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ORIGINAL ARTICLE

An In Vitro Evaluation of Passive Ultrasonic Agitation of Different Irrigants on Smear Layer Removal After Post Space Preparation: A Scanning Electron Microscopic Study

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Abstract This study evaluated the removal of debris and smear layer after post space preparation using different irrigations and passive ultrasonic agitation. Sixty human premolars were decoronated and post space prepared after endodontic therapy. The samples were then randomly divided into three experimental groups (Groups A, B, C) and one control group (Group D) with fifteen samples in each group. Groups A and B samples were treated with 10 % citric acid and 17 % ethylenediamintetraacetic acid (EDTA), respectively and passive ultrasonic agitation was done, rinsed with sodium hypochlorite and finally flushed with saline. Group C samples were conditioned with 36 % phosphoric acid and then rinsed with saline. The control group was treated with 3 % sodium hypochlorite, passive ultrasonic agitation done and flushed with saline. The samples were sectioned and evaluated for debris and smear layer removal under scanning electron microscope. 10 % citric acid showed the best removal of smear layer when compared with 17 % EDTA and 36 % phosphoric acid, but was not statistically significant ($p > 0.05$). The difference in scoring for debris and smear layer removal in the coronal, middle and apical third of post space of experimental groups in comparison with control group was statistically significant ($p < 0.001$).

Keywords Citric acid · Ethylenediaminetetraacetic acid · Sodium hypochlorite · Passive ultrasonic irrigation · Smear layer

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Introduction

An endodontically treated tooth with loss of coronal tooth structure generally requires a radicular post for restoration of the tooth function [1, 2]. Fiber posts have been recommended to rebuild endodontically treated teeth because of their dentin-matched mechanical characteristics. The use of self-etching adhesive resin luting systems for the cementation of these posts has increased recently because of the easily manageable clinical procedures associated with them [3]. The bonding mechanism of adhesive systems to root dentine wall is micromechanical in nature, based on the hybridization of the demineralized surface and formation of resin tags and adhesive lateral branch [4]. Hence the longevity of these restorations depends on the effective bonding between post, dentin and adhesive resin cement and its durability [5].

Post space preparation is commonly performed using rotary instruments. After post space preparation radicular dentin surface is covered with a thick smear layer which prevents effective resin penetration. When adhesives are used without the removal of smear layer it results in the hybridized smear layer with a weak bonding interface. The top of this hybrid layer contains disorganized collagen fibrils that degrade over time. Therefore, dentin surface of the root canal needs to be effectively cleaned before fiber post cementation, allowing the infiltration of a self-etching adhesive.

This can be achieved by chemical and ultrasonic irrigation, alone or in combination [3]. Sodium hypochlorite (NaOCl), Ethylene diamine tetraacetic acid (EDTA) and Citric acid are some of the chemical irrigating solutions used for smear layer removal. NaOCl is one of the most widely used irrigating solutions, which effectively removes organic tissue remnants present within the smear layer.

EDTA being a chelating agent effectively removes the smear layer by chelating the inorganic component. Citric acid, an organic acid, also possesses the property of smear layer removal [6].

The effectiveness of the above mentioned irrigants relies on mechanical flushing action and its chemical ability to remove the smear layer. Passive ultrasonic agitation used in combination with these irrigants facilitates smear layer removal [7]. Post space conditioning with 36 % phosphoric acid is another approach to demineralize dentin and remove the smear layer for the diffusion of the adhesive cement [8].

Many studies have been conducted to evaluate the removal of smear layer in the root canal [9, 10]. However, only few studies have been performed on the efficacy of smear layer and debris removal with different irrigations and passive ultrasonic agitation after post space preparation. Hence the purpose of this in vitro study was to evaluate the effect of different irrigating solutions with passive ultrasonic agitation on smear layer and debris removal.

In addition, the amount of dentin tubule opening at the coronal, middle, and apical thirds of the root canal dentin surface is also evaluated.

Method and Materials

Sixty human mandibular premolars which were periodontally compromised or orthodontically indicated for extraction were used in the current study. The teeth were decoronated 2 mm incisally from the cemento-enamel junction using a diamond disk. Endodontic therapy was performed for all the specimens using K3 nickel titanium rotary files in a crown-down technique up to no. 25 size 0.06 taper. EDTA (Glyde, Dentsply) was used as a lubricant throughout the procedure.

