Research Article

Effectiveness of different irrigant activation techniques in removing smear layer: a scanning electron microscope study

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Abstract: Background: This study aimed to evaluate the efficiency of Laser-Activated-Irrigation, XP-Endo Finisher, and Endo Activator irrigation protocols in removing the smear layer from root canal walls by evaluating the opening of the dentinal tubules in the coronal, middle, and apical thirds using scanning electron microscopy. Materials and Methods: Thirty single-rooted human anterior teeth were decoronated to a standardized length. The samples were prepared using the primary WavOne Gold rotary system and divided into 3 groups (n=10): Laser-Activated-Irrigation (LAI), XP Finisher and Endo Activator. In addition to the control group, which was irrigated with a conventional syringe only. The teeth were split longitudinally and examined under SEM at 1000x magnification. Images were taken at apical, middle, and coronal thirds. Data were analyzed using the Kruskal-Wallis test, with a significant p-value being less than 0.05. Results: Upon examining the removal of the smear layer in the root canal under 1000x magnification, there were no statistically significant differences in the coronal, middle, and apical third between the three studied groups. However, the study revealed significant differences compared to the control group. The LAI demonstrated a minimal smear layer and open dentinal tubules in the coronal and middle thirds, however, a smear layer was still present in the apical third. The XP-Endo Finisher effectively produced a thin, homogeneous smear layer with fewer open dentinal tubules, particularly in the apical third. In contrast, the Endo Activator resulted in a uniform smear layer with minimal tubule exposure in the coronal third, but it covered over 50% of the apical third. No significant differences among root thirds were observed, and complete smear layer removal was not achieved in the apical third with any method. Conclusions: XP-Endo Finisher was the most effective method in removing the smear layer in the apical third. Endo Activator was found to be the best in the middle third. Finally, LAI was determined to be the most effective in removing the smear layer in the coronal third. In clinical practice, it is recommended to use different techniques for cleaning different parts of the canal. Conventional needles for irrigation are less effective. Using these advanced techniques can significantly improve root canal treatments.

Keywords: Smear layer, Scanning Electron Microscope, XP-Endo Finisher, Endo Activator, Laser-Activated-Irrigation.

Introduction

One of the main goals of root canal treatment is to achieve excellent cleaning and optimal sealing of the root canal system to prevent post-treatment bacterial infiltration [1]. Disinfection of the root canal system is a critical factor in the success of endodontic treatment by reducing pathogens [2]. However, root

canal preparation alone cannot successfully reduce the bacterial count in the root canal system, and all Ni-Ti files create a smear layer along the root canal walls [3]. Therefore, irrigants are essential for removing debris and disinfecting the root canal system [4].

Successful endodontic treatment depends on effectively removing the smear layer from root canals through chemo-mechanical instrumentation. Various root canal irrigants have been introduced, and most of them have satisfactory properties. Past studies have shown that a combination of 5.25% sodium hypochlorite and 17% ethylenediaminetetraacetic acid (EDTA) is quite effective in flushing out debris and smears formed on the dentinal walls during root canal instrumentation [5]. The smear layer acts as a barrier to the penetration of irrigants and sealers [1,2]. However, none of the irrigants with the conventional irrigation system have reached the apical 1 mm of the root canal, which has maximum anatomical areas that are the most challenging and critical to debride [5,6,7,8]. Many problems are associated with the conventional irrigation systems used. The irrigant is delivered with a syringe and the needle, which is 2 mm shorter than the actual working length. It has been shown that the irrigant does not go more than 1 mm beyond the needle tip [9,10]. To make the irrigant reach the apical 1-2 mm, the needle should go close to the working length [11], which increases the risk of apical extrusion of the irrigant. The commonly used irrigant, sodium hypochlorite, is toxic to the surrounding tissues and causes acute symptoms if forced beyond the apex [12]. Mechanical cleaning and shaping were also improved with rotary Ni-Ti files. However, it was found that debris is always present in the apical 1 mm [13,14].

