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A COMPARATIVE SCANNING ELECTRON MICROSCOPIC (SEM) EVALUATION OF SMEAR LAYER REMOVAL WITH APPLE VINEGAR AND SODIUM HYPOCHLORITE ASSOCIATED WITH EDTA USING PASSIVE ULTRASONIC ACTIVATION (AN IN VITRO STUDY)

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ABSTRACT

Aim: This study compared apple cider as a single irrigant or in combination with 17% EDTA to 2.5% sodium hypochlorite (NaOCl) followed by 17% EDTA for the removal of smear layer from the middle and apical thirds in single-rooted teeth using passive ultrasonic activation.

Materials and Methods: Forty human-extracted mandibular premolars were prepared and randomized into four groups (n = 10) according to the irrigation protocol. Group I: Apple cider, Group II: Apple cider followed by 17% EDTA, Group III: 2.5% NaOCl followed by 17% EDTA and Group IV: control (Saline). Following chemo-mechanical preparation, the roots were cleaved longitudinally into two equal halves and analysed by Environmental Scanning Electron microscope (ESEM) at 1000x to evaluate the presence of a smear layer.

Results: There was no statistically significant difference between Groups I, II, and III in the middle third of the smear layer score. All three groups results were significantly lower than those of group IV. In the apical third, there was no significant difference in the scores of groups I, II, and III. Compared to group IV, groups I and II had lower scores. Group III and Group IV did not differ significantly from one another. Groups I ($p=0.247$), II ($p=0.218$), and IV ($p=0.971$) did not significantly vary in the middle and apical thirds scores from one another. Between group III's middle and apical thirds, there was a significant difference ($p<0.001$).

Conclusion: Apple cider used alone or followed by EDTA can remove smear layer comparable with NaOCl followed by EDTA.

KEYWORDS: Apple cider; NaOCl; Ethylenediaminetetraacetic acid; saline; passive irrigation.

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INTRODUCTION

The careful cleaning and contouring of the root canal system is the basis of endodontic root canal treatment. The root canal system must be prepared for this procedure, which causes the dentin to be covered in a granular, amorphous coating known as the smear layer. The smear layer will cover the root canal walls and obstruct the dentinal tubule openings, increasing the risk of bacterial infection. Furthermore, by obstructing their penetration into the dentinal tubules, irrigants and intracanal medications used in root canal therapy may be introduced more slowly due to the smear layer. Furthermore, it could hinder the ability of obturating materials to form an effective seal with the canal wall (Mohamed et al., 2022).

The principle endodontic irrigant is sodium hypochlorite (NaOCl), which is inefficient in eliminating the entire smear layer when applied alone. Concentrations of NaOCl range from 0.5% to 5.25%. In endodontics, chelating chemicals are utilized to help eliminate the inorganic smear layer and facilitate root canal irrigation (Rodrigues et al., 2013). NaOCl dissolves tissue and possesses antimicrobial qualities. It is also possible to remove the smear layer from the root canal using ethylenediamine tetra-acetic acid (EDTA). Smear layer elimination and root canal disinfection can be enhanced by irrigation with 17% EDTA and alternating NaOCl. However, EDTA solution has certain disadvantages since it can damage dentinal erosions and the periapical tissue (Mohamed et al., 2022). Because of its complex structure and the challenges of debridement, the apical part of the canal is the hardest to clean. Smear-free walls can be achieved by chelating chemicals like EDTA, mostly in the middle and coronal thirds of the wall. In the apical area of the root canal, the cleaning action is less effective and reduces as one approaches the apex. This may be explained by the apical third's small dimensions, which may prevent irrigants from being distributed effectively and limit the amount of contact between the solutions and the canal walls (Rodrigues et al., 2013). Additional substances like apple vinegar and citric acid have also been suggested as ways to remove the targeted smear layer. By mixing trace quantities of alcohol created during fermentation with acetic, citric, formic, lactic, succinate, and tartaric acids, apple vinegar reduces the surface tension of the solution (Safwat et al., 2017). The primary cause of its antibacterial activity is the acetic acid which results in the breakdown of cell integrity (Ali et al., 2019). The smear layer that blocks the dentinal tubule openings is composed of both organic and inorganic materials. This layer can be removed using apple cider vinegar. It has also been demonstrated to have bactericidal properties against bacteria like Staphylococcus aureus and Enterococcus faecalis (E. faecalis), which are commonly associated with endodontic infections (Betül and Kadriye, 2020).

