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Effects of ultrasonically activated irrigants with or without surfactant on smear layer removal after post space preparation

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Abstract

The aim of this study was to compare the effects of different NaOCl and EDTA formulations with/without ultrasonic use on smear layer removal and root canal surface characteristics after post space preparation.
Study design: After post space preparations, forty-six teeth were subjected to different post space irrigation regimes; G1, 17% EDTA; G2, 17% EDTA+Ultrasonic activation; G3, EDTA-T; G4, EDTA-T+Ultrasonic activation; G5, NaOCl; G6, NaOCl+Ultrasonic activation. Specimens were examined under scanning electron microscope and scored for debris and smear layer removal and dentinal tubule opening and statistically analyzed with Kruskal Wallis and Dunn's test. Significance value was set at $p<0.05$.
Results: EDTA and EDTA-T groups showed significantly better efficiency than the other groups in the each parts of the samples in terms of smear layer removal ($p<0.05$). In terms of dentinal tubule opening, EDTA, EDTA+Ultrasonic and EDTA-T groups had significantly better efficacy than the other groups in the middle and coronal parts of the samples ($p<0.05$).
Conclusions: Ultrasonic activation did not significantly improve the efficiency of the irrigants.

Key word: Irrigation, post space preparation, smear layer, surfactant, ultrasonics.

Introduction

In recent years, fiber posts and resin-based luting cements, which lead to fewer and favorable root fractures due to their dentin-matching mechanical characteristics, have been recommended to rebuild endodontically treated teeth (1). Adhesive techniques and resin based luting materials enhance bonding of posts to dentin, which is necessary for the long term success of the restoration. Previous studies have emphasized the importance of smear layer removal and formation of the resin-dentin interdiffusion zone to improve bonding efficiency (2, 3).

The initial step of all post and core restorations is removal of the root filling material with drills to create a suitable post space. Mechanical preparation of the post space with drills inevitably results in debris and smear layer formation containing remnants of gutta-percha and sealer (4). Failure to remove this smear layer might interfere with effective bonding of resins. Various chemical solutions or chelators, alone or combined with ultrasonics, have been evaluated for their smear layer removal efficiency in root canals and post spaces (5-8). Ethylenediaminetetraacetic acid (EDTA) is one of the most effective chelating agents for removing the inorganic debris of smear layer from the root canal. EDTA treated dentinal walls have better adhesion with filling materials (9). Detergents have been added to EDTA in order to increase dentinal penetration of the solution. This addition reduces the surface tension of the irrigant, facilitating the wetting of the entire root canal wall, and thereby increasing the ability of the chelators to penetrate to the dentin (10). One of these chelators is EDTA-T having low surface tension due to addition of a surfactant. Tasman *et al* (11) and Yılmaz *et al* (12) demonstrated that the EDTA with surfactant has lower surface tension value than other solutions.

To the authors' knowledge, only a few studies have been performed on the efficacy of smear layer and debris removal using different irrigants after post space preparations (13,14). This in vitro study evaluated the effects of different irrigation regimens with EDTA and EDTA-T solutions on smear layer removal and characteristics of the canal surface after post space preparation and to study whether or not additional ultrasonic irrigation has any effect on smear layer removal.

Material and methods

Forty-six extracted human mandibular premolar teeth were used. The crown of each tooth was removed at the cementoenamel junction perpendicular to the long axis of the root so that each root was approximately 14 mm in length. The canals were instrumented using a crown-down technique with rotary ProTaper instruments rotated at 250 rpm (Dentsply, Maillefer, Ballaigues, Switzerland) to size F4. The canals were irrigated with 2 ml 2.5% sodium hypochlorite (NaOCl) between each file. After completion of the instrumentation, 5 ml 2.5% NaOCl was applied as final flush and then the root canals were dried with #30 sterile paper points (Spident, Incheon, Korea).

Prepared root canals were obturated using a resin sealer (AH 26; Dentsply Detrey, Konstanz, Germany) and lateral compaction of gutta-percha. The teeth were then immersed in the freshly mixed thymol solution for 2 weeks to let the resin sealer polymerize completely. The gutta-percha was removed and a 10 mm post spaces were prepared with the kit drills of the double taper radiopaque translucent fiber posts (D.T. Fiber Post, Bisco, USA) taking care to leave at least 4 mm of gutta-percha to preserve the apical seal. The teeth were randomly divided into six experimental groups (n=7). Six groups were formed regarding to irrigation regimens as follows;

- *Group 1;* irrigation with 17% EDTA,
- *Group 2;* irrigation 17% EDTA with ultrasonic activation for 60 seconds,
- *Group 3;* irrigation EDTA-T ((17% EDTA + 1.25% sodium lauryl ethersulfate [Sigma-Aldrich]),
- *Group 4;* irrigation EDTA-T with ultrasonic activation for 60 seconds,
- *Group 5;* irrigation NaOCl,
- *Group 6;* irrigation NaOCl with ultrasonic activation for 60 seconds. Four teeth were used for control group and only irrigated with distilled water.

Root dentine surfaces were irrigated with 10 ml of each irrigant for 60 seconds And then to avoid the prolonged effect of these irrigants 10 ml distile water was used as a final jet. For groups with ultrasonic activation, ISO 15 ultrasonic K-file at Suprasson P-50 machine (Satelec, Merignac Cedex, France) was used for all teeth (6). #15 ultrasonic K-file placed 1 mm from the apical end of post space and in consideration of the diameter of post space, the power setting was adjusted to 4.