LAI has become increasingly popular. It works by creating cavitation, a process where the laser energy temporarily causes the irrigant to form bubbles [15,16]. One well-known method of LAI is called photon-induced photoacoustic streaming (PIPS), which involves using a fiber tip to pulse at very low energies, effectively delivering energy into the solution while only slightly increasing dental temperature [17]. This method enhances fluid exchange and debris removal by creating vapor bubbles with secondary cavitation effects [18,19].

Recently, a non-tapered Ni-Ti rotary instrument (XP-Endo Finisher) has been explicitly designed to increase the efficiency in root canal wall cleaning [20] with limited impact on dentin. The XP-Endo Finisher is made of a proprietary heat-treated NiTi MaxWire alloy (Martensite-Austenite Electropolish-FleX) with a transition temperature near body temperature, which allows the file to change its shape to the austenite phase, allowing the file to expand its reach to 6 mm in diameter [21].

The EndoActivator system (Dentsply Sirona, Ballaigues, Switzerland) is a portable, wireless handpiece for enhanced root canal irrigation. It uses a flexible polymer tip that oscillates at frequencies from 1 to 10 kHz. The tip is designed to be smooth and non-cutting to avoid altering the root dentin. The design of the tip allows for effective activation and robust agitation of the irrigant within the root canal. By using a combination of horizontal agitation and short vertical strokes, the EndoActivator creates a strong hydrodynamic effect within the root canal system. This action improves the lateral penetration, circulation, and flow of irrigants, allowing for better cleaning of complex canal anatomies. This leads to more comprehensive removal of debris and smear layer, enhancing the overall effectiveness of root canal debridement and disinfection [22].

Based on this background, the objective of this study was to use scanning electron microscopy (SEM) to assess the effectiveness of Laser-Activated-Irrigation (LAI), XP-Endo Finisher, and Endo Activator techniques in removing the smear layer from root canal walls by evaluating the opening of the dentinal tubules in the coronal, middle, and apical thirds. The study also aimed to compare these techniques with conventional irrigation. The null hypothesis was that no difference would be found among the activation protocols in smear layer removal.

Materials and Methods

Sample Selection and Preparation

After receiving approval from the local ethics committee, a total of 30 single-canal straight human anterior teeth, including upper and lower canines, were radiographed to confirm that they had a single canal and no internal calcifications, irregularities, or other anomalies. Before being used in the laboratory, all teeth were stored in 4% normal saline. The specimens were randomly allocated and the teeth were decoronated to obtain a standardized root length of 15 mm using an initial apical file ISO size 15.

Root Canal Instrumentation and Final Irrigation

The specimens were fixed in the cast to allow the operator to perform the root canal instrumentation procedures at 37 °C using a heating water bath. The working length (WL) was determined by manually inserting a K-file size 15 into the root canal. The K-file was equipped with a double stopper to minimize the risk of stopper movement during measurements. It was advanced into the root canal until its tip became visible at the apical foramen under an Endodontics Microscope (16x). This length was noted as the actual tooth length. After that, the file was withdrawn by 0.5 mm, and the distance between the file tip and the reference point was measured using a digital caliper to obtain the actual working length. Then, the sample was prepared using the rotary system Primary WaveOne Gold (Red) with a tip size of 25 and a diameter of 0.25 mm at the tip (Dentsply Sirona/USA).

During the root canal procedure, each canal was flushed with 10 mL of 5.25% sodium hypochlorite (NaOCl). The irrigation was carried out using 3 mL of 5.25% NaOCl (Coltene Canal Pro, Coltene Whaledent, Langenau, Germany), followed by 1 mL of 17% EDTA (Coltene Whaledent, Langenau, Germany) for 1 minute, and then another 3 mL of 5.25% NaOCl [23,24,25]. This was performed using a double side-vented needle inserted 2 mm shorter than the actual working length. After irrigation, the canals were dried with paper points.

