Revista Odontológica Mexicana
Órgano Oficial de la Facultad
de Odontología UNAM

Original research

Comparing XP-Endo® Finisher versus Passive Ultrasonic Irrigation in the Removal of Dentin Sludge

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Received: 26 June 2023
Accepted: 11 September 2024

Cite as:
Pérez-Vázquez EC, Barbosa-Monroy LF, Becerril-Vega TM, Garzón-Trinidad JA. Comparación de XP-Endo® Finisher *versus* irrigación ultrasónica pasiva en la eliminación de lodillo dentinario [Comparing XP-Endo® Finisher versus Passive Ultrasonic Irrigation in the Removal of Dentine Sludge]. *Rev Odont Mex*. 2024; 28(4): 34-43. DOI: 10.22201/fo.1870199xp.2024.28.4.86097

ABSTRACT

Introduction: Root canal treatment focuses on removing pulp tissue and biofilm; however, the complexity of the canal system, the presence of dentin sludge, and limitations in instrument design sometimes lead to failure of the procedure. Currently, intracanal irrigation plays a fundamental role in the penetration of difficult-to-access spaces, and different protocols have been developed to optimize the results. **Objective:** To compare XP-Endo® Finisher versus passive ultrasonic irrigation using EDTA as the final irrigation protocol to remove dentin sludge derived from root canal treatment. **Material and methods:** *In vitro* study on 32 lower first molars, the mesial roots were shaped with the Waveone Gold 0.25/07 system (Dentsply®), and irrigation was with 5.25% NaOCl. For the final irrigation protocol, the teeth were randomly divided into four groups: Group 1; without final irrigation. Group 2; irrigation with EDTA without activation. Group 3; irrigation with EDTA activated with ultrasound. Group 4; irrigation with EDTA activated with XP-Endo® Finisher. The instrumented roots were divided longitudinally to observe them through the scanning microscope, and photomicrographs were taken of the dentinal tubules, which were quantified using a scale of three scores, and a new approach of counting dentinal tubules. Both methods were subjected to a statistical analysis of Chi-square (X2). **Results:** As compared to conventional irrigation, XP-Endo® Finisher showed significant differences in the elimination of the dentinal slime, appreciating a greater number of open dentinal tubules (P<0.05). Regarding the counting methods, only one showed significant differences for XP-Endo® Finisher in the three thirds. **Conclusions:** None of the methods was able to eliminate the dentin slough layer, however, XP-Endo® Finisher showed greater efficacy in the apical third.

Keywords: Dentin sludge, XP-Endo® Finisher, ultrasound, dentin tubules, EDTA.

INTRODUCTION

The root canal system is very complex in each tooth, with anatomical irregularities included such as accessory, lateral, isthmus, and apical delta canals, which together with microorganisms are vectors to generate pulp pathology. During instrumentation, the aim is to disorganize the *biofilm*, eliminate the remains of organic tissue inside the canals, and dislodge them through irrigation. However, the accumulation of debris and the formation of the dentin slime layer also contribute to the retention of tissue and bacteria, which together with the non-instrumented areas represent potential sources of reinfection that jeopardize the success of treatment[1].

Irrigation with an effective antimicrobial agent produces the physical removal of bacteria and debris from the preparation; in addition, from the chemical point of view, irrigants maximize root canal disinfection, and facilitate the dilution of organic tissues. The most outstanding irrigant substance is sodium hypochlorite, an excellent antibacterial, capable of dissolving vital and necrotic pulp tissue, as well as organic components of dentin and biofilms[2]. Its speed and depth of action depend on the concentration and temperature. However, its action does not affect inorganic matter, creating a low impact on the dentin sludge; hence, the need for its association with other chelating agents, such as ethylenediaminetetraacetic acid (EDTA), which eliminates the final residues and increases the permeability of dentin, improving the sealing of accessory canals and dentin tubules during obturation[3].

Activation systems to remove *detritus* have provided better results in the apical third of root canals, compared to conventional syringe and needle irrigation[4], because the latter distributes the solution no further than 0-1.1 mm, resulting in inadequate and incomplete cleaning for the complex anatomy of the root canal system[5]. One of the main activation systems is passive ultrasonic irrigation, described by Weller *et al.*[6], consisting of the transmission of acoustic energy from an oscillating file, or a smooth wire, to an irrigant in the root canal. Cavitation can disrupt and disintegrate the endodontic biofilm, decreasing planktonic bacteria, due to the formation of microscopic bubbles in the irrigant that collapse and burst[7].

