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EFFECTIVENESS OF SMEAR LAYER REMOVAL USING DIFFERENT ACTIVATED IRRIGATING SOLUTIONS AND TECHNIQUES: *AN IN-VITRO* STUDY

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ABSTRACT

Introduction: Successful endodontic therapy focuses on completely eliminating microorganisms, which is the main etiology for pulpitis and apical periodontitis. The ideal endodontic irrigant should be strong enough to dissolve intracanal necrotic/vital tissue and to eliminate bacteria and gentle enough on the extra radicular tissues; it also should be non-toxic, non-antigenic and non-carcinogenic. **Aim:** This study aimed to compare the smear layer removal using saline, sodium hypo chlorite (NaOCl) + Saline + ethylenediaminetetraacetic acid (EDTA), and quaternary ammonium silane irrigants (QAS). **Material and methods:** This study was conducted on 63 freshly extracted maxillary canines. Specimens were randomly divided into 3 main groups, A1, A2, and A3 (n=42), according to the type of irrigant used (saline group, 2.25%, saline, + EDTA 17%, and quaternary ammonium silane QAS group, respectively). Each main group was further sub-divided into three subgroups according to the method of activation B0, B1, B2 (n=14) (no activation group, Manual Dynamic Activation (MDA) group. Each group was evaluated by Scanning electron microscopy (SEM). ANOVA was followed by Duncan multiple range tests (DMRTs) to compare between treatment groups or corresponding post hoc for nonparametric **Results** showed significant differences between different groups. The difference between the activation methods was statistically significant (in the cervical third, middle third, and apical third). The highest mean value was recorded in sodium hypochlorite (NOCl), followed by QAS, with the lowest value recorded in saline. The difference between groups was statistically significant in the cervical, middle and apical root thirds. There is a statistically significant difference between groups using no activation, MDA and overall (regardless of the activation technique).

INTRODUCTION

The root canal therapy procedure involves using manual and rotary equipment to widen and shape the root canals to an appropriate dimension. This allows for effectively delivering fluids with tissue-dissolving and antibacterial properties to the apical region. One of the primary challenges encountered in the field of endodontics pertains to the fluid dynamics of irrigants inside the restricted canal space. This issue inhibits the effective penetration of irrigants into the deeper regions of the canal, mostly due to the lack of turbulence throughout a significant portion of the canal volume [(1)].

A continuous stream of irrigants is crucial for achieving successful outcomes in endodontic procedures. This is because the irrigants serve multiple purposes, including the dissolution of inflammatory and necrotic tissue, the disinfection of canal walls by eliminating bacteria and biofilm, and removing debris and smear layer from the root canal. The intricate structure of the root canal system and the restricted depth of penetration into the dentine, along with the branching nature of the endodontic space, impose limitations on the efficacy of frequently employed irrigants in achieving comprehensive cleaning, debridement, and disinfection of the root canal system in all dimensions (2).

Traditional chemo-mechanical preparation methods can only partially eliminate living and dead tissues from the narrow areas of the tooth, such as the isthmuses, lateral canals, and apical ramifications. As a result, certain inflamed and/or infected tissues may remain and contribute to the development of chronic apical periodontitis (1).

Sodium hypochlorite (NaOCl) (DHARMA CALIX ,DHARMA United States) is frequently employed as the primary endodontic irrigant due to its notable antibacterial properties and ability to dissolve tissue. Various circumstances influence the efficiency of the subject, the enhancement of tissue-dissolving effectiveness can be significantly increased, up to a factor of 50, through the optimization of many factors such as surface tension, concentration, temperature, agitation, and flow. Enhancing the fluid dynamics of the irrigants within the canal space seems to impact the efficacy of root canal treatment significantly (3).

Currently, there are two methods for activating irrigants within root canal systems. Initially, the fibre is introduced into the fluid-filled channel and subsequently stimulated, either in a stationary position or while undergoing limited displacement inside the canal. The aforementioned method is commonly known as laser-activated irrigation. Furthermore, using fiber stimulates the irrigant within the pulp chamber during the root canal procedure. The technique known as photon-induced photoacoustic streaming was initially documented in the literature (4).

Ensuring complete sealing of the root canal system from the apex towards the canal orifice is of utmost importance for long-term prognosis. Throughout the past century, many root canal-filling materials and procedures have been introduced to reduce microleakage within root canals. Over the past twenty years, there has been a notable emphasis on adhesive filling materials, particularly with their ability to adhere to root dentin in root canal procedures. This increased attention is mostly owing to recognizing their effectiveness in minimizing microleakage (5).

In addition, the enhancement of fracture strength is shown through the attachment of root canal filling materials to dentin. Research in this field has predominantly concentrated on the comparative analysis of the adhesive characteristics of root canal filling materials, with a special emphasis on sealers. This study investigates the impact of various dentin surface treatments on adhesion, such as irrigants, chelators, and laser systems (6).