It has been demonstrated that irrigation techniques involving syringes and needles are unable to reach regions with limited access, such as the apical and isthmus regions. Accordingly, it has been suggested that irrigating solutions applied by a variety of techniques need to be activated in order to improve their penetration and activity (Schmidt et al., 2015). Passive ultrasonic irrigation (PUI), which employs acoustic streaming or cavitation bubble implosions, improves root canal irrigant dispersibility. This irrigation strategy allows solutions to be delivered to hard-to-reach areas. The PUI approach allows for more complete removal of the smear layer and hard tissue debris. Furthermore, PUI reduces the bacterial concentration of chemical irrigants, which increases their disinfection efficacy (Mancini et al., 2013).

This in vitro study examined the effects of utilizing PUI to remove the smear layer from the middle and apical thirds of single-rooted teeth, either alone or in combination with 17% EDTA and 2.5% NaOCl.

MATERIALS AND METHODS

Sample preparation:

Ultrasonic scalers were used to remove any hard material from the teeth, and after 30 minutes, the teeth were immersed in 5.25% NaOCl to help remove any soft periodontal tissues and debris. Until they were needed to maintain the hydration of natural teeth, the teeth were preserved in a saline solution. Forty human mandibular premolars with a single canal and single root were divided into four groups (n = 10) at random: Group I (Apple cider); Group II (Apple cider followed by 17% EDTA); Group III (2.5% NaOCl followed by 17% EDTA); and Group IV (Saline). Using a low-speed diamond disc and generous irrigation, the teeth were decoronated to obtain uniform 16 mm root lengths that were measured using an endometer ***Figure (1)***.

A standardized working length of 15 mm was achieved by inserting K-file size 10 into the root canal to check for patency, then adjusting the working length with K-file #15 until it showed from the apex and subtracting 1 mm. Using the X-smart endomotor and the Pro-Taper Next rotary system, root canals were instrumented using the X1(17/.04) file and ending with X4(40/.06) file at a speed of 300 rpm and 2-2.5 N.cm torque in accordance with the manufacturer's recommendations.

A 30-gauge Fanta blue side vented needle was used to irrigate the specimen for one minute, using three milliliters of irrigant solution, as determined by the group to whom it was assigned. One millimeter was cut off from the working length of the needle. The next step is a three-minute passive ultrasonic activation. By inserting a #10 K-file in between each rotary file, apical patency was maintained. Following root canal instrumentation, 5 milliliters of normal saline (0.9% NaCl) was used to irrigate the teeth, and dried with x4 paper points.

Specimen preparation for ESEM assessment of smear layer removal:

Following various irrigation techniques, the roots were split longitudinally and buccal and lingual grooves were created on the external root surface under profuse irrigation without entering the canal lumen. A low-speed double-faced diamond disk was used to achieve this. After that, a hammer and microtome blade were used to cut the root into two equal pieces ***Figure (2)***.

The specimens were fixed with electro-conductor glue on an environmental scanning electron microscope(ESEM) plate after being dehydrated ***Figure (3)***.

All specimens were scanned using an ESEM Quanta 3D 200i at a magnification power of 1000x, using an acceleration voltage of 20 K.V. At 1000x magnification, the middle and apical thirds of each specimen's root canal were examined individually at 7 and 12 mm from the apex, respectively (Vemuri et al., 2016). ESEM images were obtained and analyzed.