The canals were irrigated with 2 ml of 3 % NaOCl (Venson India, Batch no. 04150) using a 26 gauge needle before proceeding to the next file. All the teeth underwent final rinse with saline after instrumentation.

Obturation was done by lateral condensation technique using a no 25 size 0.06 taper gutta-percha points and AH Plus root canal sealer. The specimens were coronally sealed with glass ionomer cement (Ketac TM Fil Plus, 3 M ESPE, Germany) and stored in saline for 24 h. Post space preparation was carried out leaving 5 mm of gutta-percha apically using drills provided for carbon fiber post (Mirafit carbon fiber post drill, Hager and Werken, Germany).

Specimens were randomly divided into four groups ($n = 15$) based on the irrigant used. The experiments were carried out at room temperature and 40 % humidity.

Group A—1 ml of 10 % citric acid (pH-3) and passive ultrasonic agitation with #15 file for 1 min. This was followed by irrigation with 3 ml of 3 % NaOCl (pH-11) and final rinse with saline.

Group B—1 ml of 17 % EDTA (Prime dental products pvt ltd. Batch no.09112101, pH-7) and passive ultrasonic agitation with a #15 ultrasonic file for 1 min. This was followed by irrigation with 3 ml of 3 % NaOCl and final rinse with saline.

Group C—Conditioned with 36 % phosphoric acid (Dentsply Batch no.0911000844, pH-0.4) for 15 s, rinsed with saline and ultrasonic agitation was not performed in this group.

Group D—1 ml of 3 % NaOCl and passive ultrasonic agitation was done with a #15 ultrasonic file for 1 min followed by final rinse with saline.

Two longitudinal grooves were prepared on the buccal and lingual surfaces of each root using a diamond disk without penetrating into the canal. The roots were then split into two halves with a chisel. For each root, the half containing the most visible part of the apex was conserved and coded. The coded specimens were mounted on metallic stubs, gold sputtered and examined under scanning electron microscope.

The SEM photomicrographs were taken at magnification of $\times$1,000 at the coronal (10 mm from the coronal end of remaining gutta percha), middle (6 mm from the coronal end of remaining gutta percha), and apical (2 mm from the coronal end of remaining gutta percha) third of the post space.

The amount of debris, smear layer and sealer/gutta-percha residue on open dentine tubules were scored according to the following criteria [11].

Score 0—All dentine tubules open, without debris, smear layer and sealer/gutta-percha residue.

Score 1—Some dentine tubules open, with thin smear layer, debris and sealer/gutta-percha residue covering these openings.

Score 2—All dentine tubules blocked by thick smear layer with debris and sealer/gutta-percha residue.

Further these samples were statistically analyzed using Mann–Whitney test.

Results

In all the experimental groups the amount of debris and smear layer were significantly lower than the control group ($p < 0.05$). Table 1 (Fig. 13) shows the scoring of debris and smear layer removal at the apical, middle and coronal third of post space in all the experimental and control groups. Medians are also provided to indicate the distribution of the individual marks.

Table 1 Describing the distribution of scores according to groups at different levels

Group	Level	Score			Median
		0	1	2	
Group A	Coronal	7	7	1	1
	Middle	6	8	1	1
	Apical		6	5	1
Group B	Coronal	6	8	1	1
	Middle	4	9	2	1
	Apical	2	6	7	1
Group C	Coronal	4	10	1	1
	Middle	3	10	2	1
	Apical	1	5	9	2
Group D	Coronal	0	3	12	2
	Middle	0	1	14	2
	Apical	0	0	15	2

Table 2 Describing comparison of scores among the different groups at coronal level

Group (I)	Group (J)	Mean difference (I–J)	Z	*p* value
Group A	Group B	−0.067	−0.326	0.745
	Group C	−0.200	−0.993	0.321
	Group D	−1.200	−4.136	<0.001*
Group B	Group C	−0.133	−0.672	0.567
	Group D	−1.133	−4.087	<0.001*
Group C	Group D	−1.000	−4.015	<0.001*

* Denotes significant difference

Table 2 (Fig. 13) shows the mean amount of removal of debris and smear layer at the coronal level of the post space in group A in comparison with groups B, C and D. There were no statistically significant differences between group A and group B ($p > 0.05$), between group A and group C and between group B and group C. There was statistically significant difference between all the experimental and control group (Figs. 1, 2, 3, 4).

