OneShape**), and single reciprocating systems (**WaveOne Gold**, **Reciproc Blue**) to better understand their clinical performance and effectiveness in minimizing postoperative complications.[17]

METHODOLOGY :

Conventional access cavities were prepared after sectioning the crowns at the cementoenamel junction (CEJ) using a diamond disc attached to a straight handpiece , all while maintaining water cooling.(fig 1) This process yielded specimens measuring 15 mm in length.(fig 2) The WL was calculated by subtracting 1 mm from the initial length for each canal when the file tip was visible from the apical foramen.

60 specimens were randomly divided into 6 experimental groups (n=10). All external tooth surfaces were coated with nail varnish except at the apical foramen. The method used for the collection of apically extruded debris during chemo mechanical preparation was done according to Myer Montgomery method. The Eppendorf tube initial weight was determined in a 10 -3 g precision analytical balance.(fig 5) Three consecutive weights were obtained for each tube, and their mean value was calculated. The lid was perforated with a hot agent to create a hole in the centre of the Eppendorf tube and the root was inserted under pressure through this cover, up to the cementoenamel junction. A 27-gauge needle was also forced alongside the cover to equalize the internal and external air pressure. Then, the tubes were fitted into glass vials. The Eppendorf tube with glass vials were shielded by an aluminium sheet to eliminate bias during chemo mechanical preparation.(fig 4)

MULTIPLE ROTATING ROTARY FILE SYSTEMS(fig 3)

HCM : For the HyFlex CM group, files were operated at 500rpm with 2.5Ncm torque and the instrumentation sequence was as follows: A 25.08 instrument was initially used for coronal preparation, Subsequently, instruments with specifications 20.04, 25.04, 25.06 were used in sequence.

TRN : For the TruNatomy group, the Trunatomy files were used in rotary motion, operating at a speed of 500 rpm with a torque of 1.5 Ncm. The instrumentation sequence began with an orifice modifier (20.08) until reaching half the WL, followed by the use of a glider (17.02), small (20.04), and prime (26.04) instruments, all the way to the WL.

SINGLE ROTATING ROTARY FILE SYSTEMS (fig 3)

HEDM : For the HyFlex EDM group, glide path file (10.05) was used up to the working length operated at 300 rpm with 1.8Ncm torque and then OneFile instrument (25/~, variable taper) was utilized in rotary motion, functioning at a speed of 400 rpm with a torque of 2.5 N·cm up to the working length.

OS : For the One Shape file group, instrumentation was done at 450 rpm with 2.4Ncm with 25.06 file with continuous rotation.

SINGLE RECIPROCATING ROTARY FILE SYSTEMS (fig 3)

WOG : In the WaveOne Gold group, the Primary file (25.07) from the WaveOne Gold system was used in reciprocating motion 150° counterclockwise and 30° clockwise motions, This involved three in-and-out movements (pecks) with a stroke amplitude of 3 mm in the coronal, middle, and apical thirds of the canal, and this motion continued until the WL was reached.

RCB : In the Reciproc Blue group, the R25 instrument (25.08) from the Reciproc Blue system was operated in a slow in-and-out pecking motion. After every 3 pecks, the instrument's flutes were cleaned with gauze, and the canal was irrigated.

During the instrumentation process, the specimens received irrigation with 2 mL of distilled water, administered using a side-vented needle at intervals of every three in-and-out movements or after one-third of the root was instrumented. Following each movement and irrigation cycle, foramen patency was confirmed by using a #15 K-file that extended 1 mm beyond the foramen in all experimental groups .

After instrumentation was completed, the stopper, needle, and tooth were separated from the Eppendorf tube, and the debris adhered to the root surface was collected by washing the root with 1 mL distilled water while in the tube. The tubes were stored in an incubator at 37°C for 14 days to allow the distilled water to evaporate . The Eppendorf tubes containing the extruded debris were then weighed again in the same way to obtain the final mean weights of the tubes.(fig 6) Each tube was weighed in triplicate, and its mean weight value was calculated. The amount of extruded debris was calculated by subtracting the weight of the empty Eppendorf tube from the final weight of the assembly.

Fig 1 : Decoronating tooth with diamond disc

Fig 2: 60 decoronated teeth

Fig 3 : Different File systems used

Fig 4 : Myer Montgomery set up

Fig 5 : Pre weigh of Eppendorf tubes

Fig 6 : Post – weigh of Eppendorf tubes

STATISTICAL ANALYSIS

One-way ANOVA Test followed by Tukey's post hoc test / Kruskal Wallis Test followed by Dunn's post hoc test to compare the mean weight of apical extruded debris between 6 groups.
The level of significance [P-Value] set at $P<0.05$.

