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ORIGINAL RESEARCH

Comparison of apical debris extrusion during root canal preparation in primary molars using different file systems: an in vitro study

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Abstract

This study aimed to compare the amount of debris extrusion of four endodontic systems made of Nickle-Titanium alloy. This in vitro study was done on 80 extracted primary molars. They were selected by cone-beam computed tomography and randomly divided into four groups (n = 20) to be prepared to the apical size of 25 by one of the systems: Reciproc, Protaper Universal, Neolix, or Hyflex CM. Debris was collected into Eppendorf microtubes and placed in an incubator to evaporate the washing solution. Debris was weighed by a digital scale of 0.01 g precision. Data were statistically analysed using SPSS software. Tukey's comparison was used to determine the difference between the four file systems ($\alpha = 0.05$). Debris extrusion after Reciproc preparation (0.00320) was significantly higher than the other ($P < 0.05$), with no significant difference having been observed among the other systems ($P > 0.05$). It can be concluded that all systems under investigation exhibited debris extrusion.

Introduction

The pulp of primary teeth should be conservatively treated as caries removal can eliminate inflammation (1). Pulpectomy in primary teeth mainly aims to remove infected tissue; however, it also extrudes organic debris; hence, root canal treatment's success depends on the method and quality of preparation, washing, disinfection, and root canal filling (2). The fundamental part of root canal treatment is chemomechanical preparation, including mechanical cleaning of the root canal and rinsing. Meanwhile, parts of the necrotic pulp or debris and even the washing solution may penetrate beyond the canal and into the periapical space and cause inflammation and post-treatment pain (3).

Treatment success depends on reducing debris to prevent its movement from the infectious root canal system into the periapical tissues (3). This is equally important in both primary and permanent teeth because primary teeth have a large apical foramen, facilitating the extrusion of intracanal debris, microorganisms and detergents such as sodium hypochlorite and transportation to the periapical tissues (3). Debris extrusion can damage the periapical stem cells and the primary tooth's underlying bud (4–6). Debris extrusion from the root canal occurs in all instrumentation techniques, and no technique is known to prevent it entirely. However, the extent varies widely among different file systems, depending on their design (3,4).

Nickel-titanium (Ni-Ti) rotary instruments have accelerated and facilitated the endodontic treatment of permanent teeth compared with the manual instruments (3). The success of Ni-Ti rotary instruments has been reported in primary teeth and pulpectomy. The ProTaper file rotary system is safe and effective for preparing the molars' canal (7). The Reciproc system is designed to clean and prepare canals with just one file through reciprocating movements. This system's files are made with M-Wire technology, which increases the flexibility and resistance to cyclic fatigue (8). Rotary and reciprocating files reduce the treatment time and preparation errors while increasing endodontic treatments' accuracy (9).

Reciproc and Protaper Universal are two well-known systems; the latter (Protaper Universal) is a multi-sequence rotating system made of conventional Ni-Ti alloy, whereas the Reciproc M-wire system is made by heating the conventional Ni-Ti alloy and has greater flexibility and resistance to cyclic fatigue. Moreover, the nature of the reciprocating movement (150° counterclockwise and then 30° clockwise) releases the file blades from the canal walls and reduces fatigue (10).

The two recently marketed Hyflex CM and Neolix systems are made of CM-Wire. This new alloy is made by heating the conventional Ni-Ti alloy. It is shapeable (due to its controlled memory properties) and more resistant to fatigue and fracture (10). Thus, they can be used to safely and effectively clean and shape the root canal. The Hyflex CM system also has less debris extrusion than the ProTaper system (10). Several studies have investigated the debris extrusion in different systems, namely, Protaper Universal and Reciproc, as the most commonly studied systems; however, systems like Hyflex CM and Neolix have been limitedly evaluated. On the other hand, not many studies have studied the amount of debris extrusion in primary teeth (4,11,12). Based on the limited number of studies concerning debris extrusion in primary teeth (4–7,13), despite the higher risk rate, it presents due to the possibility of damage to teeth buds and the limited number of studies concerning systems like Hyflex CM and Neolix (10), and the present study was designed to compare the amount of debris extrusion among Reciproc, Protaper Universal Neolix, and Hyflex CM systems in primary molars.