Table 3 (Fig. 13) shows the mean amount of removal of debris and smear layer at the middle level of the post space in group A in comparison with groups B, C and D. There were no statistically significant differences between group A and group B ($p > 0.05$), between group A and group C and between group B and group C. There was statistically significant difference between all the experimental and control group (Figs. 5, 6, 7, 8).

Table 4 (Fig. 13) shows the mean amount of removal of debris and smear layer at the apical level of the post space in group A in comparison with groups B, C and D. There were no statistically significant differences between group A and group B ($p > 0.05$), between group A and group C

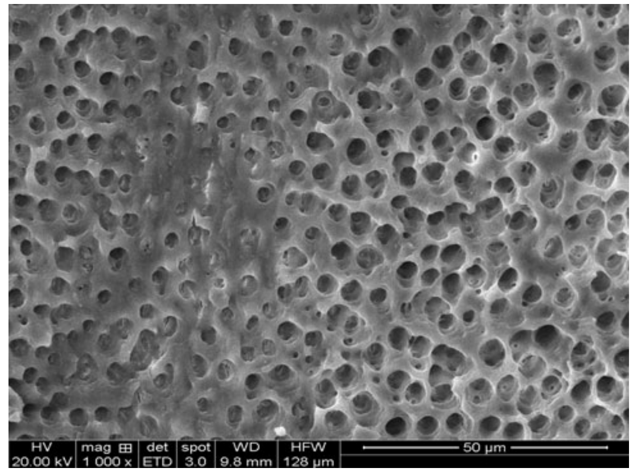

Fig. 1 Group A—coronal third of post space

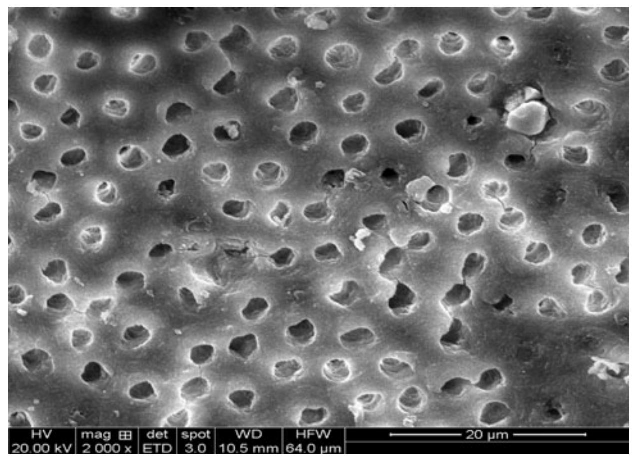

Fig. 2 Group B—coronal third of post space

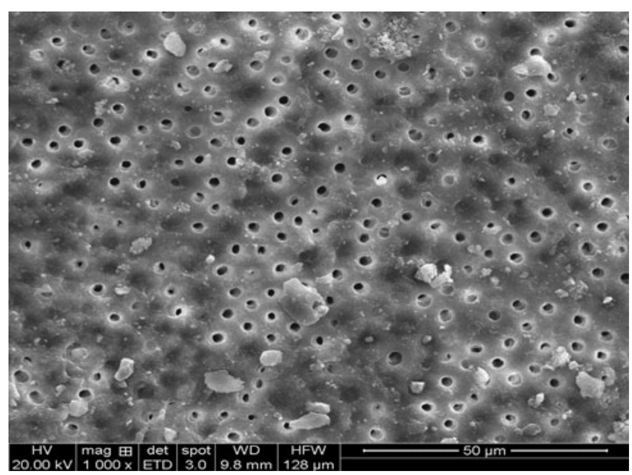

Fig. 3 Group C—coronal third of post space

and between group B and group C. There was statistically significant difference between all the experimental and control group (Figs. 9, 10, 11, 12).