Final Irrigant Protocols

After root canal preparation, the sample was randomly allocated into three groups (n=10), according to different activation protocols used:

Group A / Laser-Activated-Irrigation (n=10)

After preparing the canals as outlined in Section 2.2, flush 1 mL of 17% EDTA and let it stand for 60 seconds in the root canal. LAI (Er:Cr,YSGG with a wavelength of 2780 nm) was used in this study because it is highly absorbed by water, enhancing the laser's effectiveness in creating vapor bubbles and improving

irrigant flow within the root canal. This wavelength also allows for efficient ablation of dental tissues while minimizing thermal damage. Additionally, it supports effective disinfection by enhancing fluid movement and ensures patient safety and comfort during the procedure [26,27]. The coronal pulp chamber was exposed to a power of 1.0W and a frequency of 15Hz for 30 seconds, with 0% water and 0% air. Afterward, the canal was flushed with 3 mL of 5.25% NaOCl using a syringe 2 mm shorter than the actual working length. Then, the canal was irrigated with 5 ml of saline. Following irrigation, the root canals were dried with paper points [28].

Group B / XP Endo-Finisher (n=10)

After preparing the canals as outlined in Section 2.2, 1 mL of 17% EDTA is flushed into the canal and left to stand for 60 seconds. This is done using an XP finisher at a speed of 1000 rpm as recommended by the manufacturer, positioned 2 mm shorter than the actual working length for 60 seconds. After this, the canal flushes again as mentioned above in Group A.

Group C / Endo Activator (n=10)

After preparing the canals as outlined in Section 2.2, 1 mL of 17% EDTA is flushed into the canal and left to stand for 60 seconds. Using Endo Activator shorter than the actual working length by 2 mm for 60 seconds, following which the canal was flushed again as mentioned above in Group A.

Group D/ Controlled (n=1)

After preparing the canals as outlined in Section 2.2, 1 mL of 17% EDTA is flushed into the canal and left to stand for 60 seconds. Using a conventional needle syringe shorter than the actual working length by 2 mm for 60 seconds, following which the canal was flushed again as mentioned above in Group A.

SEM Preparation

After the root canal instrumentation and final protocol irrigation, longitudinal grooves were made on the buccal and lingual surfaces of each root using a diamond disc. These grooves were made to help fracture the roots later with a chisel. A gutta-percha master cone was placed in the root canal to prevent contamination during the fracture. After 24 hours, the roots were split into two halves using a chisel and mallet [29]. Samples were dehydrated to reduce image noise and placed in a desiccator for 24 hours before evaluation. The samples were evaluated using SEM at 1000x magnification and photographed at three different levels: apical, middle, and coronal thirds.

Scanning Electron Microscopy (SEM) Evaluation

The study assessed the smear layer using 1000x magnification and observed the opening of the dentinal tubules. In evaluating the effectiveness of different root canal cleaning techniques, a detailed scoring system was used to assess the removal of the smear layer and the openness of dentinal tubules, as observed under SEM. The scoring system, summarized in Table 1, provides a clear framework for interpreting the degree of cleanliness achieved by each technique.

Specimen preparation involves sectioning teeth longitudinally to expose the root canal walls without damaging the dentinal tubules, followed by thorough rinsing with saline and drying using a vacuum desiccator to prevent artifacts. The root canal is divided into three standardized regions—coronal, middle, and apical using the cementoenamel junction (CEJ) as a landmark. Images are captured separately for each region, focusing on the central portion to minimize edge effects, with multiple images taken per region to ensure comprehensive assessment. Quality control is achieved by imaging a control sample with known smear layer characteristics at the start of each session to calibrate SEM settings and validate the process, while images with artifacts (e.g., scratches or debris) are excluded and retaken. Data recording and storage involve labeling images with corresponding region and specimen numbers for traceability, and all images are stored in a consistent format and resolution for analysis.

Scoring System Overview

The recorded scores were as follows (as shown in Table 1): Score 1 = no smear layer (open dentinal tubules), Score 2 = small amount of smear layer covering the root canal wall (a few dentinal tubules open), Score 3 = homogeneous smear layer covering the root canal wall (only a few dentinal tubules open), Score 4 = complete root canal wall covered by a homogeneous smear layer (no open dentinal tubule), and Score 5 = heavy, nonhomogeneous smear layer covering the complete root canal wall.