Materials and Methods

This experimental cross-sectional in vitro study was performed on 80 freshly extracted human first and second primary molars (10 primary first molars and 10 primary second molars from each quadrant) with mature apex, curvatures of 15–30° (according to Schneider's method), <10 mm radius of curvature (14), a minimum length of 12 mm, non-calcified canals, with no internal and external resorption, and no previous treatment. These criteria were confirmed via proximal and buccal radiographs. The canals were evaluated by using stainless-steel K-files No. 15, and only teeth with apical size matching this file were enrolled (Fig. 1).

The teeth were immersed in distilled water and 0.5% thymol for two days. The roots were cleaned by using a curette and prophylaxis brush with a low rpm (Fig. 1). The pulp remnants were rinsed out with sodium hypochlorite and distilled water, and the residual salts were removed by using distilled water (15). Diamond vertical milling machine #4 (D + Z, Kalletal, Germany) was used to prepare the access cavity. To determine the working length, a stainless-steel K-file No. 10 was inserted into the canal, and once seen at the apical end, and this length was reduced by 0.5 mm to obtain the working length.

The debris extrusion from the apex was measured through the Montgomery method by using Eppendorf microtubes (16). Accordingly, a microtube was inserted in each penicillin vial, and after capping the microtube, a cavity with the approximate size of the root was made, and the root was inserted up to the cementoenamel junction area (Fig. 2). The roots were then sealed in the microtube with cyanoacrylate adhesive to simulate the tooth environment. To increase stability, the microtubes were attached to the vial body with the HydroXtreme silicone molding material (Coltene Whaledent, Altstatten, Switzerland). The air pressure inside and outside the vial was balanced by creating a hole within the molding material via a 7 gauge needle. Before and after the canal preparation, each microtube was rinsed, dried in an incubator, and weighed by using a digital scale with a precision of 0.01 g. The respective number of each sample was written on the microtube cap. A rubber dam was used to prevent the operator's intervention and allow visibility. While weighing, the objects were not handled by hand to preclude the weight of hands debris, epithelial debris and the glove's talcum powder (15). Before preparation, the tooth crown was cut (Fig. 1), so the pulp chamber's occlusogingival height levelled to 1 mm from its bottom. CBCT (NewTom, VGI, Verona, Italy) images were taken to select uniform samples with proper curvature (as close as possible to 20 degrees) and free of internal or external decay and calcified canals based on the researcher's judgment. For better detection of the canals, the teeth were mounted in the CBCT device with upward roots.

All files were used with a 2:1 reduction handpiece and a VDW Silver Reciproc (VDW, Munich, Germany) electric motor at the manufacturers' recommended speed and torque. The volume of irrigation was standardised for each system. Canals were rinsed with 2 mL of distilled water after using each file in rotary systems or after each pecking in Reciproc files. No activation was used for irrigation. The washing needle (25 mm length and 30-gauge tip) was inserted up into the canal until meeting the wall resistance (11). Detailed properties of all systems are summarised in Table 1. The preparation sequence for each file by using Reciproc (VDW, Munich, Germany), Protaper Universal (Dentsply Maillefer, Ballaigus, Switzerland), Neolix (Neolix, Châtres-la-Forêt, France), and HyFlex CM (HyFlex, Coltene) systems was as follows:

Figure 1 (a) Create glide path and negotiation by 15 K-file, (b) Clearing the root surface by periodontal curette and dental explorer, (c) Cut the teeth' crown with a disc.

Figure 2 Model made to collect debris from the apical area. The microtube is attached to the vial's body by the molding material, and the tooth is attached to the microtube by cyanoacrylate.

Reciproc

The samples were prepared by using an R25 file of size 25 at the tip and a convergence rate of 0.06 mm in the first 3 mm of the file with a gentle reciprocating in and out motion as specified by the manufacturer. The file flutes were cleansed after each pecking.

Protaper universal

Protaper Universal files (Dentsply Maillefer, Ballaigus, Switzerland) were used with a gentle in and out motion as specified by the manufacturer in the following sequence: SX file with two-thirds of working length, S1 and S2 files with one millimeter less than the working length, and F1 (Size: 20/Taper: 0.07) and F2 (Size: 25/ Taper:0.08) files the same as the working length. When each file was run to the working length and rotated freely, it was extracted from the canal and moved in a brushing motion away from the furcation area.