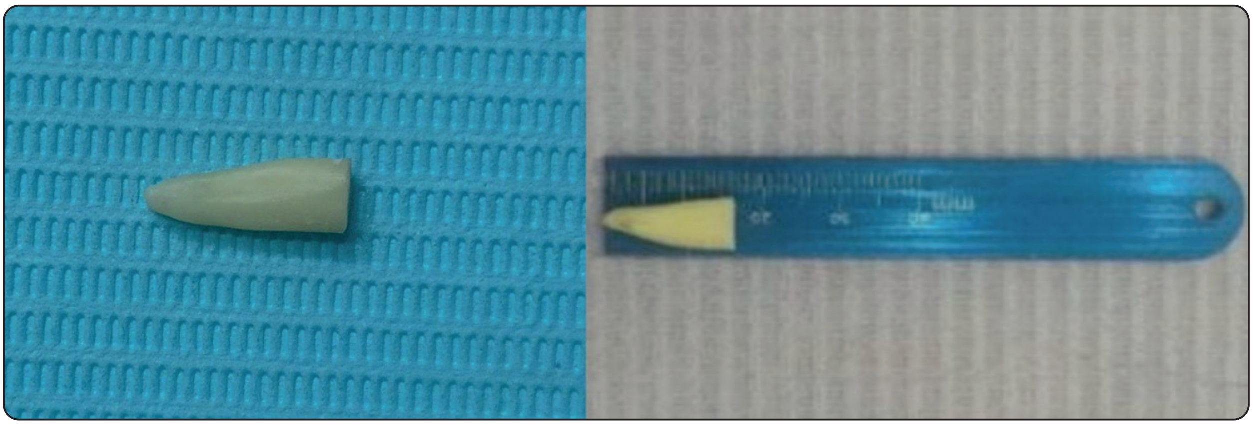

Fig. (1) Teeth after decoronation, leaving 16mm length of the root

Fig. (2) Sectioning each root longitudinally

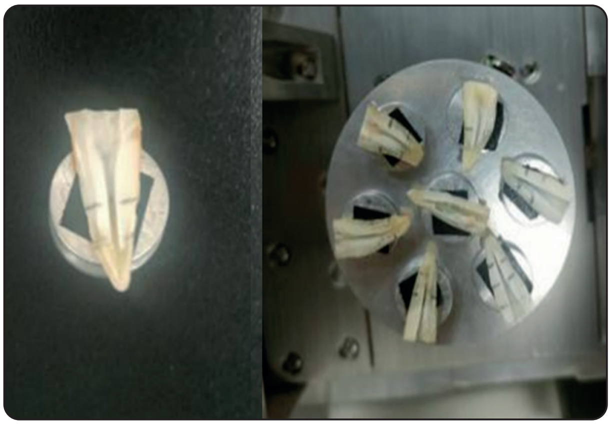

Fig. (3) Specimens after fixed on ESEM plate with electro-conductor glue

Outcome assessment:

Two observers who were blinded to the ESEM (Environmental Scanning Electron Microscopy) images used a scoring system to analyze the smear layer. For every sample, a mean smear layer score was calculated. The scoring system utilized was a 5-level scale described by Hülsmann et al. (1997), structured as follows:

- Score I: indicates that there are open dentinal tubules and no smear layer.
- Score II: indicates that there is a smear layer present but that some dentinal tubules are still open.
- Score III: shows that the root canal wall has a uniform smear layer covering it, and that very few dentinal tubules are exposed.
- Score IV: indicates that there are no apparent exposed dentinal tubules and that the root canal wall is completely covered with a uniform smear layer.
- Score V: represents a thick, uneven layer of smears that covers the whole root canal wall.

RESULTS

Smear layer scores:

At the middle third:

For the middle third of the smear layer scores, the mean and standard deviation were 1.7 (0.5) for group I, 1.8 (0.6) for group II, 1.5 (0.5) for group III, and 4.1 (0.9) for group IV. Group I had 2 (1–2), Group II had 2 (1-3), Group III had 1.5 (1-2), and Group IV had 4 (3-5) as the median and range values for the middle third's smear layer scores. The four groups differed significantly from one another ($p<0.001$) ***Figure (4)***.

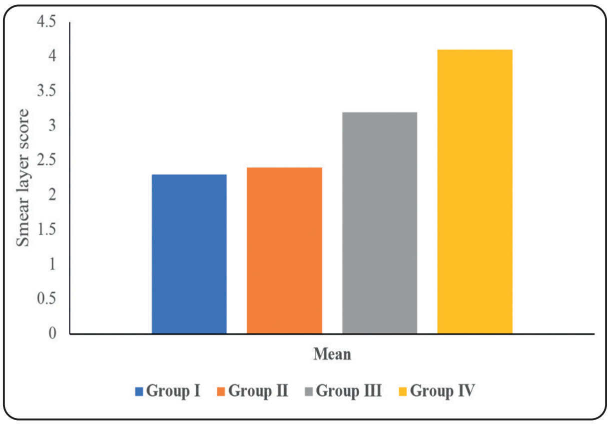

Fig. (4): Bar chart representing the mean smear layer score of the middle third in the four groups

Pairwise comparisons:

Between groups I, II, and III, there was no signficant difference in the middle third's smear layer score. Compared to group IV, all three groups' smear layer scores were significantly reduced ***Table (1)***.

At the apical third:

The mean and standard deviation values of the smear layer scores of the apical third were 2.3 (1.2) in group I, 2.4 (1.1) in group II, 3.2 (1) in group III and 4.1 (0.7) in group IV. The median and range values for the smear layer scores of the apical third were 2 (1 - 5) in group I, 2 (1 - 5) in group II, 3 (2 - 5) in group III and 4 (3-5) in group IV. There was a significant difference between the four groups (p=0.002) ***Figure (5)***.

Pairwise comparisons:

Groups I, II, and III did not significantly vary in the smear layer score of the apical third. Compared to group IV, groups I and II had much lower smear layer scores. Group III and group IV did not differ significantly from one another ***Table (2)***.