Table 1: Showing the scoring system for evaluating the opening of the dentinal tubules in the root canal walls under SEM.

Score No	Smear layer	Debris	Dentinal Tubules
Score 1	NO	NO	All open
Score 2	Thin Homogenous	Small Debris	Most of them open
Score 3	<50%	<50%	Few Dentinal Tubules Open
Score 4	>50%	>50%	No Dentinal Tubules Open
Score 5	Heavy in Homogenous	Heavy in Homogenous	No Dentinal Tubules Open

Statistical Analysis

Statistical analysis was performed using SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Statistical analysis was performed using the One-Way ANOVA test. The significance level for statistical analysis was set at $p<0.05$.

Results

When examining the smear layer removal in the root canal under 1000x magnification, no statistically significant differences were observed in the coronal, middle, and apical third among the three groups

studied (p>0.05). However, statistically significant variances were noted when compared to the control group. The summarized results can be found in Table 2 and Figure 1.

After using LAI, the coronal third of the canal wall has a minimal smear layer and open dentinal tubules (Score 2) (Figure 2, A). In the middle third of the canal wall, most dentinal tubules are open (Score 2 and 3) (Figure 2, B). Examination of the apical third of the canal wall after LAI shows the presence of a smear layer, with observable open dentinal tubules (Scores 2 and 3) (Figure 2, C).

After using the XP-Endo finisher, observation of the coronal third of the prepared canal wall revealed a thin, homogenous smear layer along the canal wall with most of the dentinal tubules present (Score 2) (Figure 2, D). In the middle third of the prepared canal wall, it was found that over 50% of the root canal wall is covered with a homogenous smear layer, and open dentinal tubules are few (Score 3) (Figure 2, E). At the apical third of the prepared canal wall, following the use of the XP-Endo Finisher, an evident thin, homogenous smear layer covering the entire root canal wall was observed (Score 1) (Figure 2, F).

After using the Endo Activator, the upper third of the canal wall shows a thin and uniform layer with minimal opening of dentinal tubules, scored as 2 (Figure 2, G). In the middle third, most dentinal tubules are open, scored as 2 and 3 (Figure 2, H). In the apical third, over 50% of the root canal wall is covered with a uniform smear layer, and only a few dentinal tubules are open, scored as 3 (Figure 2, I).

No significant differences among the root thirds were observed in all experimental groups (p>0.05). The coronal and middle thirds showed a more pronounced removal of the smear layer (see Table 2 and Figure 1), indicating that complete removal of the smear layer with any system was higher in the middle and coronal third than in the apical third. However, none of the methods used in this study showed a complete absence of a smear layer in the apical third. Representative images of all root thirds of the three experimental groups are shown in Figure 2. The apical image of the XP-Endo finisher system shows an example of a sample with fewer smear layers, whereas the coronal part of the LAI, images exhibits fewer smear layers in dentinal tubules and on the surface. A moderate amount of smear layer is shown on the coronal image of the Endo Activator system (Figure 2).