The null hypothesis is that there is no significant difference in smear layer removal using QAS (FiteBac®,3698 Largent Way Nw, Ste 101, Marietta, GA 30064, United States) or NaOCl and EDTA with or without different activation protocols.

This study aimed to conduct an *in-vitro* comparison of the efficacy of removing the smear layer between saline (NaOCl + Saline + EDTA) and quaternary ammonium silane irrigants activated by either manual agitation or laser activation techniques (Fotona, LightWalker®, Fotona Ljubljana, Slovenia).

MATERIAL AND METHODS

Methods:

Sample Selection

Sample size calculation conducted a power analysis (G power version 3.1 statistical software, Franz Faul, Universität Kiel Germany The findings indicated a minimum sample size of n= 126 samples, (14 samples for each group) based on α of 5% and a power of 95%.

Freshly extracted 63 human anonymous maxillary canines were used in the study; the teeth extracted from patients were in the age range (25-45) years. Teeth were extracted due to periodontal reasons[7]. Teeth were inspected under stereomicroscope. They were cleaned from calculus and tissue deposits using an ultrasonic scaler. The teeth collected were included in the study when they accomplished the following criteria: recently extracted human maxillary canine teeth; teeth with completely formed roots; not endodontically treated teeth; teeth with single straight root canal type I (Vertucci classification)[8]. The teeth were excluded from the study when they had cracked roots, open apices, resorptive defects, large carious lesions approaching the root and previous root canal treatment.

Sample grouping:

Teeth were divided randomly into three groups: A1, A2, and A3 (n=42), according to the type of irrigant used. Each main group was subdivided into three subgroups according to the activation method: B0, B1, and B2 (n=14). Then, each group were evaluated using SEM.

Application of the different irrigating solutions:

The root lengths were standardized to 20 mm using caliper by removing the crowns perpendicular to the long axis by means of water-cooled diamond disc for decoronation. To simulate clinical conditions, thus creating a closed-end environment, apices were sealed using wax on the root surfaces with 3mm thickness. To prevent wax from entering the canal, a #10 -file was inserted before the apex sealed.

Irrigation was done after each file with 3ml of 5.25 NaOCl using a 30-gauge syringe side vented needle mounted on a handle-held syringe (NaviTip) (Ultradent, South Jordan)[9] was used to deliver 3mL of irrigant into the canals; the needle tip was placed 2 mm short of WL, and the irrigant solution replenished every 2 min to prevent depletion of the irrigants activity and according to a final flush protocol: Group A1, canals were irrigated with saline, group A2 canals were irrigated with NaOCl +Saline +EDTA respectively and group A3 canals were irrigated with QAS[10,11]. All irrigation protocols were performed in a closed system, and irrigants were kept in the pulp space at a 3 mL/min rate during

Evaluation of smear layer removal using SEM:

The SEM was used to evaluate the smear layer removal of all teeth. Two longitudinal superficial grooves were made in the mesial and distal regions of each sample using a diamond disk, and the roots then split into labial and palatal halves from the created groove by a chisel without the disk entering the canal (Figure 1-2) [12]. The image analysis for SEM Images was processed using ImageJ software (version 1.53a National Institutes of Health, USA). The entire image area was automatically measured in μm, and then the total area of opened dentinal tubules was calculated as % of the total image area using the equation [13].

$$\text{Open dentinal tubules \%} = \frac{\textit{Total area of opened dentinal tubules } (\mu m)}{\textit{Total image area } (\mu m)} \times 100$$

Fig. (1) Photograph showing superficial grooves and chisel

Fig. (2) Photograph showing tooth assembling using chisel (a). Photograph showing labial and palatal halves of the tooth (b).

For each root, the half containing the most visible part of the endodontic wall was conserved and coded. The coded specimens were evaluated using a SEM at a magnification of 1000X.

Statistical analysis

The statistical analyses were performed for comparison between different Treatments groups (A1; A2, A3) at different activation methods "subgroup (B0, B1, B2) at three different section levels apical, middle, and cervical (C1, C2, C3).

The data was collected, checked, revised, and organized in tables and figures using Microsoft Excel 2016. Data was subjected to outliers' detections and normality statistical test to detect whether the data are parametric or nonparametric. The statistical analyses of the data were performed using analysis of variance (ANOVA) followed by Duncan multiple range tests. The Pearson Correlation coefficient test was applied to study the correlation between the different measuring methods. Data analyses were conducted using the computer software Statistical Package for Social Science SPSS (IBM-SPSS ver. 29.0 for Mac OS) [14].

RESULTS

I) Percentage of open dentinal tubules (%)

1- Intragroup comparison

1-a-Comparison of root thirds

A comparison of root thirds within the same group is presented in Table (1).

No activation, there was no statistically significant difference in the percentage of open dentinal tubules between root thirds.

Manual dynamic agitation group, there was a statistically significant difference between the three thirds.

Sweeps-Laser group, there was a statistically significant in difference In between the three thirds (P- value =0.002).

