

CLEANING EFFICACY OF DIFFERENT FINAL IRRIGATION ACTIVATION TECHNIQUES

BIZHYAN MAHDI MUSTAFA and BAHAR JAAFAR SELIVANY]

Dept. of Conservative Dentistry ,College of Dentistry. University of Duhok, Kurdistan Region–Iraq

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ABSTRACT

Purpose: The cleaning effectiveness of ultrasonic, diode laser, XP endo finisher, and finisher gentlefile brush was assessed and compared.

Methods: 40 single-rooted mandibular premolars extracted and decoronated to a coronal length of 12 mm to the apex, biomechanically instrumented with protaper Next up to size X3. The roots were then randomly divided into four groups (n=10) and received a final irrigation and activation. GI: Ultrasonic system activated the final irrigant, GII: 980-nm diode laser, GIII: Xp-endo finisher, GIV: Finisher gentle file-brush. Under a scanning electron microscope, the teeth were longitudinally sectioned into two halves and scored. To compare groups, the Kruskal-Wallis Test was used, and P 0.05 was regarded as statistically significant.

Results: Finisher gentle file brush was most efficient in removing the smear layer, with a statistically significant difference with Diode laser ($p<0.0037$) and XP EndoFinisher ($p<0.0198$). There was no statistically significant difference in the Debris removal between all groups.

Conclusions: No irrigation activation technique was able to eliminate debris and smear layer completely from root canals. The Finisher gentle file brush was most efficient in removing smear layer. Diode laser showed the least smear layer removal.

KEYWORDS: Debris, Diode laser, Irrigation activation ,Gentle file brush, Smear layer, Sodium hypochlorite, XP Endo Finisher.

INTRODUCTION

The success of endodontic treatment depends significantly on the effectiveness of the root canal cleaning and shaping process. However, due to the complex canal morphology, it is challenging to obtain proper canal preparation, which incorporates mechanical (instrumentation) and chemical elements (irrigation) (Živković et al.,2015).Both hand and rotary instrumentation produce a smear layer on the canal walls that is of varying thickness as a result of cutting the dentin (Violich and Chandler ,2010). This smear layer obstructs dentinal tubules, preventing medicaments, sealants and obturation materials from reaching their full potential in the lateral canals and dentinal tubules. It is a loosely adhesive structure that can harbour bacteria and prevent the obturating material from forming a strong bond with the canal wall, potentially allowing microleakage (Manjunath et al., 2021).Numerous irrigation solutions have been introduced in endodontic practice. The

development of their formulations is guided toward improving their properties, such as dentinal tubule penetration, antibacterial effect, smear layer removal, stability, and substantive efficacy.

None of the irrigation solutions seems to provide all these desired properties. Sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) solutions have gained wide acceptance, and their use is advocated as an effective irrigation protocol to eradicate the fragments of the smear layer . These solutions remain the gold standard for root canal irrigation due to their antibacterial action and necrotic and organic matter-dissolving activity within the smear layer (Khaleefah and Abdul-Ameer,2020).

The root canal has traditionally been irrigated with a syringe and needle combination. However, the effect of syringe irrigation is limited because the solution can only reach 1 mm beyond the tip of the needle. The activation of root canal irrigant is the recommended approach for improving irrigant distribution in

the canal system because it may reduce apical vapor lock, thereby increasing irrigation effectiveness. Many agitation strategies have been proposed to increase the effectiveness of irrigant. (Kamaci et al .,2018).

Passive ultrasonic irrigation (PUI) have been used to improve the chemical and mechanical effects of irrigation solutions (Grinkevičiūtė et al .,2019). It entails using an ultrasonic device on a file that has been placed within an irrigant-filled canal. Despite the fact that the process is ultrasonically activated, the term passive describes the file's non-cutting nature (Andreani et al .,2021). In endodontics, the diode laser has demonstrated excellent results in removing the smear layer and disinfecting the root canal to achieve reduced permeability and microleakage. The diode laser is recommended for endodontic treatment because its wavelength falls within the infrared range, where thin and flexible fibers can be used. Previous studies have shown that diode lasers with wavelengths of 810 nm and 980 nm have bactericidal effects (Abraham et al.,2019). The antibacterial effect of diode laser irradiation has been attributed to its greater depth of penetration up to 1000 μm into the dentinal tubules when compared to the penetration depth of chemical disinfectants, which were limited to 100 μm (Bitter et al .,2017).