The XP-Endo® Finisher system of the FKG Swiss endo brand, based on nickel-titanium with a patented MaxWire alloy (Martensite, Austenite, FleX electropolish), reacts at different temperature levels[8]. When cooled, it is in the martensite phase presenting a straight shape; when heated with body temperature it changes to an austenite phase, presenting a C shape in the last third. This property facilitates the final cleaning in root canal treatments[9].

The file has a small core with an ISO of 25 diameters and zero taper[5], so it was designed to be used in canals instrumented with at least the same caliber[10]. It adapts along the entire canal wall, without weakening the tooth structure, as it does not cut dentin[11], allowing better management in complex morphologies[10], particularly in curved and narrow canals. During activation, the irrigant solution is agitated by a coronal-apical movement inside the canal. The instrument can expand up to 6 mm in diameter, ensuring the flow of the irrigant along the entire canal wall.

MATERIAL AND METHODS

An *in vitro* study was performed using 32 mesial roots of extracted lower molars, which were to have divergent roots. At the beginning the teeth were photographed; subsequently, initial radiographs were taken to observe the anatomy and permeability of the canals. Before the removal of the clinical crown, the accesses were made with an FG-6 ssw® bur, and rectified with Dentsply Endo Z®. Upon completion, the root portion was divided with a low-speed carbide disc, preserving only the mesial root, whose standard apico-coronal length was 15 mm, corroborated with a Planmeca ProSensor® HD radiovisiograph, and a Dentsply® Sirona ISO 15 type K Flexofile file through labio-lingual and mesio-distal imaging. The apex was sealed with nail varnish to prevent detritus or irrigant from exiting through it, the roots were mounted on a heavy silicone base to facilitate manipulation. Root canal preparation was started with an ISO 15 type K Flexofile Densply® Sirona file, and was used to ensure patency of the canal after the rotary file. Biomechanical preparation was performed with an X-Smart® Plus motor, and the WaveOne® Gold (Primary 25/.07) system, both from Dentsply® Sirona. Constant irrigation was maintained during instrumentation, using 5 mL of 5.25% sodium hypochlorite with a hypodermic syringe, and a 27Ga Endo-Eze™ needle from Ultradent® Products, Inc. Finally, the roots were irrigated with 5 mL of physiological solution. The roots were then randomly divided to receive the different irrigation protocols.

Positive control: 2 roots to which no final irrigation protocol was applied were selected to observe the accumulation of dentin mud on the canal walls.

I. Negative control: Consisting of 10 roots, which were irrigated with 5 mL of MD-Cleanser (EDTA Solution MetaBiomed®) at 17% for 60 seconds, placing the needle 1 mm above the working length, without additional activation of the irrigant. Subsequently, a wash was performed with 3 mL of saline solution to prevent the effects of EDTA, followed by a discharge of 1 mL of 5.25% sodium hypochlorite, and a final wash with 3 mL of saline solution. Finally, the canals were dried with sterile paper tips.

II. Experimental group 1: 10 roots were included to be irrigated with 5 mL of MD-Cleanser (EDTA Solution MetaBiomed®), 17% activated with the XP-Endo® Finisher system for 60 seconds, at a speed of 800 rpm and a torque of 1 Ncm. According to the manufacturer's instructions, the XP-Endo® Finisher file was placed in the contra-angle handpiece, the working length was set using the marked millimeters plastic tube included in the blister pack, then it was cooled using Endo ICE spray (Hygienic®, Coltene), to keep the file straight (austenitic phase) since the tip has a C shape (martensitic phase). Once the file is straight, it is removed from the tube to introduce it into the canal. 0.5 mL of irrigant was placed inside the canal, the file was inserted in the canal, and the rotation began making longitudinal movements with an amplitude of 7-8 mm in a smooth way, leaning on the walls, the irrigation was kept constant for 60 seconds with 3.5 mL of EDTA at 17%. At the end, the XP-Endo® Finisher file was removed from the canal while the rotation continued (Figure 1).