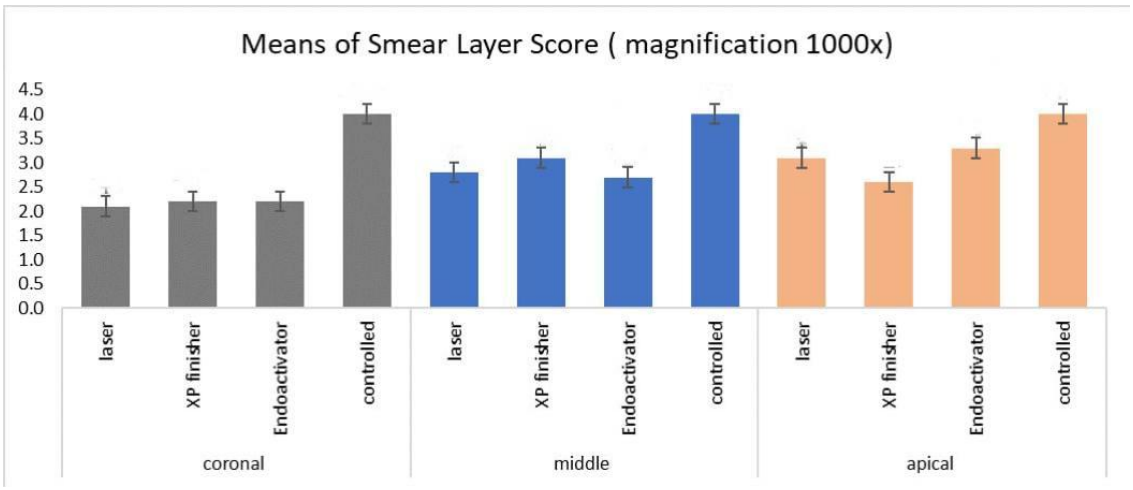

Figure 1: Showing the smear layer score in the root canal walls at the coronal, middle, and apical thirds under 1000x magnification for comparison between different groups.

Table 2: Essential sample characteristics of the amount of smear layer removal using a scoring system were compared between the coronal, middle, and apical third areas in the tooth within each group.

Groups	1000x magnification	Coronal third	Middle third	Apical third
Controlled	Score 1	0 (0%)	0 (0%)	0 (0%)
	Score 2	0 (0%)	0 (0%)	0 (0%)
	Score 3	0 (0%)	0 (0%)	0 (0%)
	Score 4	0 (0%)	0 (0%)	0 (0%)
	Score 5	1 (50%)	1 (50%)	1 (10%)
Laser-Activated-Irrigation	Score 1	2 (20%)	0 (0%)	0 (0%)
	Score 2	6 (60%)	4 (40%)	4 (40%)
	Score 3	1 (10%)	4 (40%)	4 (40%)
	Score 4	1 (10%)	2 (20%)	2 (20%)
	Score 5	0 (0%)	0 (0%)	0 (0%)
XP-Endo Finisher	Score 1	0 (0%)	0 (0%)	1 (10%)
	Score 2	8 (80%)	3 (30%)	4 (40%)
	Score 3	2 (20%)	4 (40%)	4 (40%)
	Score 4	0 (0%)	2 (20%)	0 (0%)
	Score 5	0 (0%)	1 (10%)	1 (10%)
Endo Activator	Score 1	1 (10%)	0 (0%)	1 (10%)
	Score 2	7 (70%)	4 (40%)	0 (0%)
	Score 3	1 (10%)	5 (50%)	6 (60%)
	Score 4	1 (10%)	1 (10%)	1 (10%)
	Score 5	0 (0%)	0 (0%)	2 (20%)

Discussion

This study found that the XP-Endo finisher was more effective than both Laser-Activated Irrigation and Endo Activator in removing the smear layer in the apical third of the root canal. However, none of the techniques achieved complete smear layer removal in the region, highlighting the challenges of thoroughly cleaning the apical third due to limited irrigant access and the complex dentinal tubule structure (30,31,32).

The study's methodology, using Scanning Electron Microscopy to assess smear layer removal, provided detailed, high-resolution images of the root canal walls. Evaluating the effectiveness of Laser-Activated Irrigation, XP-Endo Finisher, and Endo Activator across the three canal thirds (coronal, middle, and apical) provides a comprehensive assessment of their performance in different regions. Standardizing the canal preparation with the WaveOne Gold system and using chelating agents ensured optimal conditions for accurate comparisons. Despite its strengths, the study had several limitations.