The XP-endo Finisher (FKG Dentaire, La Chaux-de-Fonds, Switzerland) is a tool made of a unique nickel-titanium alloy (NiTi) that is used as the final step after root canal instrumentation to improve root canal cleaning and disinfection. When placed inside the canal at body temperature, the device's apical portion expands and forms a spoon-like shape. According to the manufacturer, this instrument adapts to the anatomy of the canal, performing debridement and cleaning in areas that would otherwise go undetected (De-Deus et al.,2019). The Finisher GF Brush, part of the Gentlefile system, is a brush with six Stainless Steel strands that automatically open outward when used in a handpiece at 6500 rpm . The GF Brush's primary function is to facilitate irrigation, but due to its design, it is anticipated to demonstrate exceptional effectiveness for the removal of materials from root canals (Neelakantan et al .,2018). The aim of present study was to evaluate and compare the cleaning efficacy of ultrasonic , diode laser, XP endo finisher and finisher gentlefile brush on debris and smear layer removal.

MATERIALS AND METHODS

Sample selection and preparation

In this investigation, forty mandibular premolars with single roots that were straight and recently extracted for orthodontic needs were employed. Teeth with cracks, internal or external resorption, root caries, root canal calcification or obstruction, pulp stones, or previous endodontic therapy were excluded. The teeth were cleaned immediately after collection and soft tissue remnants were removed with a cumine scaler. Finally, the samples were kept at room temperature in a plastic container containing a 0.1% thymol solution (Al-Karadaghi et al., 2015). Then those samples were decoronated to have a length of 12 mm coronally to the apex by a diamond disk and using a digital caliper to confirm the length. The remaining pulp was extirpated using a barbed broach, patency of each root was confirmed to get to the apex by using 10 K file (Dentsply, Ballaigues, Switzerland) and the working length was found by using 10 K file. When the file's tip was visible from the apex, the new working length was established by subtracting 1 mm from the total length of the root, which was initially set at 12mm (Liu et al., 2015).

The root apical foramen was sealed with acrylic resin (zhang et al., 2015), molds for holding the teeth were constructed from a water pipe and heavy body impression with catalyst. Samples were inserted in the impression material in the pipe before the impression material gets to set, leaving the coronal part of the root exposed (2mm). These close-ended molds make the tooth to be fixed in place during the preparation and creating a standardization position and orientation, and those samples were mounted later on by using a table jack (Tay et al., 2010).

Root Canal Instrumentation

Protaper NEXT rotary files (Dentsply Maillefer, Ballaigues, Switzerland) was used to prepare all root canals in crown down technique according to the manufacturer's instructions, using DENTSPLY X-Smart IQ Cordless Endo Motor . In this study, three main files of Protaper NEXT fifth generation were used, which were X1, X2, and X3, each of those files has its own tip size and taperness (Ruddle et al., 2013). For standardization purposes, every set of rotary files was used to prepare five canals and then discarded. Using a 27-gauge needle that was held 2 mm shorter than the working length, all root canals were irrigated with 3ml of 5.25%

NaOCl and 1mL of 17% EDTA during instrumentation (Al-baker et al.,2021). To counteract the effects of NaOCl, normal saline was flushed through the canals at the end of instrumentation. Following that, the samples were dried using sterile X3 paper points.

Final Irrigation Activation

After biomechanical preparation, forty roots were divided randomly into four groups of ten roots each to receive a final irrigation and activation while the irrigant inside the canal.

Group I PUI: Each root canal was irrigated with 3 ml of 5.25% NaOCl solution and ultrasonically activated with a woodpecker ultrasonic tip E12 (Ufile size 25), which inserted into the canal 1 mm short of the WL, and the irrigant was ultrasonically activated for 20 s per cycle. To avoid contact with the canal walls, the tip was kept as central as possible. The process was repeated three times. Before each activation cycle, the canal was irrigated with 1 mL of 5.25% (NaOCl) (Al-Mafrachi et al., 2018).

Group II Diode Laser: Each root canal was irrigated with 3 ml NaOCl solution (5.25%) and agitated with a 940 nm diode laser; the delivery was by fiber-optic endodontic tip, E2, with a tip diameter of 200 μ m , specimens were irradiated with 1.08 W, continues wave (CW) mode; the fiber tip was inserted 2 mm from the apex, in contact mode, and helicoidal movement at 1mm/s. According to the manufacturer's instructions, this was completed in 18 seconds and then repeated for a total irradiation time of 36 seconds (Al-Mafrachi et al., 2018).