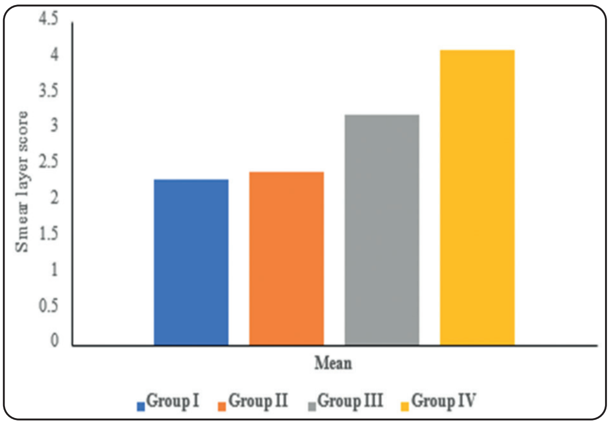

Fig. (5) Bar chart representing the mean smear layer score of the apical third in the four groups

TABLE (1) Descriptive statistics and the results of Kruskal Wallis test and pairwise comparison with Bonferroni correction for comparison of the smear layer score of the middle third between the four groups

	Group I	Group II	Group III	Group IV	*p*-value
Mean (SD)	1.7[a] (0.5)	1.8[a] (0.6)	1.5[a] (0.5)	4.1[b] (0.9)	<0.001*
Median (Range)	2 (1 - 2)	2 (1 - 3)	1.5 (1 - 2)	4 (3 - 5)	

****Significant at p<0.05*** *****Different lower-case letters indicate statistical significance***

TABLE (2) Descriptive statistics and the results of Kruskal Wallis test and pairwise comparison with Bonferroni correction for comparison of the smear layer score of the apical third between the four groups

	Group I	Group II	Group III	Group IV	*p*-value
Mean (SD)	2.3[a] (1.2)	2.4[a] (1.1)	3.2[ab] (1)	4.1[b] (0.7)	0.002*
Median (Range)	2 (1 - 5)	2 (1 - 5)	3 (2 - 5)	4 (3 - 5)	0.002*

****Significant at p<0.05*** *****Different lower case letters indicates statistical significance***

TABLE (3) Descriptive statistics and the results of Mann-Whitney U test for comparison of the smear layer score between the middle and apical thirds of the same group

	Group I		**Group II**		**Group III**		**Group IV**	
	Middle	**Apical**	**Middle**	**Apical**	**Middle**	**Apical**	**Middle**	**Apical**
Mean (SD)	1.7 (0.5)	2.3 (1.2)	1.8 (0.6)	2.4 (1.1)	1.5 (0.5)	3.2 (1)	4.1 (0.9)	4.1 (0.7)
Median (Range)	2 (1 - 2)	2 (1 - 5)	2 (1 - 3)	2 (1 - 5)	1.5 (1 - 2)	3 (2 - 5)	4 (3 - 5)	4 (3 - 5)
***p*-value**	**0.247**		**0.218**		**<0.001***		**0.971**	

****Significant at p<0.05***

Within each group:

The smear layer scores of the middle and apical thirds within groups I (p=0.247), II (p=0.218), and IV (p=0.971) did not differ significantly from one another. Smear layer evaluations in group III varied significantly between the middle and apical thirds (p<0.001) ***Table (3) Figure (6)***.

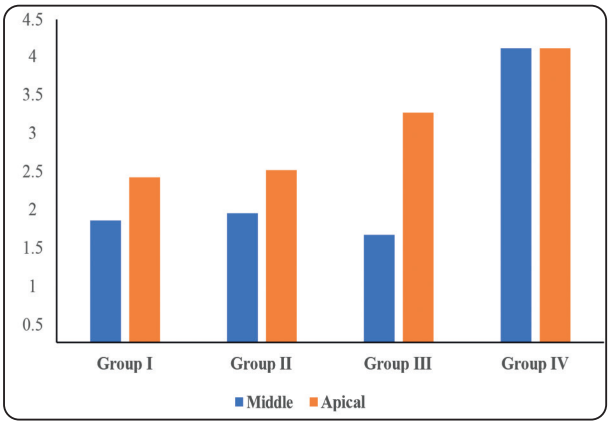

Fig. (6) Bar chart representing the mean smear layer score of the middle and apical thirds in the four groups