III. Experimental group 2: 10 roots were selected to be irrigated with 5 mL of MD-Cleanser (EDTA Solution MetaBiomed®), 17% activated with ultrasound DTE-D5®, E14 tip, using the Endo function speed level 3 for 60 seconds, following the sequence proposed by De-Deus, *et al*.[11]: Then 0.5 mL of irrigant was placed inside the canal, the ultrasound tip was positioned 2 mm above the working length, and three activation cycles of 20 seconds each were performed. Between each interval a replacement was made with 1.5 mL of EDTA at 17%, completing 5 mL. Finally, a wash was performed with 3 mL of saline solution, followed by a discharge of 1 mL of 5.25% sodium hypochlorite and a last wash with 3 mL of saline solution, drying the ducts with sterile paper tips.

At the end of the irrigation protocol, and to observe and quantify the dentinal tubules using the scanning microscope, the samples were divided longitudinally with a low-speed diamond disc. The cut was made on the vestibular and lingual sides of each root before reaching the root canal. The segments were then separated with the help of a chisel, preserving the root portion

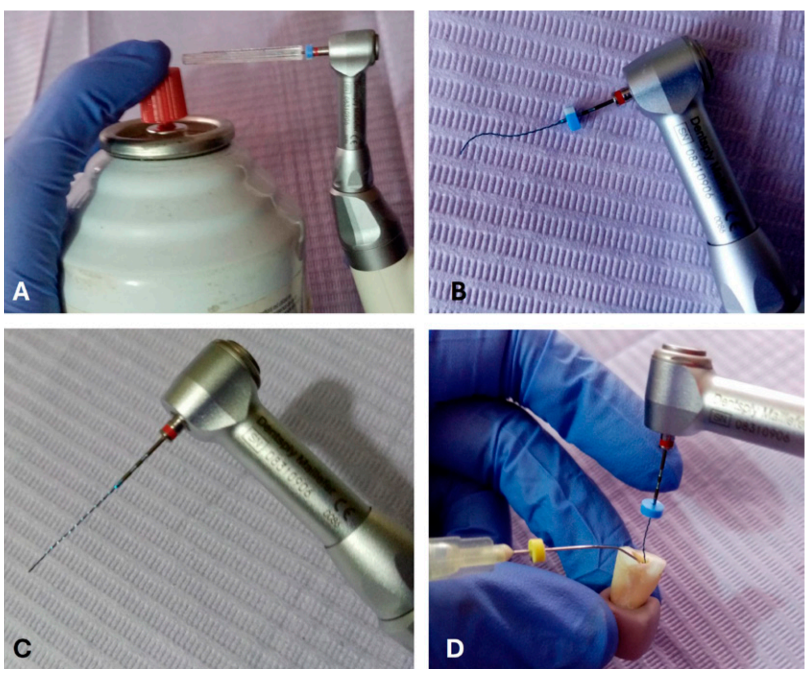

Figure 1. Preparation of the file. A. Cooling of the file with Endo ICE Spray (Hygienic). B. File in the austenitic phase. C. File in the martensitic phase. D. Use of the file.

with the greatest structure. Two marks were made every 5 mm along the instrumented canal, delimiting the cervical, middle, and apical third.

The samples without final irrigation protocol Positive control (C+) showed a dense smear layer on the canal wall in all three thirds (Figure 2. A, E, I.). In the cervical third, the three groups: conventional irrigation (C-), activation with XP-Endo® Finisher (E1), and ultrasound (E2) showed significant differences compared to the positive control group (C+). Likewise, greater removal of the dentin sludge was observed in this third, compared to the middle and apical thirds (Figure 2). In the middle third, a greater opening of the dentinal tubules is observed with the XP-Endo® Finisher system (Figure 2. G), in some samples that received EDTA activation with ultrasound, the modified canal wall is visualized (Figure 2. H). Finally, the differences in the apical third became more significant; the samples that were activated with the XP-Endo® Finisher system presented more open tubuli (Figure 2. K), while in the conventional irrigation and ultrasound activation groups a greater amount of dentin sludge and obliterated tubuli were observed (Figure 2. J-L).