Group III Xp-endo Finisher: Each root canal was irrigated with 3 ml NaOCl solution (5.25%) and activated by using XP-endo finisher. At temperatures above 35°C, the file is in its austenitic phase, which is difficult to be inserted in the canal. So, after working length adjustment to 11 mm inside the tube, the finisher file was cooled down with ethyl chloride spray while it is inside the tube. The file was used according to the manufacturer's instructions, the settings of the endodontic micro motor was set at 800 rpm and 1.0 Ncm for speed and torque respectively. The activation time inside the canal was 60 seconds to perform slow, gentle movements up to the WL and make contact with all canal walls (Khaleefah and Abdul-Ameer,2020).

Group IV Finisher gentle file brush (disinfectant brush): Each root canal was irrigated with 3 ml NaOCl solution (5.25%) and activated by using the Finisher gentle file brush (Gentle File, France) placed 1 mm shorter than

the working length. The activation time was 60 seconds inside the canal, the brush was moved up and down, as per the manufacturer's instruction (Khaleefah and Abdul-Ameer,2020). All of the canals were rinsed with 3 ml of distilled water immediately after activation, and they were all dried with X3 Protaper Next paper-points.

SEM Preparation and Evaluation

To determine the longitudinal groove depth without having to penetrate the canal for scanning electron microscopy investigation, the X3 ProTaper Next gutta-percha cone was placed into the root canal (Mancini et al., 2013). This precaution was implemented to prevent the cutting disc from spitting debris into the canals and potentially contaminating the specimens (Alakshar et al., 2020). After creating longitudinal grooves on the buccal and lingual surfaces with a diamond disc at a slow speed, each root was carefully split in half with a chisel (Ali et al., 2018). Each specimen received half of each tooth containing the most visible part of the apex, while the other half of each tooth was discarded (Nair et al ., 2019). The DC sputtering technique was used to apply a very thin layer of gold on the teeth first. The gold film was being added at a rate of 2 nm per minute and was roughly 20 nm thick. The specimens were then examined at with a scanning electron microscope to evaluate the microscopic pattern of magnification (TESCAN MIRA3 FEG-SEM purchased by the Queensland University of Technology, Australia). For comparison, a standard series of three photomicrographs at X200 for the debris and X2000 for the smear layer were taken in the apical, middle, and coronal thirds of the canal. Using the scanned images, two trained observers independently evaluated the smear layer and remaining debris.

The surface debris and smear layer were assigned a conventional semi-quantitative evaluation in four groups, according to the classification (Gutmann et al.,1994).

STATISTICAL ANALYSIS

After calculating the mean and standard deviation for each group, JMP pro 14.3.0 performed a statistical analysis on the data. Wilcoxon / Kruskal-Wallis Tests were Utilized, with statistical significance established at $p < .05$.

RESULTS

Smear layer

Table 1 displays the mean scores and standard deviation for each of the tested groups. The smear layer on the canal walls of any of the tested groups could not be completely removed. Finisher gentle file brush activation was found to be significantly more effective

than Ultrasonic, XP EndoFinisher, and Diode laser in removing the smear layer. There were significant differences when Finisher gentle file brush was compared to Diode laser and XP EndoFinisher (p.05). There was no statistically significant difference between the other groups (p>.05).

Table (1): Pairwise comparisons of smear layer removal between study groups

Study groups		total smear results		
		Mean ±SD	Mean ±SD	p-Value
Ultrasonic	Diode laser	1.46±0.43	1.99±0.48	0.1948
Ultrasonic	XP EndoFinisher	1.46±0.43	1.87±0.52	0.6385
Ultrasonic	Finisher gentle file brush	1.46±0.43	1.20±0.36	1.0000
Diode laser	XP EndoFinisher	1.99±0.48	1.87±0.52	1.0000
Diode laser	Finisher gentle file brush	1.99±0.48	1.20±0.36	0.0037
XP EndoFinisher	Finisher gentle file brush	1.87±0.52	1.20±0.36	0.0198

Table 2 and Figure 1 showed a significant differences between groups in the coronal and apical thirds, but there was no significant differences for all of the groups in the middle third. As it shows the lowest values of smear in coronal third was in Finisher gentle file brush and ultrasonic groups, while the highest values

of smear in coronal third was in diode laser group. The lowest values of smear in apical third was in Finisher gentle file brush followed by Ultrasonic, XP EndoFinisher, while the highest values of smear in apical third was in Diode laser group.