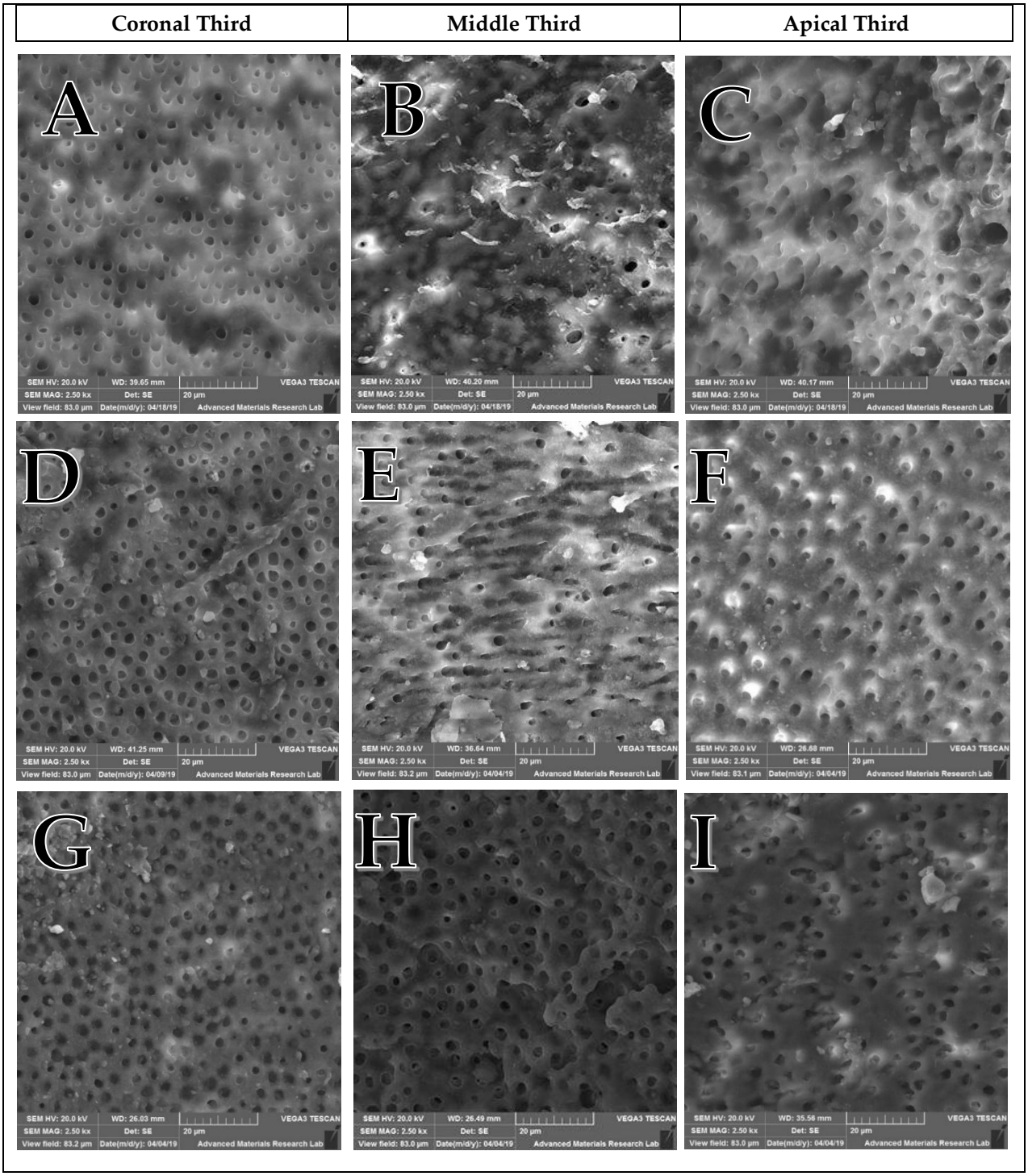

Figure 2: The results of the scanning electron microscope (SEM) in the coronal, middle, and apical thirds show differences in the removal of the smear layer among the different groups. (A, B, C) Laser-Activated-Irrigation group, (D, E, F) XP-Endo Finisher activation group, and (G, H, I) Endo Actıvator activation group. SEM (Hv: 20.0 kV, 1000x magnification, view field: 208 um, WD: 35.93 mm, VEGA SEMs) are used due to their design for high-resolution imaging, enabling detailed observation of sample surfaces and structures at the nanometer scale.

Although differences in smear layer removal were noted, none of the methods achieved complete removal, especially in the apical third of the root canal. This finding aligns with previous studies that have reported similar difficulties in cleaning this specific area. The difficulty in fully removing the smear layer, especially in complex root canal anatomies, may reflect the inherent limitations of the techniques used. Additionally, the study used single-canal teeth with standardized preparation (WaveOne Gold system) and a working length of 15 mm, ensuring consistency but not fully replicating the complexities of real-world clinical cases, where canals are often curved, oval, or have additional anatomical features like fins or isthmuses.