To count the presence or absence of dentin mud along the root canal surface, two procedures were used to evaluate the dentin tubules by photomicrographs; the first one was proposed by Torabinejad, *et al.*[12] with the following parameters:

- Score 1 (no dentin sludge). There is no presence of a smear layer on the surface of the root canals, the tubuli are clean and open.
- Score 2 (moderate dentin sludge). No dentin mud on the canal surface, and dentin tubuli have *debris* remnants.
- Score 3 (with dentin sludge). Dentin sludge completely covers the dentin tubuli

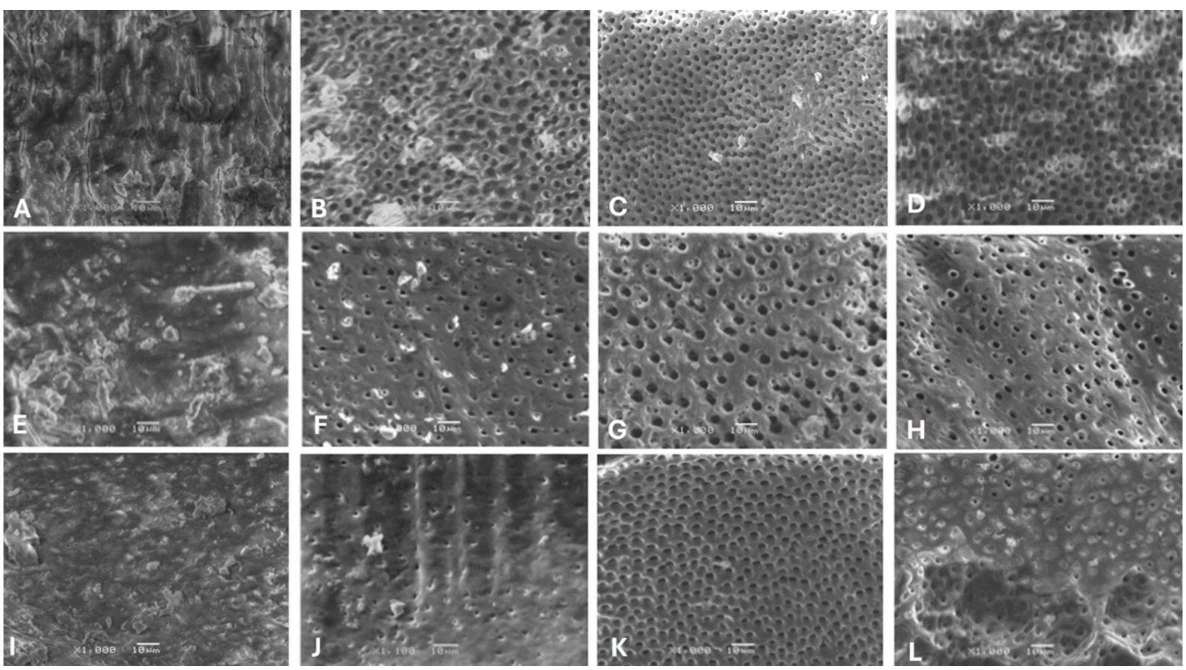

Figure 2. Photomicrographs. **Cervical third:** A. Without a final irrigation protocol. B. EDTA 60s irrigation without activation. C. EDTA 60s irrigation with XP-Endo activation® Finisher. D. EDTA irrigation 60s activation ultrasound. **Middle third:** E. No final irrigation protocol. F. EDTA 60s irrigation without activation. G. EDTA 60s irrigation with XP-Endo activation® Finisher. H. EDTA irrigation 60s activation ultrasound. **Apical third:** I. No final irrigation protocol. J. EDTA 60s irrigation without activation. K. EDTA 60s irrigation with XP-Endo activation® Finisher. L. EDTA irrigation 60s activation ultrasound.

The second observation is a statement derived from this research in search of a more objective method to assess the presence of dentin sludge, for which the photomicrographs were analyzed with the public domain digital image processing program ImageJ (National Institutes of Health, NIH), which allowed the counting of open dentin tubules. The images were calibrated within the program, taking the 10 µm scale as a reference. From the 96 captures, a representative image of each third was selected, and a zoom was performed to determine the area of the dentinal tubule: the mean obtained in the zoom of the tubules was 2.5 µm for each third. This parameter served as a reference for the program to count only the tubules that have an equal or larger area, discarding those of smaller size, assuming that they contain dentin sludge. The particle count was performed by displaying a contrasted image in red showing the tubules that complied within the established parameter. This process was performed in each of the photomicrographs (Figure 3).