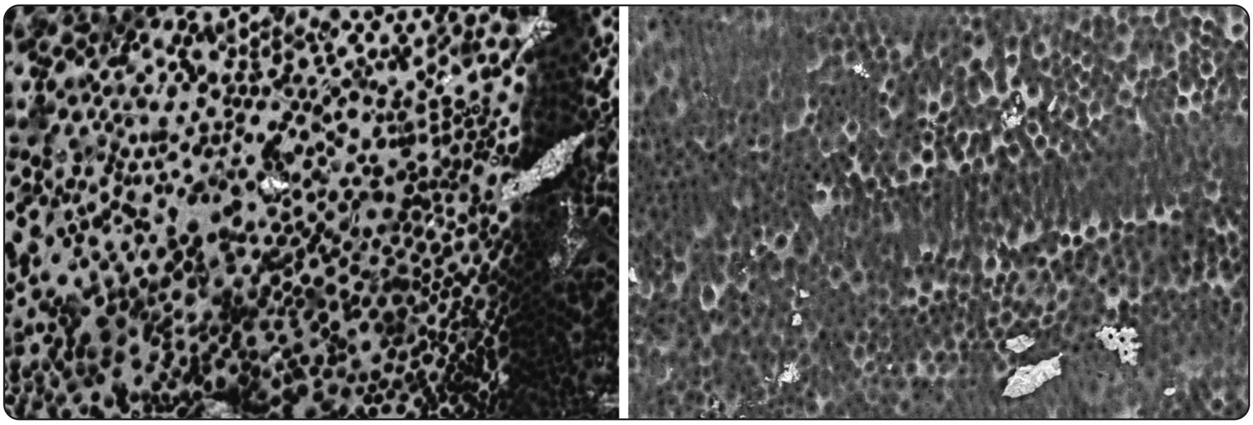

Fig. (7) ESEM micrograph of group I (apple cider) middle third (left), apical third (right)

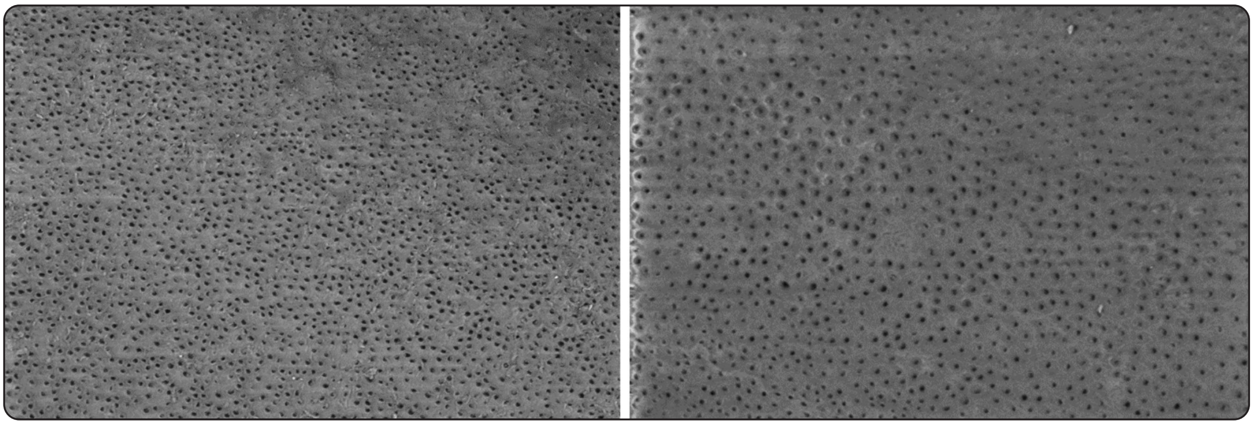

Fig. (8) ESEM micrograph of group II (apple cider + EDTA) middle third (left), apical third (right)

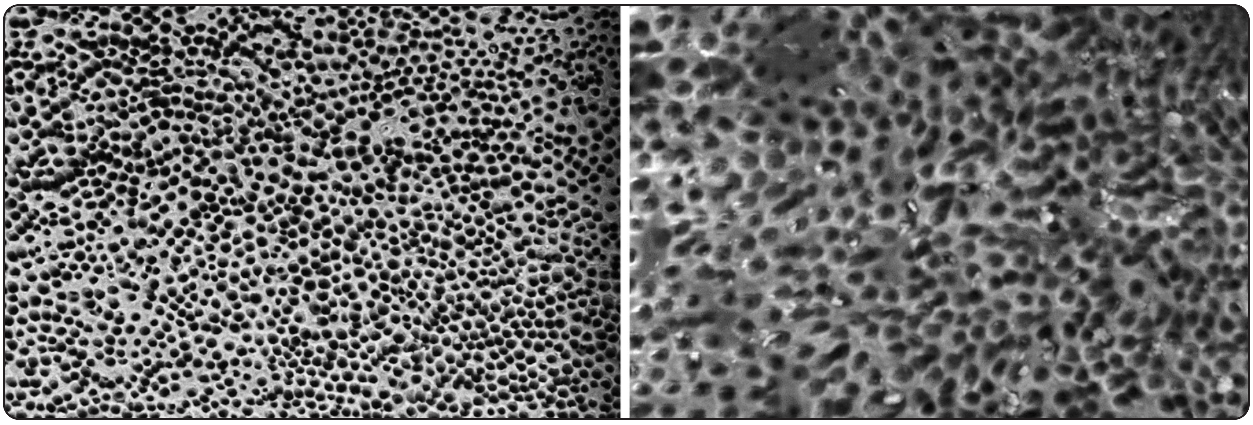

Fig. (9) ESEM micrograph of group III (NaOCl + EDTA) middle third (left), apical third (right)