Table (2): Comparisons of root thirds in smear layer removal between study groups

Sides	Study groups	Statistics of smear results		p-value (two-sided)
		Mean	Std Dev	
Coronal	Ultrasonic	1.0	0.0	0.0145
	Diode laser	2.1	1.20	
	XP EndoFinisher	1.3	0.48	
	Finisher gentle file brush	1.0	0.0	
Middle	Ultrasonic	1.30	0.48	0.3599
	Diode laser	1.33	0.5	
	XP EndoFinisher	1.70	1.25	
	Finisher gentle file brush	1.0	0.0	
Apical	Ultrasonic	1.8	1.03	0.0003
	Diode laser	2.8	0.92	
	XP EndoFinisher	2.6	0.70	
	Finisher gentle file brush	1.0	0.00	

Wilcoxon / Kruskal-Wallis Tests (Rank Sums) was performed for statistical analysis..

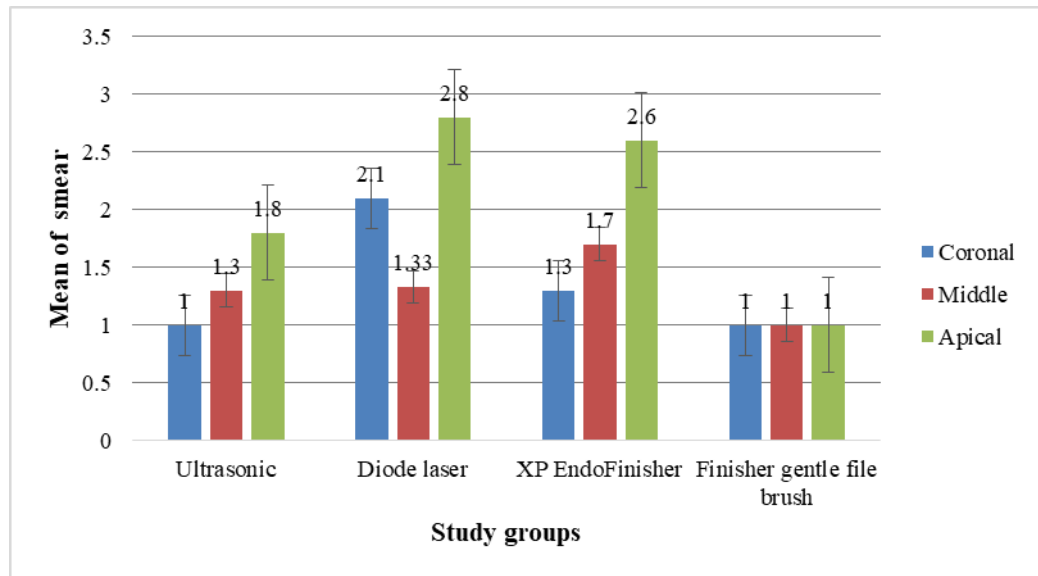


Fig. (1): The bar graph displays a summary of the smear layer scores in three regions of the prepared canals.

Debris layer

Table 3 showed that there was no significant difference in the debris removal between ultrasonic, Diode laser, XP EndoFinisher, and

Finisher gentle file brush that there was no significant difference in the Debris removal between ultrasonic, Diode laser, XP EndoFinisher, and Finisher gentle file brush .

Table (3): comparison of study groups in Debris layer removal

Study groups	Total debris results		p-value
	Mean	Std Dev	
Ultrasonic	1.27	0.32	0.1915
Diode laser	1.63	0.38	
XP EndoFinisher	1.59	0.57	
Finisher gentle file brush	1.43	0.39	

Table 4 and Figure 2 showed a significant difference in debris removal in the coronal third among all groups, but there was no significant

difference in the middle and apical thirds of all groups.