The highest mean value was recorded in the sweeps–laser group, followed by Manual dynamic agitation, with the lowest value recorded in the no activation group. The difference between the activation methods was statistically significant (p=0.007 in the cervical third, p=0.011 in the middle third and p=0.045 in the apical third).

Table (1) *Mean ±SD of the percentage of open dentinal tubules (%) in the different thirds for all groups.*

	Group	Cervical	Middle	Apical	P-value*
Saline	**No activation**	2.47±0.85^{aC}	1.17±0.17^{bC}	0.71±0.08^{cC}	**0.000^{S}**
	Manual dynamic agitation	5.44±0.74^{aB}	2.42±0.66^{bB}	1.11±0.14^{bB}	**0.011^{S}**
	Sweeps – laser	8.31±1.47^{aA}	5.05±2.22^{bA}	2.62±1.69^{cA}	**0.006^{S}**
	**P-value	0.000* **S**	0.000* **S**	0.005* **S**	
NaOCl	**No activation**	8.18±0.48^{aC}	5.33±0.72^{bB}	2.66±0.27^{cB}	**0.004^{S}**
	Manual dynamic agitation	11.29±0.49^{aB}	5.92±0.6^{bB}	4.12±2.24^{cA}	**0.008^{S}**
	Sweeps – laser	14.19±0.57^{aA}	8.49±1.68^{bA}	5.56±1.21^{cA}	**0.013^{S}**
	**P-value	0.000* **S**	0.000* **S**	0.007* **S**	
QAS	**No activation**	3.51±1.68^{aC}	1.41±0.6^{bC}	1.37±0.47^{bB}	**0.002^{S}**
	Manual dynamic agitation	6.24±1^{aB}	2.99±0.86^{bB}	1.91±0.62^{bB}	**0.029^{S}**
	Sweeps – laser	9.8±3.08^{aA}	5.35±1.48^{bA}	2.76±0.34^{cA}	**0.002^{S}**
	**P-value	0.000* **S**	0.000* **S**	0.000* **S**	
All solutions	**No activation**	4.72±3.04^{aC}	2.64±2.34^{aC}	1.58±0.99^{aC}	**0.055 NS**
	Manual dynamic agitation	7.66±3.17^{aB}	3.78±1.88^{bB}	2.38±1.56^{cB}	0.001* **S**
	Sweeps – laser	10.77±3.06^{aA}	6.30±1.91^{bA}	3.65±1.66^{cA}	**0.000*S**
	**P-value	0.007* **S**	0.011* **S**	0.045*	

1-b- Comparison of activation methods

Small letters for Intragroup comparison (cervical vs. middle vs. apical) and Capital superscript letters for intragroup comparison between the three activation methods (No activation vs MDA vs laser). The means with different superscripts are statistically significant at $P \leq 0.05$ (Tukey post hoc test).* P-value for comparison between the three-thirds (cervical, middle, and apical) in every group (ANOVA test). **P-value for comparison between activation methods (No activation, MDA, and laser) in every group (ANOVA test). S= Statistically Significant (p-value ≤ 0.05), NS= non-significant (p-value < 0.05).

2- Intergroup comparison

Results are summarized in Table (2), Figures (3-5).

2-a- Comparison between groups using each activation method

The highest mean value was recorded in NOCl, followed by QAS, with the lowest value recorded in saline. The difference between groups was statistically significant in the cervical third (p=0.005), middle third (p=0.003), apical third (p=0.001) and in all root thirds (p=0.003).

2-b- Overall comparison between groups

In the root overall, we can observe the following:

- The highest penetration was achieved in the NaOCl laser group and the lowest in the saline No act group.
- There is a statistically significant difference between groups using no Activation (p=0.002),

MDA (p=0.031) and overall (regardless of the activation technique) (p=0.003). However, there was no significant difference between groups of irrigation solutions when used with laser activation (p=0.11).

- The overall p-value was statistically significant, meaning there were differences between groups, especially between NaOCl laser (the highest mean of percentage of open dentinal tubules) and Saline No act (the lowest mean of percentage of open dentinal tubules).

Table (2) *Mean ±SD of the percentage of open dentinal tubules (%) in the different thirds for all groups.*