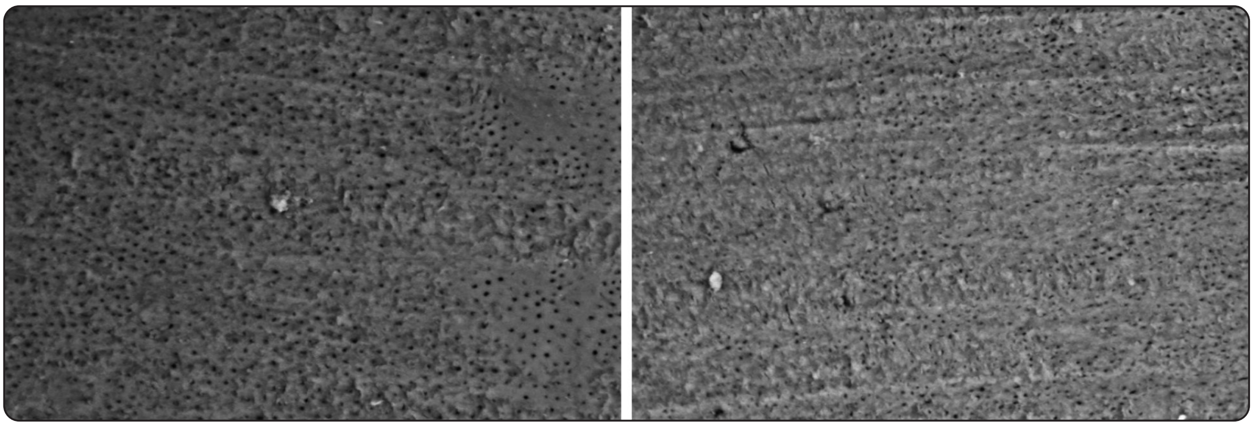

Fig. (10) ESEM micrograph of group IV (saline) middle third (left), apical third (right)

DISCUSSION

Endodontic therapy has a high success rate of 86% to 98%. According to Tabassum and Khan (2016), success depends on a number of variables, including proper chemo-mechanical preparation, root canal system cleaning, and three-dimensional obturation that lessens or eradicates the infection. Moreover, total bacterial eradication and smear layer removal have been found to be critical variables influencing the endodontic outcome. It is essential to eliminate bacteria and their byproducts from the root canal system in order to stop the development of apical periodontitis (Ørstavik, 2003). The elimination of the smear layer is essential to achieving these goals. While the question of whether to remove or leave the smear layer is still up for debate, this layer of bacteria can act as a barrier between the filling material and the canal wall, preventing disinfectants from entering the root canal and preventing the formation of a hermetic seal. Moreover, Alamoudi (2019) notes that the structure is weakly adherent, which could permit leakage between the root canal filling and the dentinal walls. Over time, numerous irrigants have been proposed as the perfect solution to fulfill all the requirements of a superior root canal irrigant, such as biocompatibility, antibacterial properties, and the capacity to eliminate the smear layer (Topbas & Adiguzel, 2017).

The most popular irrigating solution for root canal system cleansing and shaping is NaOCl. But because it primarily affects the organic component of the smear layer, research has revealed that its capacity to remove the smear layer from the root canal walls is insufficient (Safwat et al., 2017). 2.5% NaOCl has a strong ability to dissolve organic tissues and denature bacterial toxins, according to a research by Vaziri et al. (2012). Moreover, NaOCl has a significant impact even in areas without instruments. But as further investigations have shown, NaOCl cannot remove the smear layer (Dioguardi et al., 2018; Zeid et al., 2021).

The most commonly employed chelating agent as a final irrigant is 17% EDTA, which strongly could eliminate the smear layer. Nevertheless, it is cytotoxic, has a limited ability to reduce microorganisms, alters the dentinal structure significantly, and remains a pollutant even after it is manufactured (Zeid et al., 2021).