Table (4): Comparisons of thirds of debris results among and between study groups

Thirds	Study groups	Mean	Std Dev	P-value
Coronal	Ultrasonic	1.0	0.0	0.0138
	Diode laser	1.6	0.70	
	XP EndoFinisher	1.0	0.0	
	Finisher gentle file brush	1.3	0.48	
Middle	Ultrasonic	1.4	0.52	0.9685

	Diode laser	1.4	0.52	
	XP EndoFinisher	1.7	1.25	
	Finisher gentle file brush	1.3	0.48	
Apical	Ultrasonic	1.4	0.52	0.2719
	Diode laser	1.9	0.74	
	XP EndoFinisher	2.0	0.82	
	Finisher gentle file brush	1.7	0.67	

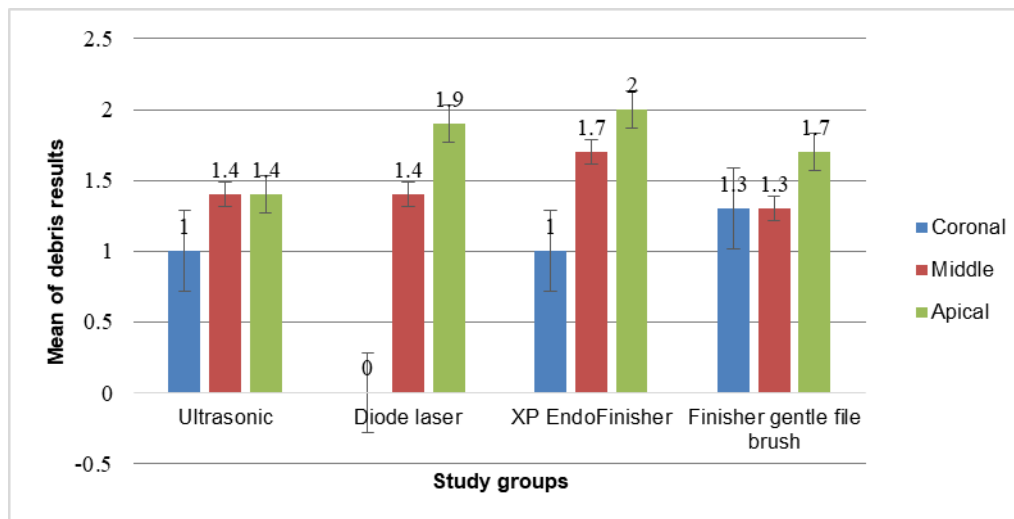


Fig. (2) : Comparisons of thirds of debris among study groups

DISCUSSION

Smear layer

Endodontic therapy's primary goal is to thoroughly clean and prepare the root canal walls in order to remove necrotic and vital pulp tissue, bacteria, debris, and smear layer, as well as to prevent canal re-contamination (Azimian et al., 2019). Due to the reduced size of the apical third of the root (relative to the other thirds), which impedes the circulation and action of the irrigating solutions and causes vapor lock formation, it appears to be difficult to entirely remove the smear layer (Arslan et al., 2013). The bone socket encloses the root in a clinical setting, and the canal functions as a closed end channel. This leads to gas entrainment at the end of this area, which creates a vapor lock effect during conventional irrigation procedures. In the present study, all groups treated with 3ml of 5.25% NaOCl and 1mL of 17% EDTA during shaping procedure and then irrigated with 3ml of 5.25% NaOCl and activated regardless of the agitation technique used.

For the evaluation of postoperative root canal cleanliness, the standard technique is the investigation of the root segments under the

scanning electron microscope (SEM). (Hülsmann, et al., 2005). Table. 1 showed that there was significant difference between ultrasonic, Diode laser, XP EndoFinisher, and Finisher gentle file brush in the smear layer removal. Finisher gentle file brushes produced the least amount of smear layer, followed by Ultrasonic, XP EndoFinishers, and Diode lasers. This could be related to numerous device characteristics. It seems that this ability is due to design of Finisher gentle file brush that enhance debridement of smear layer in the apical third of root canals. When rotated, the Finisher GF Brush opens its six Stainless Steel strands. In comparison to syringe irrigation, this may scrape the canal walls to remove tissue and microbial biofilms that are adhered (Neelakantan et al., 2018).