	Group	Cervical	Middle	Apical	All root thirds
No activation	**Saline**	$2.47{\pm}0.85^{E}$	$1.17{\pm}0.17^{D}$	$0.71{\pm}0.08^{B}$	$1.45{\pm}0.91^{C}$
	NaOCl	$8.18{\pm}0.48^{CD}$	$5.33{\pm}0.72^{BD}$	$2.66{\pm}0.27^{AB}$	$5.39{\pm}2.76^{A}$
	QAS	$3.51{\pm}1.68^{DE}$	$1.41{\pm}0.6^{CD}$	$1.37{\pm}0.47^{B}$	$2.10{\pm}1.22^{B}$
	P value*	**0.000^{S}**	**0.000^{S}**	**0.000^{S}**	**0.002^{S}**
Manual dynamic agitation	**Saline**	$5.44{\pm}0.74^{DE}$	$2.42{\pm}0.66^{CD}$	$1.11{\pm}0.14^{B}$	$2.99{\pm}2.22^{C}$
	NaOCl	$11.29{\pm}0.49^{BC}$	$5.92{\pm}0.6^{BC}$	$4.12{\pm}2.24^{A}$	$7.11{\pm}3.73^{A}$
	QAS	$6.24{\pm}1^{DE}$	$2.99{\pm}0.86^{CD}$	$1.91{\pm}0.62^{AB}$	$3.71{\pm}2.25^{B}$
	P value*	**0.000^{S}**	**0.000^{S}**	**0.002^{S}**	0.031^{S}
Sweeps - laser	**Saline**	$8.31{\pm}1.47^{CD}$	$5.05{\pm}2.22^{BD}$	$2.62{\pm}1.69^{AB}$	$5.43{\pm}2.85^{B}$
	NaOCl	$14.19{\pm}0.57^{AB}$	$8.49{\pm}1.68^{AB}$	$5.56{\pm}1.21^{A}$	$9.41{\pm}4.39^{A}$
	QAS	$9.8{\pm}3.08^{AC}$	$5.35{\pm}1.48^{BD}$	$2.76{\pm}0.34^{AB}$	$5.87{\pm}3.59^{B}$
	P value*	**0.000^{S}**	**0.004^{S}**	**0.000^{S}**	0.11^{NS}
All activation methods	**Saline**	$5.41{\pm}2.92^{B}$	$2.98{\pm}2.15^{B}$	$1.48{\pm}1.01^{C}$	$3.29{\pm}2.01^{C}$
	NaOCl	$11.22{\pm}3.01^{A}$	$6.58{\pm}1.68^{A}$	$4.11{\pm}1.45^{A}$	$7.30{\pm}2.02^{A}$
	QAS	$6.52{\pm}3.15^{B}$	$3.15{\pm}1.83^{B}$	$2.01{\pm}0.70^{B}$	$3.89{\pm}1.89^{B}$
	P value*	**0.005^{S}**	**0.003^{S}**	**0.001^{S}**	0.003^{S}
P- Value**		**0.000^{S}**	**0.002^{S}**	**0.024^{S}**	

*Capital letters for Intergroup comparison and the means with different superscripts are statistically significantly different at P ≤ 0.05 (Tukey post hoc test). *P value using each irrigation solution **Overall P-value for intergroup comparison (ANOVA test). S= Statistically Significant (p-value ≤ 0.05).*