Several medical conditions, including cancer, heart disease, joint and body aches, diabetes, and weight loss, can be treated with apple cider. Its primary antibacterial effect stems from the acetic acid it contains, which breaks down cells. Apple vinegar lowers the surface tension of a solution by combining small amounts of alcohol produced during fermentation with acids such as acetic, citric, formic, lactic, malic, and tartaric. In addition, the fermentation process of apple vinegar produces alcohol, which lowers the substance's surface tension. According to reports, a root canal irrigant's effectiveness is contingent upon its close interaction with debris and dentin walls. This attribute is closely linked to the irrigant's surface tension (Safwat et al., 2017). Few studies have looked into apple cider vinegar's potential as a root canal irrigant (Mohanty et al., 2017). Natural irrigants, including apple vinegar, have been developed to lessen the detrimental effects of EDTA on dentin and periapical tissues on these tissues. Apple vinegar has been proposed for use as an irrigant in the chemomechanical process because it shows promising results similar to EDTA. Several investigations evaluated the efficiency of apple vinegar in removing smear layer and discovered that, when used as a last rinse for one minute, it outperformed 17% EDTA without lowering the intraradicular dentin's calcium level. After one minute of NaOCl irrigation, five milliliters of 17% EDTA and commercial apple vinegar were employed as a final rinse. It has been noted that smear layers can be successfully removed by irrigating with 5 ml of 17% EDTA for one minute of contact time. Similarly, smear layers may be effectively removed with a one-minute apple vinegar irrigation, according to research. The fact that apple vinegar is mostly made up of acids—malic acid being the primary ingredient responsible for the vinegar's medicinal effects—could help to explain these findings (Abdelghany et al., 2020). One chemical that makes an organism more resistant is malic acid. Cells produce energy through a reaction because this acid is one among those engaged in the Krebs cycle. Apple cider vinegar also has a great deal of medical potential because it contains essential minerals (calcium, potassium, magnesium, phosphorus, fluoride, sulfur, and silicon) as well as other compounds like pectin, beta-carotene, enzymes, and amino acids that fight free radicals and strengthen immunity. Furthermore, it has been shown to have bactericidal action against bacteria like as E. faecalis and Staphylococcus aureus, which are frequently associated with endodontic infections (Betül and Kadriye, 2020). According to Abdelghany et al. (2020), there was a statistically significant difference in the median smear layer scores between the all-root levels.

When compared to the intermediate and coronal levels, the apical level had the statistically significantly highest median smear layer score. Nonetheless, no statistically significant difference was seen between the coronal and intermediate levels. According to studies, the coronal and intermediate levels have an easier time eradicating the smear layer than the apical level. The irrigating solution works better in these thirds because the canals are broader than in the apical. The irrigating solution's effectiveness in the apical third has been shown to have obviously diminished on average. The dentin may be more sclerosed at the apical level, and the diameter of the root canal and dentinal tubules may have shrunk, limiting irrigant access and flow.

PUI uses acoustic streaming or cavitation bubble implosions to enhance the dispersion of root canal irrigants. This method of irrigation makes it possible for solutions to enter hard-to-reach places.

The PUI method encourages a more complete removal of hard tissue debris and the smear layer. Furthermore, by lowering the bacterial content, PUI increases the chemical irrigants' disinfection efficiency (Schmidt et al., 2020).

In contrast to 2.5% sodium hypochlorite followed by 17% EDTA, the aim of this study was to assess the effectiveness of using apple cider alone or in combination with 17% EDTA in removing smear layers from the middle and apical thirds of single-rooted teeth using passive ultrasonic activation.

Because of its many benefits, including the capacity to examine the ability to remove the smear layer and the inability to analyze results clinically as in clinical trials, this research design was implemented in a research institute.

Because the ESEM may yield subjective results depending on the areas under investigation and the operator's interpretation of the data, it was employed in this study. In this study, the pictures were collected at set lengths from the root apex (3, 7 and 12 mm) in order to standardize the readings. In addition, two skilled and blinded examiners carried out the ESEM examination in order to optimize the accuracy and dependability of the results (Mendonça et al., 2015).

The ability to scan samples without pretreatment, such as applying conducting coatings, eliminates the possibility of artifacts created during the SEM sample preparation process, which is one of the most important potential benefits of using the ESEM over SEM (Kirk et al., 2009). Furthermore, with the least amount of effort and time required, the ESEM offers technology for imaging hydrated or dehydrated materials (Collins et al., 1993). High-quality pictures with a spatial resolution as low as 1.5 mm and reduced electrostatic distortion are produced by using low vacuum and low voltage, which is 3–6 times better than SEM (Fitzek et al., 2015).

Magnifications ranging from low to high magnification power were utilized in the studies. High magnification power preserves surface detail when studying a large surface area, whereas low magnification power does the opposite. The smear layer was examined in the current study with a 1000x magnification because it produces a vast surface area with distinct details (Rüttermann et al., 2007; Zmener et al., 2009).

Because single-rooted mandibular premolars have a single oval canal cross-section, which is difficult for the rounded cross-sectioned endodontic file to touch and thoroughly clean, leaving large areas of unclean canal walls and accumulating hard-tissue debris in irregularities within the root canal space, this study includes these teeth (Peters et al., 2001; Mohammadi et al., 2015). These undeveloped areas may cover up to 35% of the canal walls overall, according to published research (Peters et al., 2001). As a result, the irrigants' efficacy and functionality would be more consistent.

Teeth with lengths ranging from 18 to 25 mm were selected for the decoronation process so that the final roots would measure 16 ± 1 mm. This is due to the fact that Cleghorn and Christie (2019) state that the average length of mandibular premolars is 22.5 mm.