Reactive oxygen species are produced in the final irrigation solution as a result of hydrodynamic turbulence caused by ultrasonic irrigation activation. The combination of these factors raises the temperature and hydrostatic pressure, creating waves that hit the root canal walls and pierce the dentinal tubules, effectively combating the smear layer (Castagna et al.,

2013). As a result, more smear layer clearance is encouraged by the use of final irrigant solutions and ultrasonic irrigation, especially in difficult and complex regions like the middle and apical thirds. Passive ultrasonic improved canal cleaning, according to earlier investigations (Mancini et al., 2013; Leoni et al., 2017). This investigation supported the findings of Bao et al. (2017) who reported that PUI had a superior cleaning effect to conventional needle irrigation. These outcomes might be explained by the ultrasonic device's acoustic microstreaming along the instrument, which formed irrigating jets that were directed at the root canal wall (Jiang et al., 2011; Malki et al., 2012; Wagner et al., 2017).

The metallurgy of the XP-endo Finisher file is responsible for its proficiency in the elimination of debris and smear layers. The design and production of XP-endo Finisher files are based on the NiTi alloy's shape-memory properties. The file is straight in the martensitic phase that develops as it cools. The file will change shape to the austenitic phase when it is heated to body temperature (in the canal). This is due to its shape memory. The manufacturer asserts that the austenitic phase form in the rotation mode enables the file to contact and clean places that would be challenging to access with instruments. The file can be manually brought back to its original straight shape (martensitic phase) after it has cooled down (SA, 2016). Jayakumar et al., (2019) reported that using XP-endo Finisher as an adjunctive during shaping and cleaning ultimately results in cleaner root canal walls. Sanabria-Liviach, et al., (2017) reported that Smear layer removal in both the middle and apical canal thirds was more successful with XP-Endo-finisher activation of NaOCl/EDTA than with PU activation of NaOCl with and without EDTA.

This study shown that, when compared to other groups, diode lasers caused the creation of the most smear layer. The process of laser energy absorption, vapor bubble production, bubble collapse, bubble acoustic streaming, and finally cavitation lead to the laser activation of irrigating solutions. Current study results came in agreement with Saraswathi et al., (2012) who noticed a better removal of smear layer when agitated NaOCl with laser.

Debris layer

Table 3 showed that there was no significant difference between ultrasonic, Diode laser, XP EndoFinisher, and Finisher gentle file brush in

the Debris layer removal, this could be attributed to several devices characteristic.

Acoustic streaming is the best possible reason for the cleaning efficiency of ultrasonic irrigation. The instrument should vibrate freely in the canal for efficient acoustic streaming. The highest efficiency is obtained with small file, high frequency and large displacement amplitude. Therefore, diameter of the canal is important because it can influence the amplitude displacement. The file should remain loose inside the canal while irrigating, without any pressure on the walls of the canal or intentional removal of dentine, characterizing the passive ultrasonic irrigation technique. which helps in the reflux of irrigant, causing further debris to be pushed coronally, thus preventing irrigant extrusion into periapical tissue. Ultrasonic waves help in the energy transfer from the vibrating file to the irrigant in the canal which causes hydrodynamic turbulence, causing cavitation of the irrigant and bubble impact waves, resulting in debris removal (Manjunath et al., 2021)

Diode lasers improve tubular network penetration, allowing cleaning of previously inaccessible deeper dentin layers. The mechanism for laser activation of irrigating solutions is generated by laser energy absorption by the irrigant solution, the creation and collapse of vapor bubbles, acoustic streaming and cavitation (Al-Mafrachi et al., 2018).

Several factors may be responsible for the XP-Endo finisher file's effectiveness. The first is its capability for expansion. With a small ISO 25 diameter core and no taper, because of its flexibility, in a variety of locations, the file can come into contact with the canal walls. The file may increase its reach by 100 times or 6 mm in diameter, according to the manufacturer. The second is the effect of shape memory. The file is straight in its M-phase after cooling, which is achieved. Due to its molecular memory to the A-phase, the file will change its form when it is exposed to body temperature (within the canal). When in rotation mode, the A-phase form enables the file to access and clean regions that are otherwise inaccessible to standard instruments (Sanabria-Liviach, et al., 2017). The Finisher Gentle file brush's rotation is what makes it effective at eliminating debris (6500 rpm). This rapid rotation may also produce centrifugal forces strong enough to push irrigants into the irregularities of the canal.

CONCLUSIONS

No method of irrigation activation was able to entirely remove debris and smear layer from root canals, especially in the middle and apical thirds. The Finisher gentle file brush activation was the most effective in removing smear layer from the entire root canal wall. Passive Ultrasonic enhance the smear layer removal in coronal, middle and apical third. Diode laser was the least effective in removing smear layer. All activation devices showed enhancement in cleaning activity in removing debris.

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