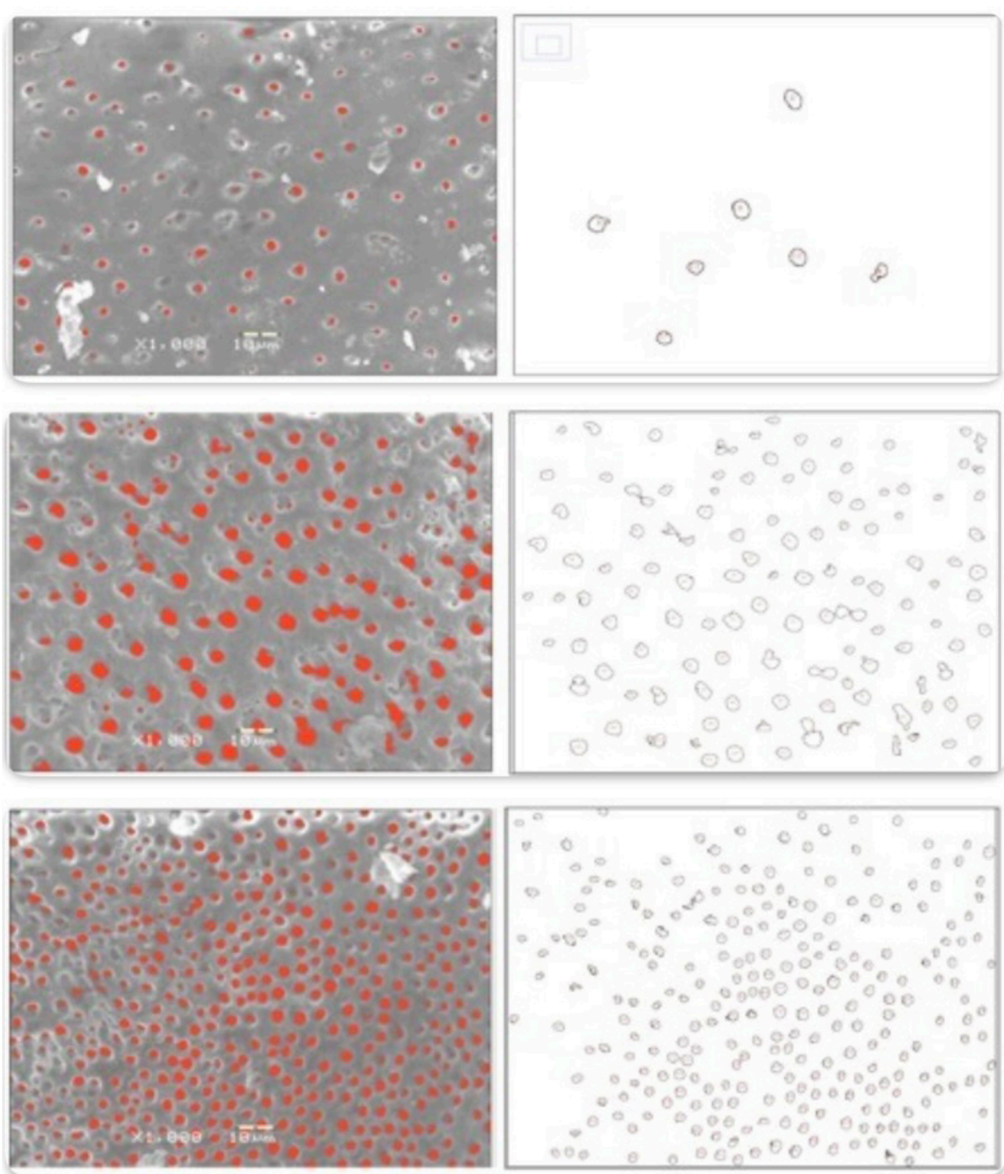

Figure 3. Examples of dentinal tubule counts using ImageJ software.

RESULTS

The figures obtained in both systems were tabulated in Microsoft Excel sheets, and the Chi-square statistical test (X^2) was applied for evaluation. The results show significant differences between the control group and the three evaluated methods. Open dentinal tubules were observed ($P<0.05$). However, none of the methods eliminated the remaining smear layer (Tables 1 and 2). The statistical analysis showed a discrepancy in the Torabinejad scale in the middle third with the ImageJ program (Tables 1 and 2). The same application showed significant differences for XP-Endo® Finisher in the three thirds.