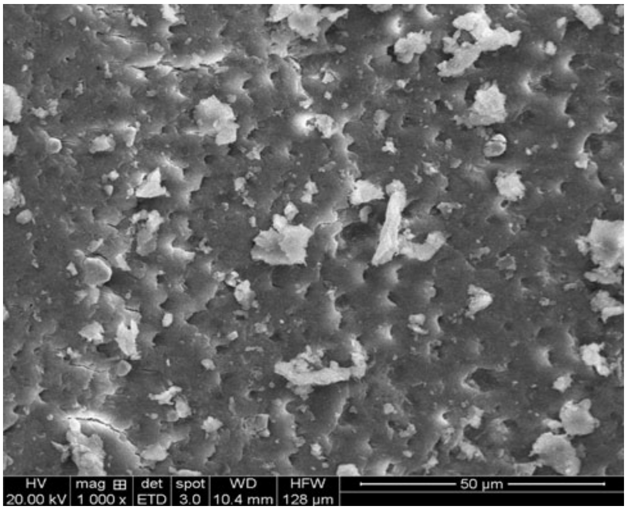

Fig. 4 Group D—coronal third of post space

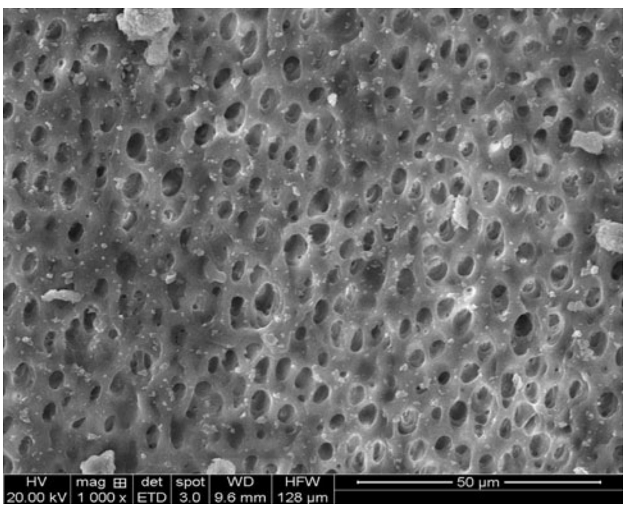

Fig. 5 Group A—middle third of post space

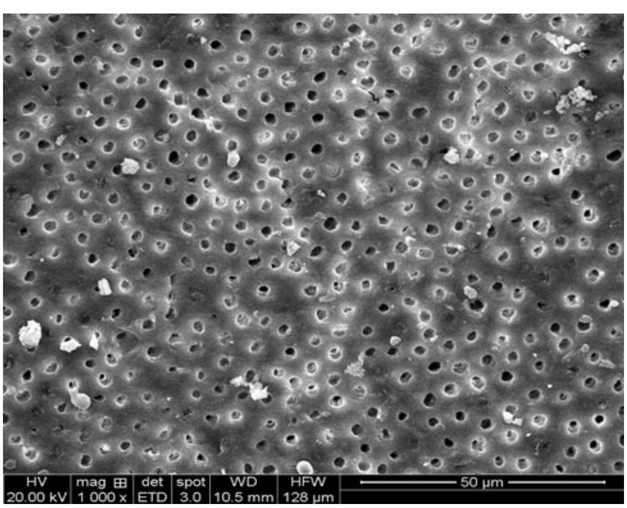

Fig. 6 Group B—middle third of the post space

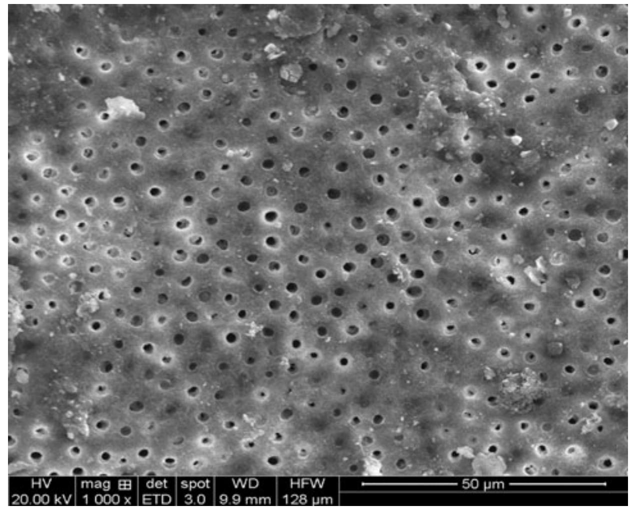

Fig. 7 Group C—middle third of the post space

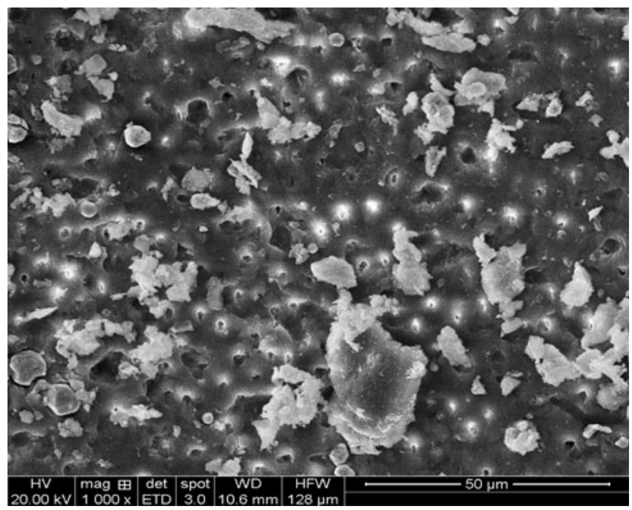

Fig. 8 Group D—middle third of the post space

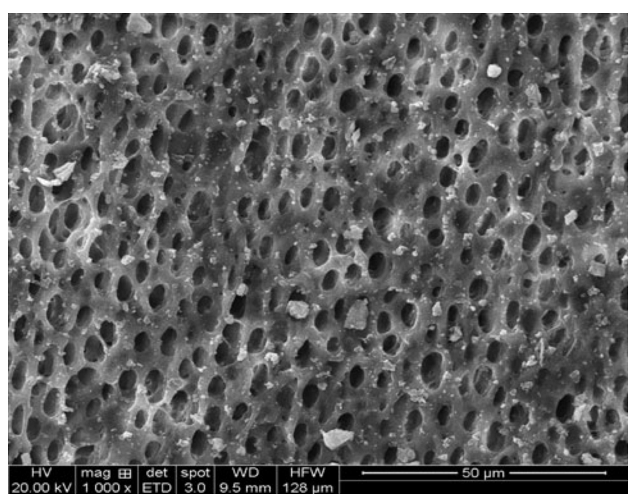

Fig. 9 Group A—apical third of the post space

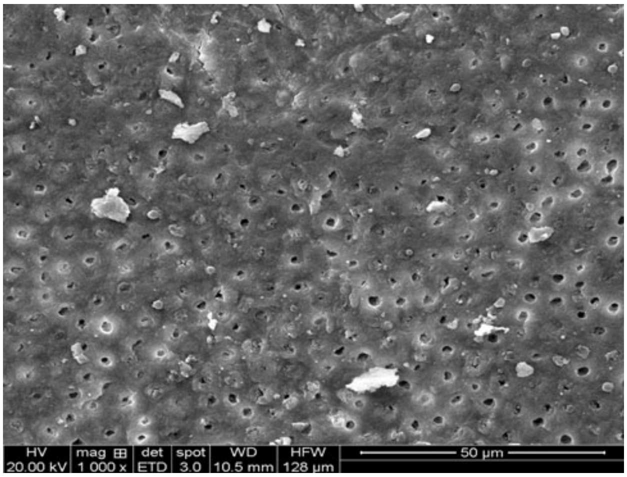

Fig. 10 Group B—apical third of the post space

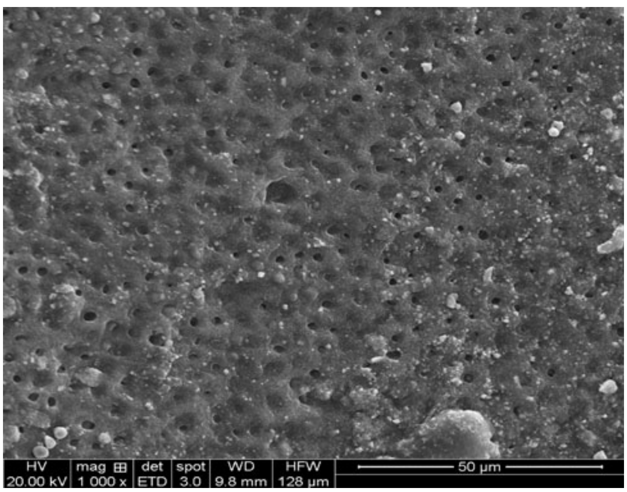

Fig. 11 Group C—apical third of the post space

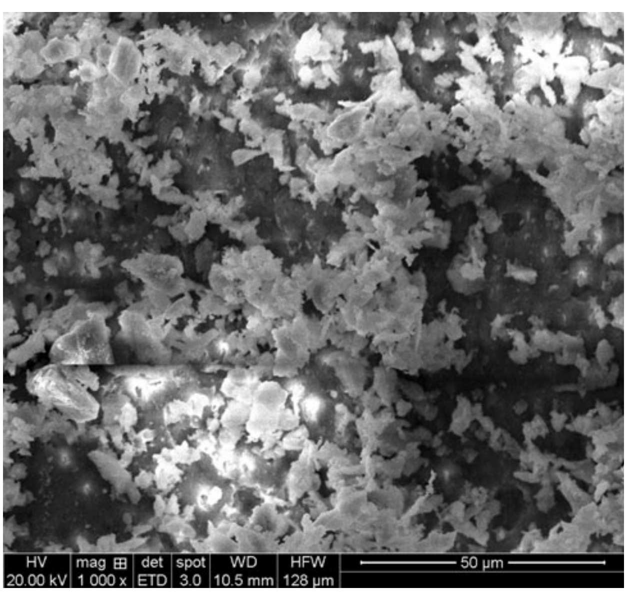

Fig. 12 Group D—apical third of the post space

Table 3 Describing comparison of scores among the different groups at middle level