These variations in canal anatomy were not addressed in this study, but they could influence the effectiveness of the irrigant activation techniques. The *in vitro* nature of the study, common in dental research, is another limitation, as it excluded biological factors like dentinal fluid and the dynamic nature of living tissues. These factors could affect the performance of the techniques in real clinical situations, where *in vivo* conditions, such as dentinal tubule density and biological debris, may further complicate the cleaning process. Moreover, the study did not investigate the effects of varying irrigation times or concentrations of irrigants, which could significantly impact smear layer removal. The standardization of irrigation protocols may have limited the ability to determine the optimal conditions for each technique, and variations in irrigation time or concentration might lead to different results. Additionally, the study focused only on the immediate effectiveness of smear layer removal using SEM, without exploring long-term clinical outcomes like post-treatment complications or root canal healing. Further clinical studies are needed to assess how these techniques affect patient outcomes.

LAI was most effective in the coronal third, where the laser energy could be directed efficiently toward the crown without the need to insert the laser tip deep into the canal. The laser's energy helped in breaking up and removing the smear layer more effectively in this area. The effectiveness of LAI decreased in the middle third. The laser's penetration and the ability to effectively activate the irrigant diminishes as the distance from the laser source increases, making it less effective in this region compared to the Endo Activator. In the apical third, LAI was the least effective among the techniques. The challenges in delivering sufficient laser energy and irrigant to the apical region resulted in lower smear layer removal compared to both the XP-Endo Finisher and Endo Activator [26, 32].

The XP-Endo Finisher files are developed and manufactured using the shape-memory principles of the NiTi alloy. When the file is cooled, it becomes straight in its martensitic phase. However, when it comes into contact with body temperature, it reverts to its austenitic phase, phase A, and adopts a rotational shape. This shape allows the file to access and clean areas that it couldn't reach in its standard form. When it cools down again, the file returns to its straight shape [33]. The XP-Endo Finisher is designed to clean the inner canal walls of various root canal morphologies, including irregular canals, large canals, C-shaped canals, oval canals, isthmuses, and furcation canals [34]. The XP-Endo Finisher has demonstrated superior smear layer removal in the apical third compared to other techniques. Its design allows it to adapt to the root canal's shape, enhancing its ability to reach and clean this challenging area.

The file's ability to flex and expand as it warms up increases its effectiveness in accessing the apical third and facilitating better irrigant distribution, contributing to its higher performance in smear layer removal. Despite its success in the apical third, the XP-Endo Finisher showed less effectiveness in the middle third,

which may be due to the file's shape and movement dynamics. In the coronal third, the XP-Endo Finisher's performance was effective but not as noteworthy as in the apical third [21].

In the apical third, the Endo Activator was less effective compared to the XP-Endo Finisher. The limitations in reaching the apical region and the reduced intensity of fluid agitation in this part of the canal may have contributed to its lower performance. In the middle third, the Endo Activator showed the best performance. This success is attributed to its mechanism of action, which involves sonic agitation of the irrigant and hydrodynamic activation. Vigorous intracanal fluid agitation combined with sonic oscillating movements produces ample shear forces to achieve cleaner canals [35,36].

In the coronal third, the Endo Activator also performed well, but similar to the XP-Endo Finisher, it was not the most effective technique in this area. The ease of access to this region generally allows for effective smear layer removal across various techniques [22,23].

The use of a chelating substance is essential for removing the smear layer during root canal treatment. Final irrigation procedures can help the chelator reach inaccessible areas, making it more effective [1,37,38]. In this study, single-canal teeth were prepared to a working length of 15 mm using the WaveOne Gold system. A larger apical preparation was performed with a primary file (tip size 25) to improve cleaning in the apical area, enhance irrigant effectiveness, and expose more dentinal tubules.