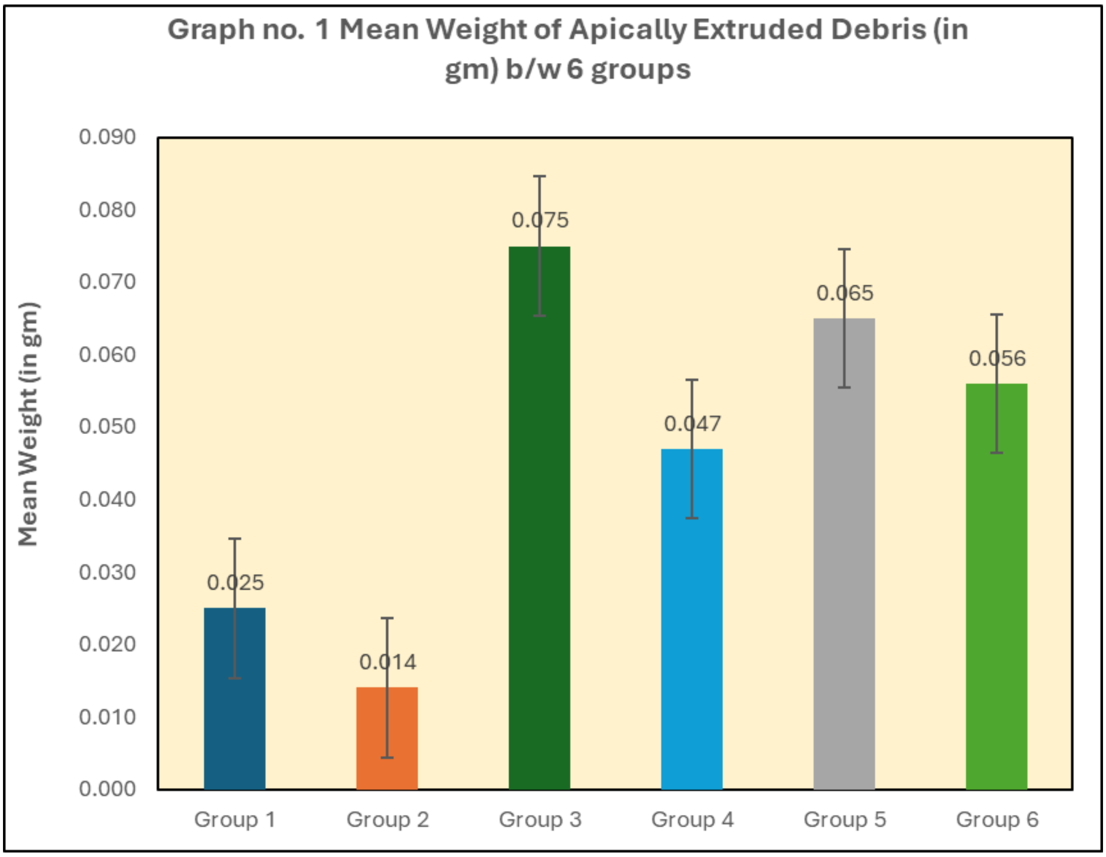
RESULTS

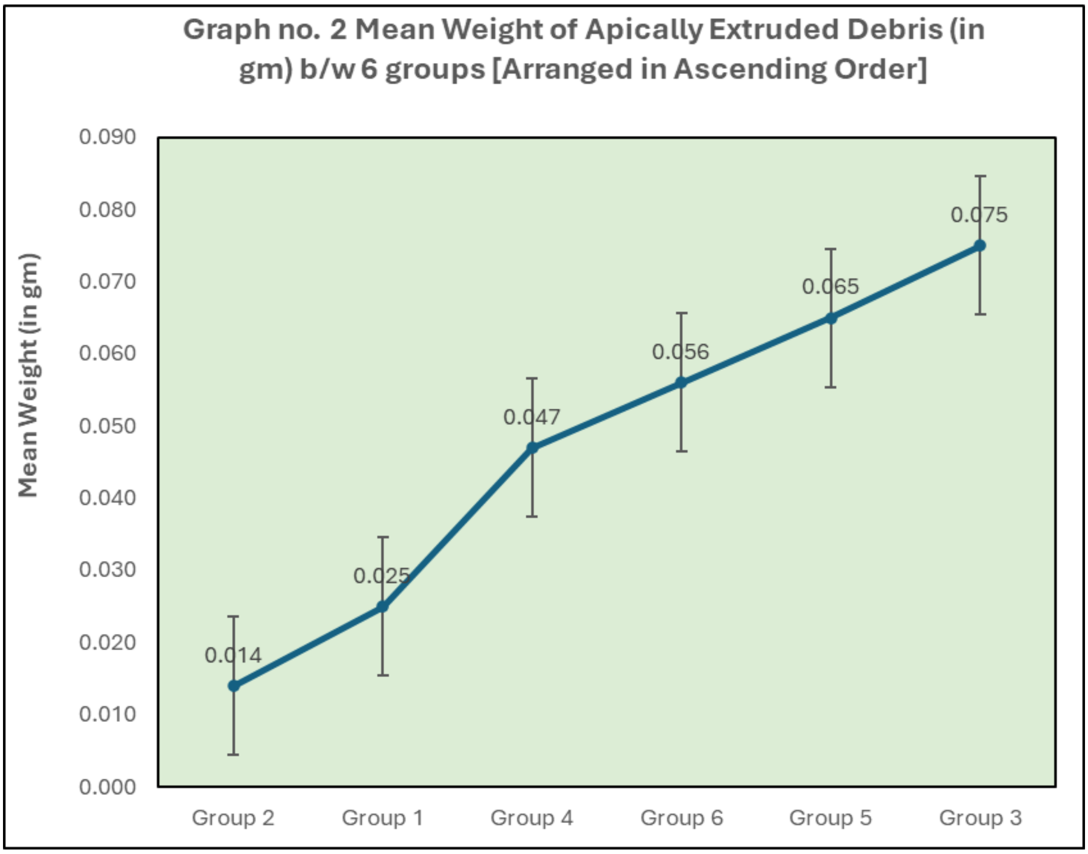
Comparison of mean Weight of Apically Extruded Debris (in gm) b/w 6 groups using One-way ANOVA Test