Hyflex CM

The canal was opened to make a glide path by using stainless-steel K-file No. 10 and 15 with a gentle in and out motion, a speed of 500 rpm, and a torque of 250 gr/

Table 1 Characteristics and structural information of the studied systems

File type	Cross-section	Cutting edges	Tip	Taper	Radial Land	Technology
Reciproc	S-shaped	2	Noncutting	Fix	Without	M-wiring
Protaper Universal	Convex-Triangular	3	Semi-cutting (shaping files) Noncutting (finishing files)	Variable	Without	Conventional Ni-Ti
Neolix	Non-homothetic rectangular	4	Noncutting	Fix	Without	CM-EDM
Hyflex CM	Triangular	3	Noncutting	Fix	Without	CM

cm as specified by the manufacturer. The sequence of using the files was two-thirds of the working length for the 25/0.08 (Size/Taper) file and the same as the working length for the 25/0.06 (Size/Taper) file. The file was moved in a brushing motion away from the furcation area.

Neolix

According to the manufacturer's instructions, the canal was opened to make a glide path by using stainless-steel K-file No. 10 and 15. Then, file C1 (Size 25/ Taper 0.12) was used to dilate one-third of the coronal canal, and A1 (Size 25/ Taper0.06) was used to clean the middle and apical canal areas. The file was moved in a brushing motion away from the furcation area.

To uniform the conditions, samples in all groups were prepared in the apical area up to size 25 of the used file system. The number of pecking motions during instrumentation was similar for all systems (three times). Each file was used to prepare four canals. After canal preparation, the debris extruded from the bottom of the root was collected in a microtube using a spoon excavator. The tubes were inserted into the penicillin vial. The roots were then rinsed with 1 mL of distilled water to collect the debris attached to the root surface. The contamination on the microtubes' surface was rinsed with alcohol. The tubes were incubated at 60 °C for 72 h to evaporate the distilled water before measuring the debris weight. The amount of debris was calculated by subtracting the final weight of the microtube from its initial weight. Data were statistically analysed using SPSS software (version 24, SPSS Inc., Chicago, IL, USA). One-way ANOVA and Tukey's HSD post hoc test were used to compare the mean weights of samples. Two-way ANOVA was used to determine the effect of two treatment modes (the type of file) and the type of tooth on debris extrusion. Tukey's multiple comparison was used to determine the difference between the four file systems ($\alpha = 0.05$).

Results

The statistical indices of debris extrusion in the four studied groups and four types of teeth (D, E maxilla, and mandible) are displayed in Table 2. According to the two-way ANOVA results, the debris extrusion was not significantly affected by the tooth type ($P = 0.051$). However, it was higher in the mandibular second molars than in other groups (Table 3). However, the type of treatment (the type of file) significantly affected the debris extrusion ($P < 0.001$, Fig. 3). The Bonferroni-paired comparison results revealed that the Reciproc system (VDW, Munich, Germany) had a significantly higher debris extrusion than the three other systems ($P < 0.001$). However, the Protaper Universal system's (Dentsply Maillefer, Ballaigus, Switzerland) debris extrusion was not significantly different from that of the Neolix (Neolix, Châtres-la-Forêt, France) ($P = 1.00$) and Hyflex CM system (HyFlex, Coltene) ($P = 0.18$). Nor was any statistically significant difference between the Neolix and Hyflex CM (HyFlex, Coltene) systems regarding debris extrusion ($P = 0.368$) (Table 4). The highest and lowest debris extrusions were, respectively, observed in the Reciproc system (VDW, Munich, Germany) ($P < 0.05$) and Hyflex CM system (HyFlex, Coltene) ($P < 0.001$). (Table 5).

Discussion

Cleaning and preparation of the root canal are some of the most critical stages of endodontic treatment. Meanwhile, canal preparation is associated with debris extrusion, which can cause post-treatment problems such as pain, inflammation, and patient dissatisfaction with the treatment. It may also necessitate emergency referrals to the dentist due to flare-ups triggered by the imbalance between the host and the invasion of bacteria (3). Therefore, studies on debris extrusion intend to introduce safer methods and instruments with fewer flare-ups.