Table 1.
Torabinejad Scale

Code	Groups			Total	Analysis	
	edta	XP-Endo® Finisher	Ultra Sound		(X^2) Table	(X^2) Calculated
Cervical Third						
1	3	9	3	15	9.487	13.800
2	3	1	6	10		
3	4	0	1	5		
Total	10	10	10	30		
Middle Third						
1	1	5	1	7	9.487	6.771
2	3	3	4	10		
3	6	2	5	13		
Total	10	10	10	30		
Apical third						
1	0	4	0	4	9.487	10.583
2	2	3	3	8		
3	8	3	7	18		
Total	10	10	10	30		

Table 2.
ImageJ Scale

Sample	Groups	Total	Analysis			
	EDTA	XP-Endo® Finisher	Ultra Sound		(X^2) Table	(X^2) Calculated
Cervical Third						
A	133	120	236	489	28.869	813.648
B	273	150	131	554		
C	279	391	181	851		
D	248	248	178	674		
E	100	253	124	477		
F	76	238	178	492		
G	66	236	36	338		

Table 2. Continued

Sample	Groups	Total	Analysis			
	EDTA	XP-Endo® Finisher	Ultra Sound		(X^2) Table	(X^2) Calculated
Cervical Third						
H	256	119	44	419	28.869	813.648
I	185	288	192	665		
J	49	406	236	691		
Total	1665	2449	1536	5650		
Middle Third						
A	23	128	60	211	28.869	908.619
B	90	206	105	401		
C	104	319	82	505		
D	17	358	2	377		
E	139	226	129	494		
F	39	24	196	259		
G	7	139	92	238		
H	25	132	213	370		
I	16	302	217	535		
J	10	59	81	150		
Total	470	1893	1177	3540		
Apical third						
A	1	89	3	93	28.869	737.117
B	108	167	39	314		
C	87	311	18	416		
D	20	324	86	430		
E	13	24	1	38		
F	9	45	55	109		
G	1	57	1	59		
H	1	73	65	139		
I	1	124	48	173		
J	146	53	40	239		
Total	387	1267	356	2010		

DISCUSSION

It has been demonstrated in several investigations that, regardless of the instrumentation system used during canal shaping[1], a layer of dentin sludge is always generated that adheres to the walls and obliterates the dentin tubuli[11], as observed in the samples of the control group (C-). This research reviewed the activation of EDTA with ultrasound and XP-Endo® Finisher to eliminate the layer of dentin sludge, both systems favored the cleaning of the canal walls, obtaining results similar to those of Leoni *et al.*[13] where the reduction of dentin sludge was achieved regardless of the EDTA activation method.

The XP-Endo® Finisher system was the only one that had a significant effect on the smear layer, since a greater number of open dentin tubules were observed, particularly in the apical third. These findings contrast with various investigations on instrumentation in this segment and point out that, despite this, bacteria can lodge in the dentinal tubules, or in the smear layer itself with high pathogenic potential, favoring persistent irritation of the periradicular tissue, delaying healing[14] so that any method that improves the conditions of this area, greatly favors the prognosis of the treatment. The results were analyzed with the two scoring methods referred to in this research, both the Torabinejad scale and the ImageJ approach, both of which made it possible to contrast the different EDTA activation protocols and determine the efficacy of each one in the elimination of the dentin sludge. Although the results were generally similar for both systems, the Torabinejad scale showed a discrepancy in the middle third, which could be caused by the subjective appreciation of the operator when observing the photomicrographs. Therefore, the use of ImageJ (National Institutes of Health, NIH), a public domain digital image processing program, is suggested to establish a more objective and accessible method for any researcher, based on a quantitative analysis.

CONCLUSION

Within the limitations of the present study, it can be concluded that EDTA activation with the XP-Endo file® Finisher proved to be more effective in the removal of the layer of dentin sludge, compared to the use of ultrasound, particularly in the apical third, where it proved to be the only system capable of having a significant impact, despite the limited instrumentation and the irregularities of this area. These results could be extrapolated to clinical practice, considering the advantages and disadvantages offered by the system; however, it is pertinent to question the need to use it in a generalized manner, or to use it selectively only in patients presenting apical periodontitis, or re-treatments with persistent lesions that require greater attention to the apical third. Since none of the evaluated methods eliminated the smear layer, research in this area should continue in search of a final irrigation protocol that guarantees complete disinfection of the canal system.

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