Groups	N	Mean	SD	Min	Max	p-value
Group 1	10	0.025	0.005	0.02	0.03	<0.001*
Group 2	10	0.014	0.005	0.01	0.02	
Group 3	10	0.075	0.011	0.06	0.09	
Group 4	10	0.047	0.005	0.04	0.05	
Group 5	10	0.065	0.005	0.06	0.07	
Group 6	10	0.056	0.005	0.05	0.06	

Multiple comparison of mean difference in Weight of Apically Extruded Debris b/w groups using Tukey's post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
Group 1	Group 2	0.011	0.003	0.020	0.004*
	Group 3	-0.050	-0.059	-0.042	<0.001*
	Group 4	-0.022	-0.031	-0.014	<0.001*
	Group 5	-0.040	-0.049	-0.032	<0.001*
	Group 6	-0.031	-0.040	-0.023	<0.001*
Group 2	Group 3	-0.061	-0.070	-0.053	<0.001*
	Group 4	-0.033	-0.042	-0.025	<0.001*
	Group 5	-0.051	-0.060	-0.043	<0.001*
	Group 6	-0.042	-0.051	-0.034	<0.001*
Group 3	Group 4	0.028	0.020	0.037	<0.001*
	Group 5	0.010	0.002	0.019	0.01*
	Group 6	0.019	0.011	0.028	<0.001*
Group 4	Group 5	-0.018	-0.027	-0.010	<0.001*
	Group 6	-0.009	-0.018	-0.001	0.03*
Group 5	Group 6	0.009	0.001	0.018	0.03*





DISCUSSION

In an ideal scenario, endodontic procedures would be more straightforward if root canals exhibited a smooth, tapering shape without curvatures or complexities, and the apical foramen was consistently at the radiographic apex. However, the actual root canal anatomy is complex, with curvatures, accessory canals, and deviations. Cleaning and shaping such canals require advanced instruments and meticulous irrigation. Endodontic therapy involves debridement, disinfection, and obturation. The goals of cleaning and shaping are to eliminate infected tissue, facilitate disinfectant penetration, and prepare the canal for obturation.[24,26]

During preparation, dentinal debris, pulp remnants, microbes, and irrigants may extrude apically, causing inflammation, pain, or flare-ups. Seltzer et al. (1968) reported that extruded dentin particles led to inflammatory edema and chronic tissue response. Dentin fragments embedded in granulation tissue were surrounded by inflammatory cells, indicating sustained inflammation and potential persistent apical periodontitis. Seltzer and Naidorf (1985) noted that altered pulp proteins can trigger inflammation, and Naidorf (1985) demonstrated immune responses to canal-derived antigens, leading to antigen-antibody complex formation, membrane disruption, prostaglandin release, and bone resorption.[3,4,27]

Mathiesen (1973) and Perrini and Fonzi (1985) identified mast cells in periapical lesions. Torabinejad et al. (1985) found that these cells release histamine when irritated, contributing to flare-ups. Studies show a positive correlation between debris volume and inflammation severity. The severity of flare-ups depends on microbial virulence and quantity, as well as physical and mechanical factors such as apical constriction size, dentin hardness, tooth position, irrigant volume, file size, motion type, and file design.[28,29]