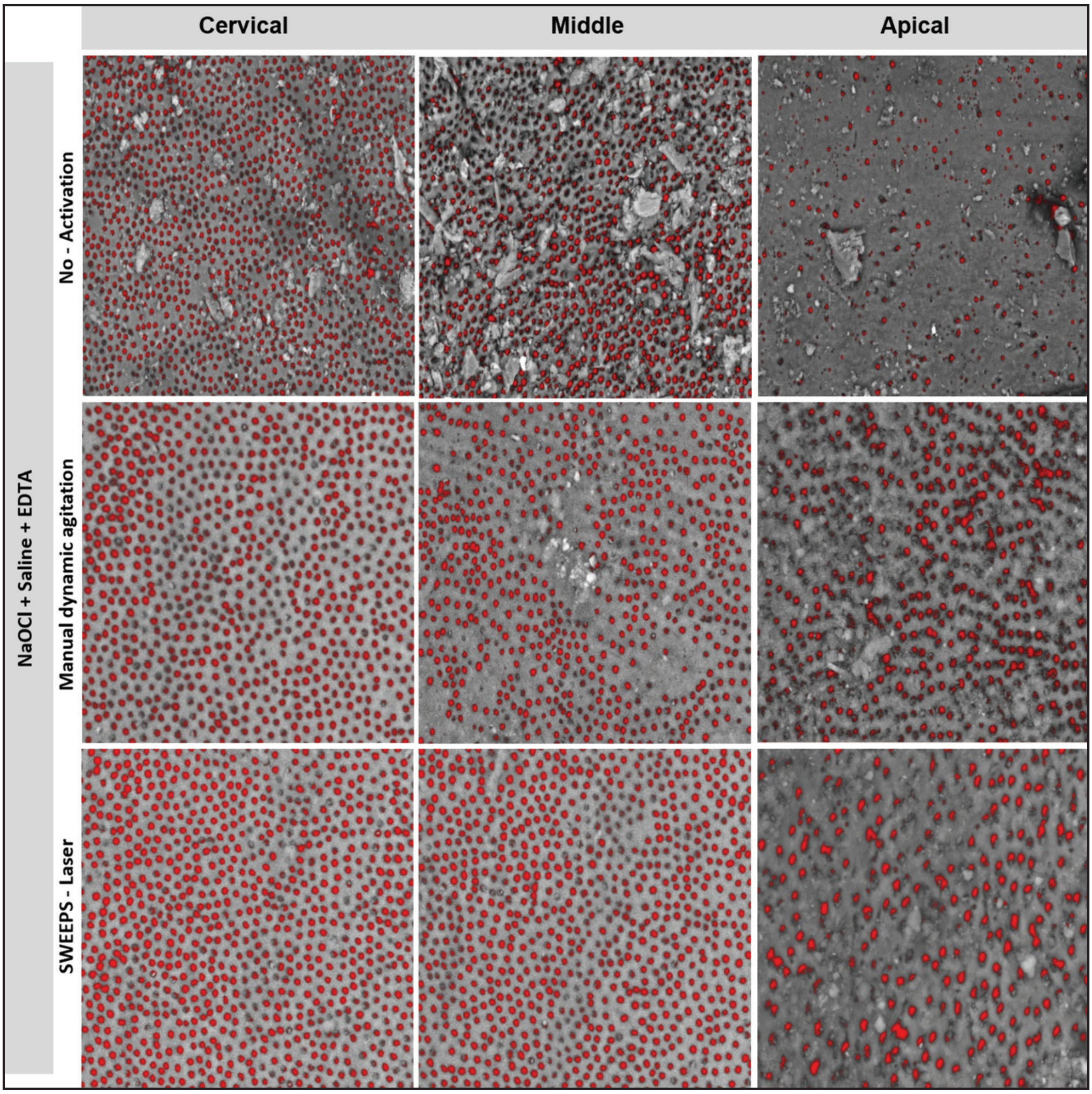

Fig. (3) SEM images (magnification 2000X) showing the percentage of open dentinal tubules (%) for NaOCl No Act, NaOCl MDA, and NaOCI SWEEPS- Laser groups at the cervical, middle, and apical thirds.