Group (I)	Group (J)	Mean difference (I–J)	Z	*p* value
Group A	Group B	−0.200	−0.868	0.461
	Group C	−0.267	−1.216	0.224
	Group D	−1.267	−4.546	0.001*
Group B	Group C	−0.067	−0.315	0.806
	Group D	−1.067	−4.241	<0.001*
Group C	Group D	−1.000	−4.246	<0.001*

* Denotes significant difference

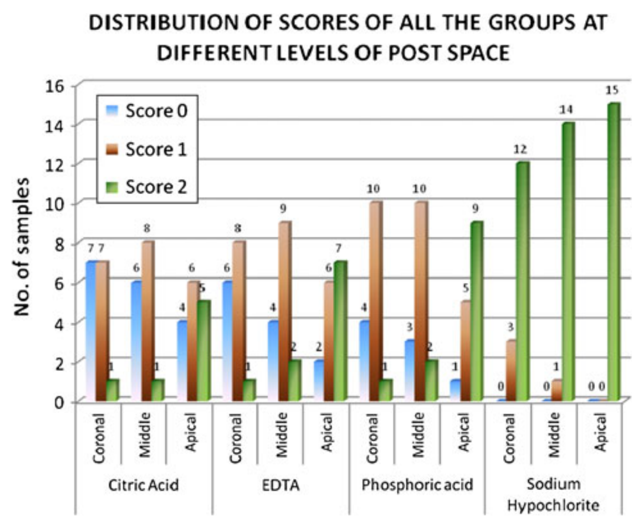

Fig. 13 Distribution of scores

Table 4 Describing comparison of scores among the different groups at apical level

Group (I)	Group (J)	Mean difference (I–J)	Z	*p* value
Group A	Group B	−0.267	−0.937	0.349
	Group C	−0.467	−1.669	0.095
	Group D	−0.933	−3.734	<0.001*
Group B	Group C	−0.200	−0.789	0.486
	Group D	−0.667	−3.218	0.001*
Group C	Group D	−0.467	−2.683	0.007*

* Denotes significant difference

Discussion

The use of adhesive systems and fiber posts for the restoration of endodontically treated teeth depends on smear layer removal and the creation of hybrid layer between root canal, resin and fiber post. Effective bonding between the post, dentin and adhesive resin cement and its durability are essential for the longevity of the restorations.

Post space preparation of endodontically treated teeth frequently requires removal of root canal filling material (gutta-percha and/or sealer). The process of post space preparation creates smear layer, debris on the canal walls, leading to increase in leakage and occlusion of dentin tubules, thus impairing the adhesive luting of fiber posts. Achieving clean dentinal surfaces after mechanical post space preparation seems to be a critical step for optimal post retention when resin cement is used. Therefore, an optimal removal of smear layer is required.