In order to replicate a clinical scenario where the root apex is surrounded by periodontal ligaments and encased in the alveolar bone socket, a flowable composite was employed to seal the apex (Boutsioukis et al., 2014).

Pro-Taper Next rotary system was used for mechanical preparation in order to increase procedural efficiency, standardize the canal diameter, eliminate pulp tissue, and provide a more predictable preparation form (Capar et al., 2014; Matheus Albino Souza et al., 2021). This is due to the offset mass rotation motion, which results in an exclusive asymmetrical rotary motion. The file only touches the wall twice at any given cross-section, which reduces the taper lock and gives the file more cross-sectional space for improved debris loading and cutting (Ghobashy et al., 2016).

In order to achieve proper preparation, apical preparation was carried out using an X4 file as a master apical file, which is equivalent to size #40 ISO. This was necessary because large apical preparations (minimum ISO #40) and preparations smaller than file #40 leave much more unprepared dentin, ranging from 35% to 50% of the canal's surface (Hecker et al., 2010). The investigation by Usman et al. (2004) revealed that even with the taper set at 0.06, root canals prepared to size #20 showed significantly more apical debris than those prepared to size #40. Consequently, the standard procedure of sizing the canal tools three sizes bigger than the original file would not be sufficient to sufficiently clean the dentinal walls. Furthermore, fewer bacteria are present in larger apical preparations because bacteria remaining in the apical portion of the root may contribute to failure. In order to eliminate contaminated dentin and facilitate deeper irrigant flow, larger apical preparations are necessary. Furthermore, it was demonstrated that syringe irrigation was less successful when root canals smaller than size #40 were constructed (Hecker et al., 2010). According to Altaf et al. (2019), conventional needle irrigation has been shown to be insufficient for thoroughly cleaning the intricate anatomy of the root canal system, particularly the lateral canals, isthmuses, and the apical third.

The irrigant found it easier to flow through the apical third to clean the root canal of all debris because the 30-gauge side-vented needle employed in this study permitted the needle tip to be 1-2 mm shorter than the tooth apex (Van der Vyver et al., 2009).

A common method for assessing smear layer removal is a scoring system (Ahlquist et al., 2001). The scoring scale developed by Hülsmann et al. (1997) was employed in this study because, as evidenced by the literature (Safwat et al., 2017; Haupt et al., 2020; Nasher et al., 2020), it is straightforward, accurate, and easy to use.

There was no signficant difference in groups I, II, and III's middle third smear layer scores when it came to the removal of the smear layer. All three groups' smear layer ratings were much lower than those of group IV. It has been reported that middle thirds are easier than apical level to remove the smear layer from. This is because the irrigating fluid is more effective in these thirds since the canals there are larger than those in the apical. According to previous studies (Ali et al., 2019; Abdelghany et al., 2020), this is consistent.

Groups I, II, and III did not significantly differ in the smear layer score of the apical third with regard to smear layer removal. Groups I and II had significantly lower smear layer ratings than group IV. According to earlier research, this is the case (Safwat et al., 2017; Ali et al., 2019; Abdelghany et al., 2020; Mohamed et al., 2022).

The reason for our findings is that the irrigants cannot reach the apical third due to the presence of sclerotic dentin in the apical region of the canal, which makes the smear layer hard to completely remove (Paqué et al., 2006; Zeid et al., 2021). The coronal and middle thirds of the canal are broader than the apical third, which is the smallest part, allowing the irrigants to flow more easily (Ballal et al., 2016; Kato et al., 2016; Barcellos et al., 2020).

When compared to 2.5% NaOCl followed by 17% EDTA, the findings of using apple cider alone or followed by 17% EDTA as a final irrigant revealed no discernible variation in the elimination of the smear layer. This is consistent with other research (Candeiro et al., 2011; Ali et al., 2019).

CONCLUSIONS

Within the limitations of this in-vitro study, it can be concluded that:

- Apple cider can be used alone or followed by EDTA in the removal of smear layer.
- Apple cider whether used alone or followed by EDTA can remove smear layer with results comparable with NaOCl followed by EDTA.

RECOMMENDATIONS

Under the condition of the current study, we can recommend that:

- More research is needed to investigate the ability of apple cider to remove the organic part of the smear layer.
- Further research is needed to investigate the antimicrobial efficacy of apple cider.
- Further research is required using irrigants with different concentrations, pH, contact time and higher temperature.
- Further research comparing the efficacy of apple cider with other natural irrigants.
- Further research evaluating the effect of apple cider as single irrigant on the quality of sealer penetration within dentinal tubules.
- Further trials are to be done to precisely evaluate the effectiveness of apple cider as a single irrigant on multi-rooted teeth with curvatures.

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