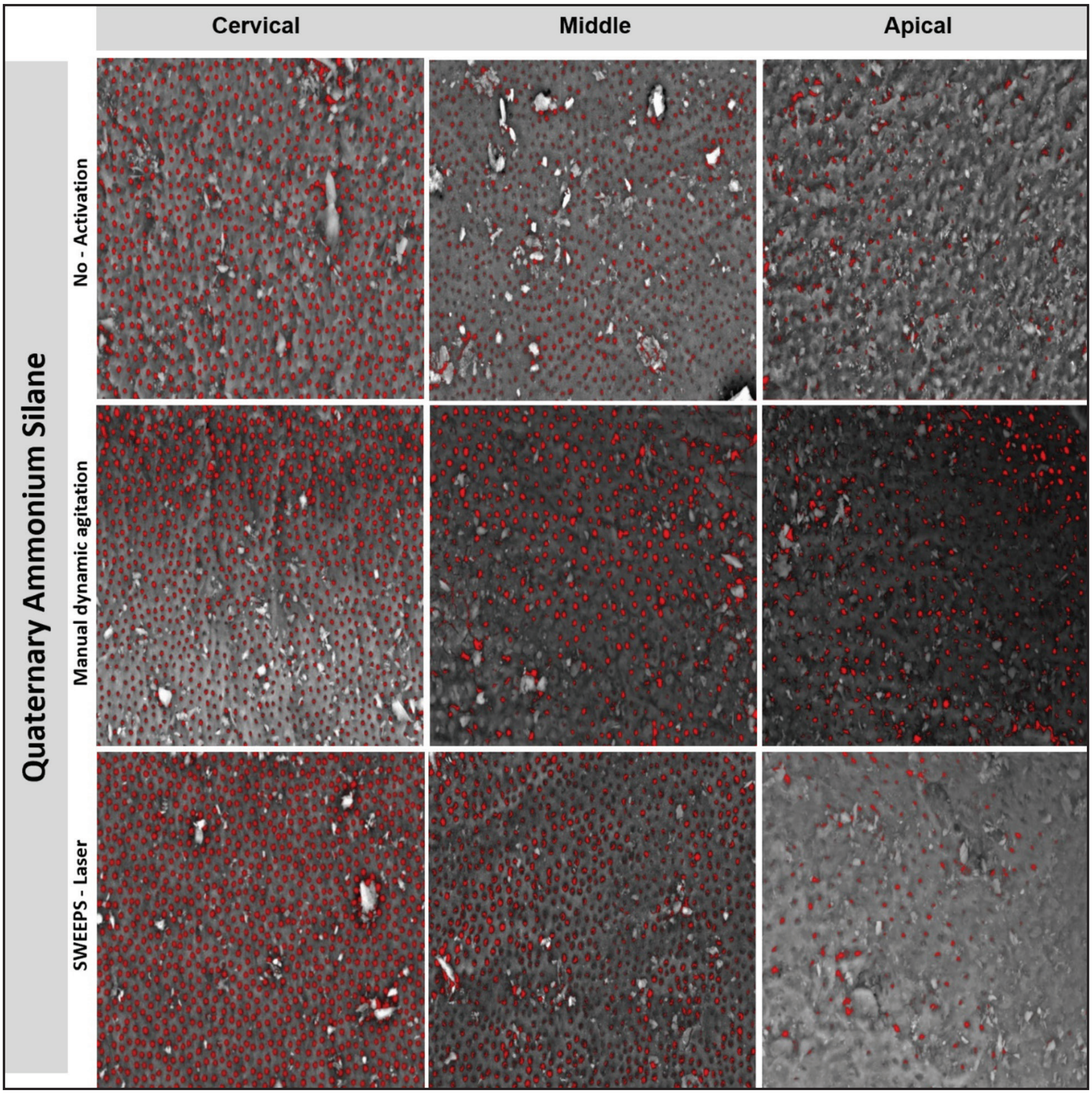

Fig. (4) SEM images (magnification 2000X) showing the percentage of open dentinal tubules (%) for QAS No Act, QAS MDA, and QAS SWEEPS- Laser groups at cervical, middle, and apical thirds

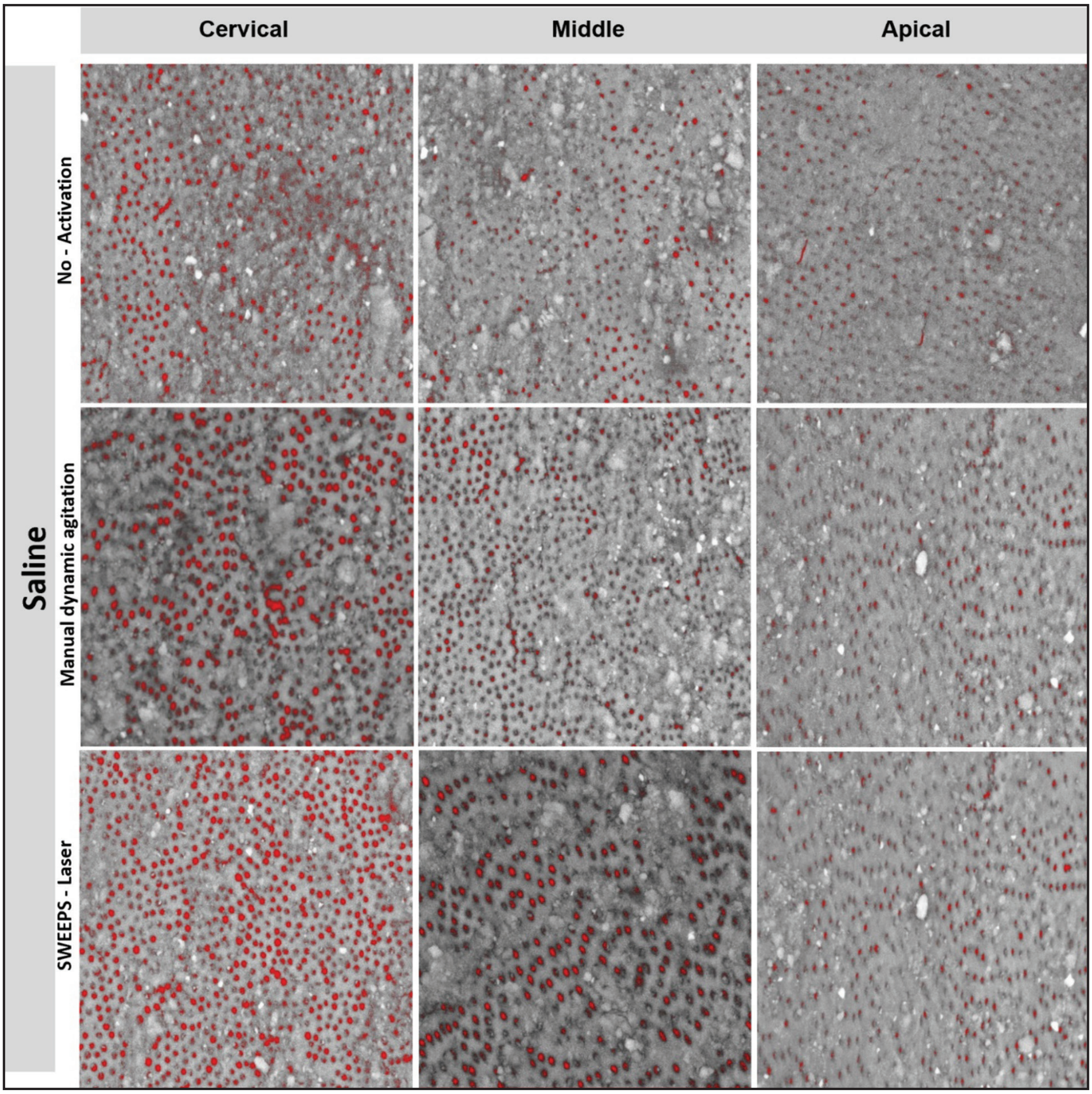

Fig. (5) SEM images (magnification 2000X) showing the percentage of open dentinal tubules (%) for Saine No Act, Saline MDA, and Saline SWEEPS- Laser groups at cervical, middle, and apical thirds