Several studies have investigated the effect of different types of manual files and Ni-Ti on the extrusion of debris, bacteria, and detergents during root canal treatment in permanent teeth (10,17). This complication is also important in primary teeth because of the adverse effects of necrotic debris extrusion and its detrimental effect on stem cells (5,18). Preservation of the permanent teeth follicle stem cells underneath the primary teeth and the apical papillary mesenchymal stem cells is an important prerequisite for reperfusion and maturation of the root of the underlying permanent tooth (19). Since the primary apical teeth have wider foramen than permanent teeth, the canal material's extrusion into the periapical tissue during root canal treatment occurs more frequently (4). All the currently used methods and instruments have some degrees of debris extrusion, which can be minimised by choosing the most appropriate options. In the

Table 2 The mean debris extrusion weight in the four studied groups and four types of teeth

Tooth type File type	D max	D man	E max	E man
Reciproc	0.0034	0.0026	0.0027	0.0039
Protaper Universal	0.00024	0.0023	0.0023	0.0021
Neolix	0.0022	0.0020	0.0019	0.0027
Hyflex CM	0.0018	0.0018	0.0015	0.0020

Table 3 The mean effect of type of teeth (D, E Maxillary and D, E Mandibular) debris extrusion weight (n = 20 per group)

Tooth type	Mean ± SD	P-value
D max	0.00249 ± 0.00084	0.051
D man	0.00222 ± 0.00067	
E max	0.00214 ± 0.00065	
E man	0.00269 ± 0.00011	

present study, different degrees of debris extrusion were observed in the study groups.

The crown down preparation method provided better access to the apical area, less debris extrusion, and fewer post-treatment problems (20). Souza et al. reported that discounting the apical patency resulted in accumulating the debris and dentin fragments produced during canal preparation into the canal's apical area. This can be prevented by passing a small tipped instrument that does not stick to the canal wall's apical area (usually stainless-steel K-file No. 1) through the apical foramen (21). The instrument size is so important to create minor stimulation in the periradicular tissues when crossing the apical foramen (3). Since patency is frequently performed in clinical conditions, all samples in the present study underwent patency before and during preparation.

According to Parirokh et al., the debris extrusion depended on the type of washing solution, as the sodium hypochlorite concentration and debris extrusion were directly related. They also found that precipitation of sodium hypochlorite crystals affected debris's weight extruded (22). Therefore, like most other studies, distilled water was used as the washing solution (23, 24).

The in vitro model presented by Mayers and Montgomery was used in this study. Despite the simple structure, this model is criticised for reconstructing pulp and