A number of chemicals have been investigated as irrigants to remove smear layer. The purpose of irrigation is twofold: to remove debris, the organic component and to remove smear layer, mostly the inorganic component [6].

Unfortunately, no irrigating solution is capable of acting simultaneously on the organic and inorganic elements of the smear layer. In an effort to remove this layer completely, many authors suggested the use of combination of solutions [12–14].

The effective delivery of irrigants can be enhanced by using ultrasonic devices [15, 16]. The concept of using ultrasonics in endodontics was first introduced by Richman. Two types of ultrasonic irrigation have been described in the literature; one where irrigation is combined with simultaneous ultrasonic instrumentation (UI) and another without instrumentation, which is known as passive ultrasonic irrigation (PUI) [17].

Hence the protocol used in this study was a combination of irrigants which was ultrasonically agitated; where in groups A and B samples were treated with citric acid and EDTA respectively. Subsequently, both the groups were then irrigated with NaOCl. One milliliter of 17 % EDTA was used in the canal for 1 min. The application of EDTA for more than 1 min and in volume more than 1 ml has been reported to be associated with dentinal erosion [18].

The other most frequent technique used to achieve clean dentin surface suitable for adhesion, is conditioning with 36 % phosphoric acid [8]. Group C samples in the present study was conditioned using 36 % phosphoric acid.

The current study showed that the process of debris and smear layer removal in groups A, B was more effective in the coronal and middle third than in the apical third of the post space. This finding is in agreement with the results of various studies that have shown an effective cleaning action in the coronal and middle third of the root canal space [12, 19, 20]. A larger canal diameters in the coronal and middle third exposes the dentin to a higher volume of irrigants. Simultaneously it facilitates the ultrasonic activation of the irrigant, allowing a better flow of solution and hence, improving the efficacy of smear layer and debris removal [19].

Group A showed the best removal of smear layer when compared with groups B and C but, it was not found to be statistically significant ($p > 0.05$).

Inefficient removal of debris and smear layer in the apical third of post space in groups A and B is due to the definite decline in the efficacy of irrigating solution along the apical part of the post space [21]. This can probably be explained by the fact that dentin in the apical third is much more sclerosed and the number of dentinal tubules present there is less [22]. In contrast to this, studies have shown effective removal of debris and smear layer from the apical third of the root canal [15, 16, 23].

Group C samples also showed inefficient debris and smear layer removal from the apical third of the post space. This finding is in agreement with a previous study conducted to evaluate the removal of debris and smear layer after post space preparation [1]. In theory, the action of the drills used to remove the root filling material to create post space produces a new smear layer rich in sealer and gutta-percha remnants plasticized by the friction heat of the drill. This may diminish the penetration and chemical action of the phosphoric acid [1].

The relative inefficiency of the control group D for debris and smear layer removal in this study corroborates with the results of other studies [11, 24]. Although, some studies have shown effective removal of debris and smear layer using a combination of ultrasonics and NaOCl [20, 25]. NaOCl, is the irrigant of choice for root canal disinfection but, when used alone it is ineffective in smear layer removal [26]. It is a proved fact that NaOCl is efficient in removing only the organic component of the smear layer leaving behind the inorganic component intact [27].

The samples used in this study were single-rooted premolars with relatively straight canals. The results may be limited to only such clinical instances. Clinically, in canals with a greater degree of curvature, difficulties might exist in the introduction of the ultrasonic file into the apical part of the canal without contacting the canal walls. In a curved canal, the volume of irrigant available may be reduced and the depth of penetration of solution may decrease. Further studies are required to look into this aspect of smear layer removal in canals with greater degree of curvature.

Contact of the ultrasonic file with the canal walls during the agitation of the irrigant causes the dampening of the vibrations created; leading to decrease in the cleaning efficacy of ultrasonics [16]. This fact must be taken into consideration while using ultrasonics.

Conclusions

Within the limitations of this study.

- Coronal and middle third of the post space showed good smear layer and debris removal using citric acid and EDTA, along with ultrasonic agitation.

- In comparison with the coronal and middle third, apical third of the post space showed inadequate removal of debris and smear layer irrespective of the etching procedure or the irrigant (citric acid, EDTA) used.

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