DISCUSSION

The implementation of three-dimensional disinfection within the root canal system is a crucial determinant for the attainment of successful endodontic therapy. Disinfection procedures in the field of dentistry typically involve the utilization of mechanical instruments, chemical irrigants, and intra-canal medicines. One of the initial difficulties encountered during the mechanical preparation process involves the removal of the smear layer that obstructs the canal lumen. The smear layer is a microcrystalline structure consisting of dentinal shavings, soft tissue debris, and leftover microorganisms [(15)].

Several irrigants have been suggested to enhance the cutting efficacy of root canal instruments, facilitate the removal of debris, and dissolve both organic and inorganic components within the smear layer. NaOCl is widely recognized as the predominant irrigant solution employed in root canal irrigation, having been utilized as a standard procedure for several decades. The substance functions as a natural solvent for organic compounds and fats, breaking down fatty acids and converting them into fatty acid salts and glycerol. This process subsequently decreases the surface tension of the solution. In addition, it should be noted that NaOCl can neutralize amino acids, resulting in the formation of water and salt. The departure of hydroxyl ions results in a decrease in pH. NaOCl is a chemical compound that can dissolve organic tissues, whereas its impact on inorganic tissues is minimal [(16)].

In the present investigation, a protocol involving the sequential use of NaOCl and an alternative irrigant solution, such as EDTA, was employed to address the limited effectiveness of NaOCl alone in removing inorganic tissue. Saline intervals prevent the interaction between NaOCl and EDTA, two commonly used irrigants in dental procedures. EDTA, or ethylenediaminetetraacetic acid, is widely used in various applications as a chelating agent. In dentistry, it is commonly employed to interact with calcium ions present in dentine, resulting in the formation of soluble calcium chelates. Extensive literature has demonstrated that EDTA effectively decalcifies dentine, reaching a depth of 20 to 30 micrometers within a period of 5 minutes [(1)].

Currently, QAS is being utilized for root canal irrigation because it provides optimal antimicrobial protection within the root canals. This facilitates a toxic effect against the *Enterococcus Faecalis* biofilm. Additionally, QAS exhibits low viscosity and low surface tension, enabling it to penetrate more dentinal tubules than alternative irrigation solutions [(17)].

The present study utilized maxillary canines because of their notable bilateral symmetries in terms of root and canal numbers and shape. According to ***Kumar et al.*** [(18)]***,*** a significant proportion of maxillary canines had a solitary root with a singular canal characterized by a type I canal structure. This uniformity in root and canal morphology minimized the influence of variable factors within the study.

The present study adopted a conservative approach for canal shaping, utilizing an apical size of #40 and a taper of 0.04. This approach aimed to minimize the removal of dentinal tissue while allowing for the assessment of the sealer's maximal penetration depth. To replicate the conditions of the oral cavity and prevent the escape of irrigants during preparation, the apex is sealed with wax during irrigation [(19)].

The irrigation delivery method employed in the present investigation primarily involved the utilization of the NaviTip, an end port needle and positive pressure irrigation device that is widely employed. Utilizing a needle with a gauge size above 27 is advantageous as it enables enhanced infiltration of irrigants into the apical portion of the canal. Most of the studies in the analysis employed a side-vented needle for irrigation, a technique that enhances safety by reducing the risk of irrigant extrusion [(4)].

One of the major difficulties encountered during the mechanical preparation phase is the intricate nature of the root canal system, which includes various anatomical features such as the apical delta, isthmus, ramifications, and lateral canals. These structures are commonly found in the apical region, and their thorough cleaning is crucial for successful treatment outcomes [(17)].

Given that mechanical instrumentation alone is only capable of eliminating 50% of bacteria from the root canal, the use of irrigating solutions becomes necessary to eradicate microbiota from areas that are inaccessible to instruments effectively. A root canal is a dental procedure that involves the removal of infected or damaged pulp from the root canal system of a tooth. The various techniques employed for irrigation can be classified into two primary classifications: manual delivery of the solution and utilization of machine-assisted agitation devices. Manual irrigation, or traditional syringe irrigation, involves using a syringe to apply positive pressure. Various types of machine-assisted irrigation equipment encompass sonic, ultrasonic, negative pressure irrigation, and laser-assisted irrigation. Various activation approaches are suggested for enhancing the efficacy of irrigation systems. The utilization of endodontic irrigants has been found to have advantageous effects in the mitigation of post-operative pain and enhancement of canal and isthmus cleanliness in the field of Endodontics [(16)].