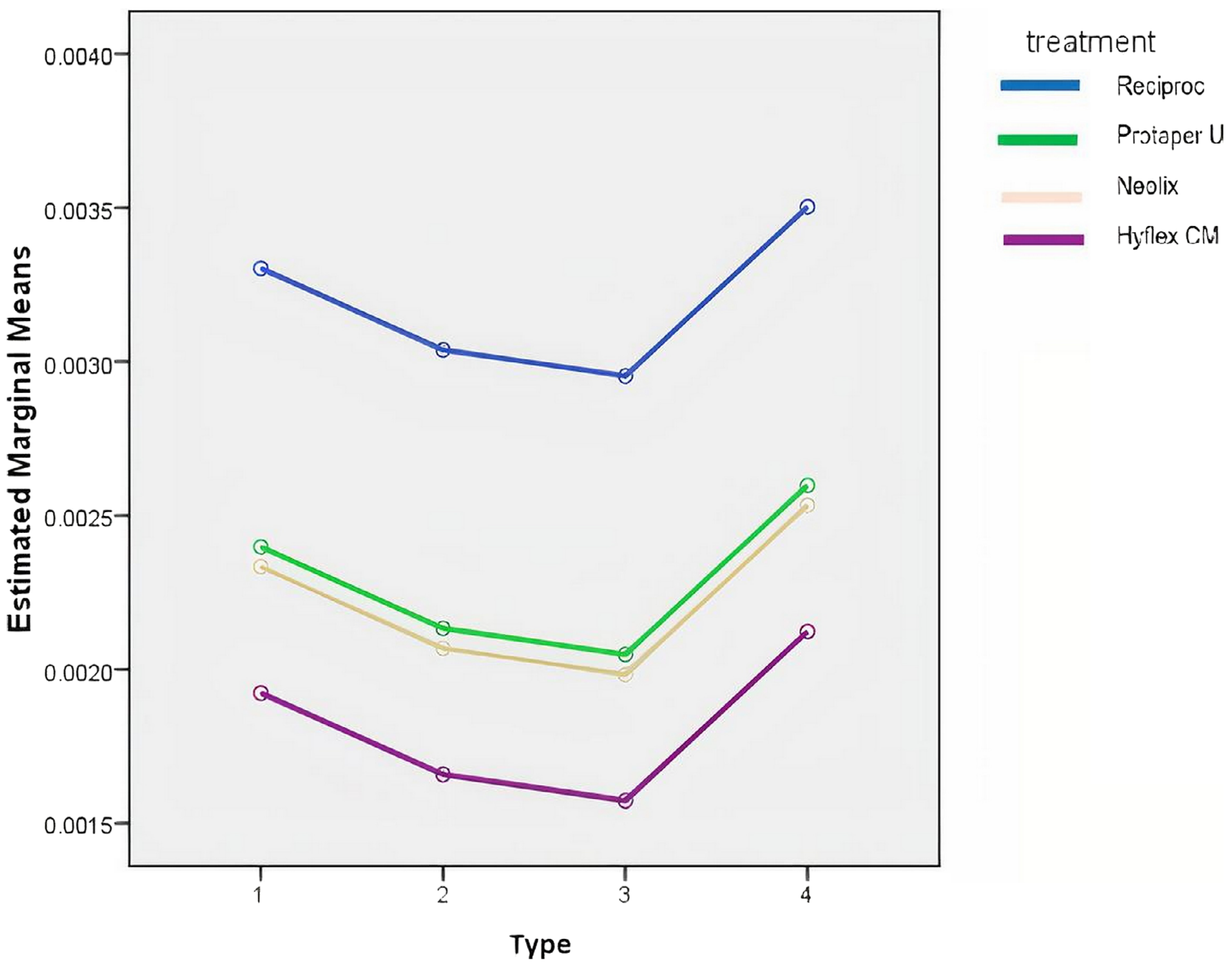

Figure 3 The effect of type of treatment (a type of file) on debris extrusion rate.

Table 4 Pairwise comparison of the debris extrusion weight between the groups

File type (I)	File type (J)	Mean difference (I–J)	Std. Error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
Reciproc	Protaper	0.00905*	0.0002157	0.000	0.000320	0.001490
	Neolix	0.000970*	0.0002157	0.000	0.000385	0.001555
	Hyflex	0.001380*	0.0002157	0.000	0.000795	0.001965
Protaper	Reciproc	0.000905*	0.0002157	0.000	0.001490	0.000320
	Neolix	0.000065	0.0002157	1.000	0.000520	0.000650
	Hyflex	0.000457	0.0002157	0.185	0.000110	0.001060
Neolix	Reciproc	0.000970*	0.0002157	0.000	0.001555	0.000385
	Protaper	0.000065	0.0002157	1.000	0.000650	0.000520
	Hyflex	0.000410	0.0002157	0.368	0.000175	0.000995
Hyflex	Reciproc	0.001380*	0.0002157	0.000	0.001965	0.000795
	Protaper	0.000475	0.0002157	0.185	0.001060	0.000110
	Neolix	0.000410	0.0002157	0.368	0.000996	0.000175

*Indicates significant difference.

Table 5 Mean debris extrusion weight in the different studied system (*n* = 20 per group)

File type	Min	Max	Mean	SD
Reciproc	0.0026	0.0039	0.0032[a]	0.00113
Protaper Universal	0.0021	0.0024	0.0022[b]	0.00047
Neolix	0.0019	0.0027	0.0022[b]	0.00046
Hyflex CM	0.0015	0.0020	0.0018[b]	0.00046

Different letters indicate a statistically significant difference ($P = 0.05$).

pressure conditions created by the apex periapical tissues. In this model, the tooth apex is suspended in the air, so there is no barrier to the extrusion of debris and washing solution (16). Hachmeister et al. suggested using floral foam to simulate the pressure of apex peripheral tissues. However, the problem is the absorption of debris and washing solution by the foam (25).