An important consideration in our study is that the shape of the canal could affect the results. When the canal is wider and more oval, it becomes harder to reach the canal walls. Moreover, the effectiveness of the cleaning process may be limited in cases where the root canals have complex anatomies, such as curved root canals [39]. An SEM study conducted by Haupt et al. in 2018 discovered that no activation technique was able to entirely remove debris and smear layers from the walls of curved canals [25]. In 2022, Miguéns-Vila R et al. evaluated the effectiveness of various irrigation methods (passive ultrasonic irrigation (PUI), continuous ultrasonic irrigation (CUI), apical negative pressure (ANP) irrigation, and conventional irrigation) in removing the smear layer using SEM as an analytical tool. They found that CUI was more effective in removing the smear layer compared to PUI and ANP. The study showed that irrigant activation systems (PUI, CUI, and ANP) were more successful in removing the smear layer than traditional irrigation methods when observed using SEM. However, none of the irrigation protocols were able to eliminate the smear layer from the root canals [40].

Conclusions

XP-Endo Finisher was the most effective in removing the smear layer in the apical third. Endo Activator was found to be the best in the middle third. Finally, LAI was determined to be the most effective in removing the smear layer in the coronal third.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

Authors contributed equally to the research.

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None

Informed consent

Informed consent was obtained from all individuals, or their guardians included in this study.

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فعالية تقنيات تنشيط الري المختلفة في إزالة طبقة اللطاخة: دراسة بالمجهر الإلكتروني الماسح

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المستخلص:

هدفت هذه الدراسة إلى تقييم كفاءة بروتوكولات الري **La-ser-Activated-Irrigation (LAI)**، و**XP-Endo Finisher**، و **Endo Activator** في إزالة طبقة اللطاخة من جدران قناة الجذر عن طريق تقييم فتح الأنابيب العاجية. في الثلث الإكليلي والوسطى والقمي باستخدام المجهر الإلكتروني الماسح. تم تزييين ثلاثين سناً أمامية بشرية أحادية الجذر بطول موحد. تم تحضير العينات باستخدام النظام الدوار **WavOne Gold** الأساسي وتم تقسيمها إلى 3 مجموعات متساوية (العدد = 10). تم تنشيط المجموعة 1 باستخدام **XP Finisher**. تم تنشيط المجموعة 2 باستخدام ليزر **Er**، **Cr**، **YSGG**. تم تنشيط المجموعة 3 باستخدام المنشط الداخلي. تم تقسيم الأسنان طوليًا وفحصها تحت المجهر الإلكتروني المجهري (**SEM**) بتكبير **x**1000. تم التقاط الصور في الثلث القمي، الأوسط، والإكليلي. تم تحليل البيانات باستخدام اختبار كروسكال واليس، مع قيمة **p** كبيرة أقل من 0.05. النتائج: عند فحص إزالة طبقة اللطاخة في قناة الجذر تحت تكبير **x**1000، لم تكن هناك فروق ذات دلالة إحصائية في الثلث الإكليلي والوسطى والقمي بين المجموعات الثلاث المدروسة. ومع ذلك، كشفت الدراسة عن اختلافات كبيرة مقارنة بالمجموعة الضابطة. أدى **LAI** إلى متوسط درجات طبقة اللطاخة قدره 2.2 في الإكليل، و2.8 في الوسط، و3.1 في الثلث القمي. وفي الوقت نفسه، أظهر **XP Finisher** درجات 2.2 في الإكليل، و3.1 في المنتصف، و2.6 في الثلث القمي. أظهر **Endo Activator** درجات 2.2 في الإكليل، و2.7 في المنتصف، و3.3 في الثلث القمي. الاستنتاجات: استنادا إلى القيود المفروضة على هذه الدراسة، كان **XP-Endo Finisher** هو الأكثر فعالية في إزالة طبقة اللطاخة في الثلث القمي. وجد أن **Endo Activator** هو الأفضل في الثلث الأوسط. أخيرًا، تم تحديد **LAI** ليكون الأكثر فعالية في إزالة طبقة اللطاخة في الثلث الإكليلي.سرى السنافي