Even small amounts of virulent debris can provoke significant immune responses. Thus, thorough disinfection before apical instrumentation is vital. Using systems that minimize debris extrusion enhances treatment outcomes. Rotary NiTi files produce less extrusion than hand files due to their continuous motion, as confirmed by Schäfer and Vlassis (2004).[10,30]

This study assessed six rotary systems: Hyflex CM and TruNatomy (multiple rotating), Hyflex EDM and One Shape (single rotating), Reciproc Blue and WaveOne Gold (single reciprocating). These newer systems shape canals using a single file without needing a glide path. Debris extrusion varies by file design and irrigation. Despite controlled instrumentation, some extrusion is inevitable. Influencing factors include patency, foramen size, curvature, working length, instrument design, needle type, insertion depth, and irrigation method. Innovations in instrument design aim to reduce extrusion and related complications.[2]

Studies often use single-rooted teeth due to simpler morphology and standardization benefits. Mandibular premolars with single, straight canals and closed apices were chosen to reduce variability. Teeth were decoronated to standardize working length. These conditions help limit apical pumping action and ensure consistency.[1]

The Myers and Montgomery model was used to collect extruded debris, known for its reproducibility. However, it lacks periapical tissue resistance found in vivo, possibly overestimating extrusion. Tube contamination also poses a limitation. Sodium hypochlorite was excluded due to residual crystals affecting debris weight. Distilled water, free from crystallizing solutes, was used to ensure accurate measurement.[4]

A size #25 file was chosen based on the average apical foramen diameter in mandibular premolars. All systems used this size, except TruNatomy (#26), for consistent canal enlargement. Despite efforts, variations in metallurgy, geometry, and taper among systems remain a limitation. Irrigation used 2 mL of distilled water via side-vented needle after every three strokes or each third of canal instrumentation, as inadequate irrigation can increase extrusion.[17]

HyFlex EDM (HEDM) showed the highest extrusion (mean 0.075). Its unwinding reduces flute depth, limiting debris clearance. Its continuous rotary motion and variable cross-section increase cutting efficiency but restrict debris space. Its 8% taper exceeds WOG's 7%, contributing to more extrusion, consistent with findings by Elaishry M et al.[2]

Reciproc Blue (RCB) had a mean extrusion of 0.065. Its aggressive cutting design and reciprocating motion limit coronal debris transport, increasing extrusion. WaveOne Gold (WOG), with a larger core and shallower flutes, improves coronal debris transport, showing less extrusion (mean 0.056). These results align with studies by Abduljalil M et al.[4]

One Shape (OS) extruded 0.047. Its asymmetrical design, variable pitch, and continuous rotation enhance coronal debris removal. This aligns with Hadi et al., who noted higher extrusion from OS than Hyflex CM, possibly due to its 6% taper versus Hyflex CM's 4%.[31]

Hyflex CM showed 0.025 extrusion. Its lower taper (0.04) and canal-conforming design reduce dentin removal and extrusion. TruNatomy (TRN) had the lowest extrusion (0.014), attributed to its slim core, regressive taper, and conservative shaping approach that preserves anatomy and facilitates debris removal.[32]

A systematic review found cross-sectional design more impactful on extrusion than motion type. Instruments with smaller tapers and less metal mass extrude less debris. No correlation was found between instrument number and extrusion volume, consistent with previous studies. However, variability in methods limits direct comparisons. While in vitro findings offer insights, clinical translation requires in vivo research to address biological complexities not captured in laboratory settings.[33]

CONCLUSION

This study provides a detailed comparative analysis of apical debris extrusion associated with various endodontic rotary and reciprocating file systems. Despite the inherent limitations of an in vitro model, the findings clearly demonstrated that all tested systems—whether employing continuous rotating or reciprocating motion—resulted in some level of apical debris extrusion. The extent of extrusion, however, varied significantly depending on the instrumentation system used.

Among the file systems evaluated, the **TruNatomy (TN)** system resulted in the **lowest amount of apically extruded debris,** with the difference being statistically significant when compared to all other groups. This was followed, in increasing order of extrusion, by **HyFlex CM, OneShape, WaveOne Gold, Reciproc Blue**, and with the **highest amount of debris extrusion observed in the HyFlex EDM** group. The superior performance of TruNatomy in minimizing debris extrusion may be attributed to its conservative design, which aims to preserve dentin and maintain the natural canal anatomy during root canal preparation.

The study also highlights that both the **design features** of the files (such as cross-sectional geometry, taper, and core mass) and their **kinematic motion** (rotary vs. reciprocating) play a critical role in influencing the amount of apically extruded debris. These variables directly impact the efficiency of coronal debris evacuation and the potential for apical compaction.

While these results offer valuable insights into the performance of different systems under controlled laboratory conditions, **further in vivo studies** are warranted to assess the clinical significance of these findings—particularly in terms of postoperative pain, flare-ups, and long-term treatment outcomes.

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