The MDA method is a straightforward, efficient, and economical approach for inducing agitation of irrigants within the root canal system. MDA is a technique that induces increased pressure variations within the root canal. This is achieved by employing vertical strokes of a gutta-percha cone in the canal. The purpose of this technique is to displace the apical air bubble, which is known to cause the vapour lock effect. By doing so, MDA facilitates improved irrigant penetration into the root canal. Prior research has indicated that the utilization of irrigants' activation can enhance the infiltration of irrigants within lateral canals and the apical third of the canal, compared to relying solely on positive-pressure irrigation. Furthermore, a recent study by ***Kumar et al.*** [(18)] showed the efficacy of manual dynamic agitation in eliminating smear layers and debris in both closed canal and open systems. The results indicated that manual dynamic agitation achieved significantly greater smear layer removal levels than standard irrigation techniques.

The current investigation evaluated the efficacy of root canal cleaning using SEM. The SEM offers several key benefits, namely superior resolution and magnification capabilities. The SEM can achieve magnifications of up to 500,000 times, allowing for evaluating surface characteristics ranging from the microscale to the nanoscale. In contrast to optical microscopes, SEM does not rely on light. Consequently, the specimen's colour does not impact SEM images, a crucial factor when evaluating dental samples. The objective of this study was to assess the impact of three distinct irrigating solutions, namely saline, a combination of NaOCl, saline, EDTA, and QAS, with various activation methods on the removal of smear layer and sealer penetration at the apical, middle, and coronal thirds of the dentine wall.

This study aims to assess the percentage of open dentinal tubules using a scanning electron microscope

(Zeiss MERLIN Field Emission Scanning electron microscope, Carl Zeiss NTS GmbH, Oberkochen, Germany), specifically focusing on intragroup comparisons. The investigation comparing the apical, middle, and cervical root portions showed that the coronal slice consistently exhibited the largest proportion of open dentinal tubules across all activation methods and irrigant solutions.

According to ***Vatanpour et al.*** [4]***,*** the coronal level of the root canal exhibited the highest proportion of open dentinal tubules. This can be attributed to the coronal level's greatest diameter and the highest density of dentinal tubules.

The findings of the present investigation indicate that the activation of irrigants in the apical region resulted in lower values than the coronal and middle thirds. According to ***Tan et al.***[15]***,*** the hindrance of irrigant transportation into dentinal tubules is influenced by various factors, including anatomical variables such as a decrease in the number of tubules with smaller diameters and sclerotic dentine. Additionally, accessibility also plays a role in impeding this process. Another potential cause could be attributed to the apical vapour lock effect. The apical vapour lock effect refers to the phenomenon where an air bubble becomes trapped during irrigation in a closed-ended channel, specifically in the apical portion of the root canal. This occurrence hinders the penetration of irrigants, substances used to clean and disinfect the root canal.

A study conducted by ***Suman et al.*** [2] showed that the diameter of a root canal exhibits a reduction as one progresses from the coronal to the apical third. Therefore, during the irrigation process, the coronal dentin is subjected to a greater quantity of irrigants, which facilitates a more efficient flow of the solutions compared to the apical dentin. As a consequence, the removal of the smear layer from the coronal third is enhanced.

Comparing several activation approaches within each irrigant's third (apical, middle, coronal), the study revealed that the SWEEPS technique exhibited the most statistically significant difference. The manual dynamic agitation technique followed this, while the absence of an activation strategy resulted in the lowest level of effectiveness.

The phenomenon can be attributed to the ability of SWEEPs to induce acoustic streaming through the collapse of bubbles, resulting in the generation of a highly accelerated irrigant jet near the walls of the root canal. The application of acoustic streaming might potentially augment the efficacy of surface cleaning by subjecting the walls to elevated levels of shear stress. Utilizing the SWEEPS tip in clinical practice offers the notable benefit of preventing the need to bring the laser tip to the apical region [4]. Merely retaining the SWEEPS tip within the chamber adequately fulfils its intended function.

The present investigation showed that the use of MDA resulted in enhanced sealer penetration within the root canal system. This effect was achieved by the hydrodynamic mechanism, wherein the repeated motions of the master GP cone with short vertical strokes generated elevated intracanal pressure. The alteration in pressure facilitates the removal of the apical vapor lock, leading to enhanced penetration of the irrigant and thus explaining the superior outcome of MDA compared to the non-activation technique [20].

There was significantly recommended that better disinfection of the root canal system with laser activation and better removal of smear layer removal so successful root canal treatment can be achieved.

CONCLUSION AND RECOMMENDATIONS

From the present study we can conclude that, NaOCl + Saline + EDTA (5.25%) followed by saline and EDTA (17%) as an irrigating solution recorded the highest value in all root sections. QAS. is not an effective irrigating solution during root canal treatment in comparison to NaOCl +Saline +EDTA. Further studies target new irrigation solutions which increase sealer penetration depth and smear layer removal. A larger sample size was recommended to maximize the accuracy and validity of the resulted data.

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