Mitchell et al. inserted the teeth into agarose gel to simulate periapical tissues and the resulting stress. When removing the sodium hypochlorite washing solution, the gel turns purple. The discoloration indicates a washing solution's extrusion determined by imaging and analysis (26). However, this method's drawbacks are the gel's uniform concentration, which does not simulate a lesion or periapical tissue (3). Moreover, as the pH changes, the discolored area tends to expand over time. Besides, measuring visual changes such as discoloration requires proprietary indices. Due to these methods' pitfalls and difficulties, the classical Mayers and Montgomery's method was used in this study (16). To prevent debris contamination with hand oil and air humidity during and after canal preparation, powder-free gloves were used throughout the study, and the samples' dryness was ensured. Nevertheless, no method ensures heating all samples to the same extent as evaporating the washing solution (3).

Studies showed that preparation at the apical foramen level yielded more debris extrusion than preparation 1 mm less than that. Studies have also determined the working length to be 1 mm shorter than the apical foramen level (16,27), as done in the present study. Only a few studies have compared the debris extrusion in different primary teeth systems. Tinaz et al. showed that increasing the apical diameter leads to higher debris extrusion (28). Considering the root's physiological decay in primary teeth compared with permanent teeth, the debris extrusion during canal preparation in primary teeth is much higher (6).

In the present study, the Reciproc system (VDW, Munich, Germany) had a higher debris extrusion than other groups, which was consistent with some previous studies' results (10,11). This can be due to the s-shaped cross section of the Reciproc file and its sharp blades (11), which gives it a higher cutting capacity to remove more of the dentinal walls within the canal and thus produce more debris. Additionally, the nature of reciprocation results in more debris extruding from the apical foramen (11). On the other side, an orifice shaper in the Protaper Universal System (SX file) improved the canal cleaning by the crown down method. Therefore, more debris is extruded from the coronal area. In contrast, Silva et al. showed a lower debris extrusion in the Reciproc system than Protaper Universal, due to the reciprocation movement, which could better control the debris extrusion from the apical area (24). Different findings might be attributed to the different types of studied teeth and sample selection methods. A study on primary teeth revealed a similar debris extrusion in Reciproc and Protaper systems (13). This might be due to the different types of studied primary teeth (milk canine) and the test conditions (incubation at 37°C for 15 days) compared with the present study.

The Protaper Universal (Dentsply Maillefer, Ballaigus, Switzerland) and Neolix (Neolix, Châtres-la-Forêt, France) systems were not significantly different in terms of debris extrusion. The A1 file in the Neolix system (Neolix, Châtres-la-Forêt, France) has an abrasive surface and a non-homothetic and square cross section, whereas the Protaper Universal files system has a convex and triangular cross-section (29). According to Silva et al., the Protaper Universal system's multi-sequence nature and several file insertions for washing the canal produced more debris than single-sequence systems (24). Therefore, the simultaneity of cutting and multi-sequence characteristics could result in the similarity of debris extrusion of the Protaper Universal (Dentsply Maillefer, Ballaigus, Switzerland) and Neolix (Neolix, Châtres-la-Forêt, France) systems. The Hyflex CM system (HyFlex, Coltene) had a lower debris extrusion than others, which was only significant compared with the Reciproc system (VDW, Munich, Germany). Investigating the permanent teeth, Capar et al. noted that the debris extrusion was not significantly different between Protaper Universal (Dentsply Maillefer, Ballaigus, Switzerland) and Hyflex (HyFlex, Coltene) systems (12).

Within the limits of the present in vitro study, it can be concluded that all the rotary systems used during root canal treatment reveal apical debris extrusion. The absolute amount of debris extrusion can be affected by the employed preparation technique. It was also found that the crown down preparation technique was more effective in multi-sequence systems with an orifice shaper (SX in Universal Protaper system(Dentsply Maillefer, Ballaigus, Switzerland)) than the single-sequence systems with reciprocating movement (Reciproc system (VDW, Munich, Germany) in this study). The coronal area's debris extrusion was lower than that from the apical area, indicating that the specifically designated orifice shaper helps efficient extrusion of the debris at the beginning of the treatment from the coronal area, which further reduces the debris extrusion from the apical foramen. Further in vivo studies are required to evaluate post-instrumentation pain with these instrumentation systems.

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Author contributions

The study was conceived and designed by DM, RH, NBN and, MB. MM and RF did the literature review. DM, RH, and MM clinically carried out the experiments. RH and MM did the statistical analyses. RH, NBN, RF and, MB was prepared the manuscript. The final manuscript was reviewed and approved by all authors.

Disclosure statement

None to declare.

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