After post space irrigation, teeth were grooved along the buccal and lingual surfaces by using a diamond disc at low speed and split longitudinally with a chisel and mallet into two halves. While during this procedure we ensured that the diamond disc doesn't touch on the root canal walls. These halved specimens were dehydrated in ethanol (50%, 75%, 95%, and 100%) and then dried in desiccators for 24 hours. Each specimen was gold sputtered to achieve a conductive coating and then examined with a scanning electron microscope (SEM), (JEOL JSM-6400, Japan) at 1-, 4.5-, and 8-mm levels from the apical to the coronal third of the post space (13).

The specimens were coded and examined in a blind manner by 2 observers. Separate evaluations were performed for smear layer and dentinal tubules opening at x1000 magnification. For each tooth, the mean marks of debris and dentinal tubules opening were calculated separately at three parts of radicular dentin (coronal, middle, and

apical third). In order to evaluate the compatibility of two observers, kappa factor was checked. Compatibility was found as 94%.The average of the observers' scorings for each section was used for the statistical analysis.

The amount of debris was marked from 0 to 2 (14).

0: No debris particles

1: Few debris particles, with maximum diameter of less than 20μm,

2: Large amount of debris particles, with diameter greater than 20μm.

The number of dentinal tubule opening was marked from 0 to 2;

0: All dentinal tubules open, without debris, smear layer, and sealer/gutta-percha residue

1: Some dentinal tubules open, with a thin smear layer, debris, and sealer/gutta-percha residue covering these opening

2: All dentinal tubules blocked by thick smear layer with debris and sealer/gutta-percha residue.

Statistical differences among the experimental groups were analyzed using Kruskal Wallis test. Multiple comparisons performed by Dunn's test. Significance value was set at $p<0.05$.

Results

The median rank of debris and dentinal tubules opening marks at different thirds of root canals was recorded to evaluate the differences within each group (Table 1).

In terms of smear layer removal; control group, groups with ultrasonic activation and NaOCI group were less efficient than the other groups in the apical parts of the samples ($p<0.05$). EDTA and EDTA-T groups showed significantly better efficiency than the other groups in the each parts of the samples ($p<0.05$). However these two groups had no significantly difference ($p>0.05$).

In terms of dentinal tubule opening, EDTA, EDTA+Ultrasonic and EDTA-T groups had significantly better efficacy than the other groups in the middle and coronal parts of the samples ($p<0.05$). In the apical part, only EDTA+Ultrasonic and EDTA-T groups showed significantly higher efficacy when compared with other groups ($p<0,05$).

Irrigation with ultrasonic activation (Groups 2, 4, and 6) had no additional significant effect on smear layer removal and dentinal tubule opening when compared with those with respective irrigation without ultrasonic activation ($p>0.05$). However among the ultrasonic groups, only EDTA+Ultrasonic group showed better efficiency in the middle and coronal part of the samples in terms of both dentinal tubule opening and smear layer removal.

When root canal surfaces were compared on the removal of smear layer at each level, there was a significant difference at the coronal parts of the root canal surfaces, when compared with apical and middle thirds ($p<0.05$). The least amount of debris remained at the coronal thirds. Similarly, more and larger dentinal tubule was visible at the coronal part, when compared with other parts of the root canal surfaces ($p<0.05$) (Fig. 1, Fig. 2).

Discussion

Cleaning surfaces of canal walls after post space preparation has been reported to be a critical procedure for optimal post retention (15). When fiber post and resin luting systems are used to restore endodontically treated teeth, the gutta-percha remnants and smear layer must completely be eliminated from the root canal in order to create ideal conditions for optimal adhesion to root canal dentin. Currently, a final irrigation sequence with a chelating agent, such as EDTA is recommended to remove the inorganic components of the smear layer (16). Saito *et al* (17) found that shortened irrigation time with EDTA less than 1 minute could significantly decrease smear layer removal. Thus, in our study, EDTA and NaOCl were used for irrigation separately, with a 1-minute irrigating time.

Surface tension can be defined as the force between molecules that produces a tendency for the surface area of the liquid to decrease. This force tends to prevent the spread of a liquid over a surface or limit its ability to penetrate a capillary tube (18). Reducing surface tension of an endodontic irrigating solution improves its wetting ability (19) and spread into narrow canals (20). Therefore it can be speculated that a surfactant added endodontic irrigating solution, has lower surface tension and this reduction of its surface tension might improve its efficacy in the apical region of the root canal. Thus, it

Group	n	Smear Layer and Debris			Dentinal Tubule Opening		
		Apical	Middle	Coronal	Apical	Middle	Coronal
EDTA	7	1,000± 0,516	1,000 ±0.408	1.000±0.000	2.000±0.408	1.000±0.516	1.000±0.000
EDTA+ULTRASONIC	7	2.000±0.516	1.000±0.408	1.000±0.408	1.000±0.632	1.000±0.752	1.000±0.408
EDTA-T	7	1.000±0.516	1.000±0.516	1.000±0.408	1.000±0.516	1.000±0.000	1.000±0.516
EDTA-T+ULTRASONIC	7	2.000±0.408	2.000±0.516	2.000±0.516	2.000±0.516	2.000±0.516	2.000±0.836
NaOCl	7	2.000±0.000	2.000±0.000	1.500±0.547	2.000±0.000	2.000±0.000	2.000±0.000
NaOCl+ULTRASONIC	7	2.000±0.000	2.000±0.408	2.000±0.516	2.000±0.000	2.000±0.000	2.000±0.000
CONTROL	4	2.000±0.000	2.000±0.000	2.000±0.000	2.000±0.000	2.000±0.000	2.000±0.000

Table 1. Median and Standard Deviation of smear layer, debris and dentinal tubule opening at three levels of root canal dentin surface after cleaning with different irrigation solutions.

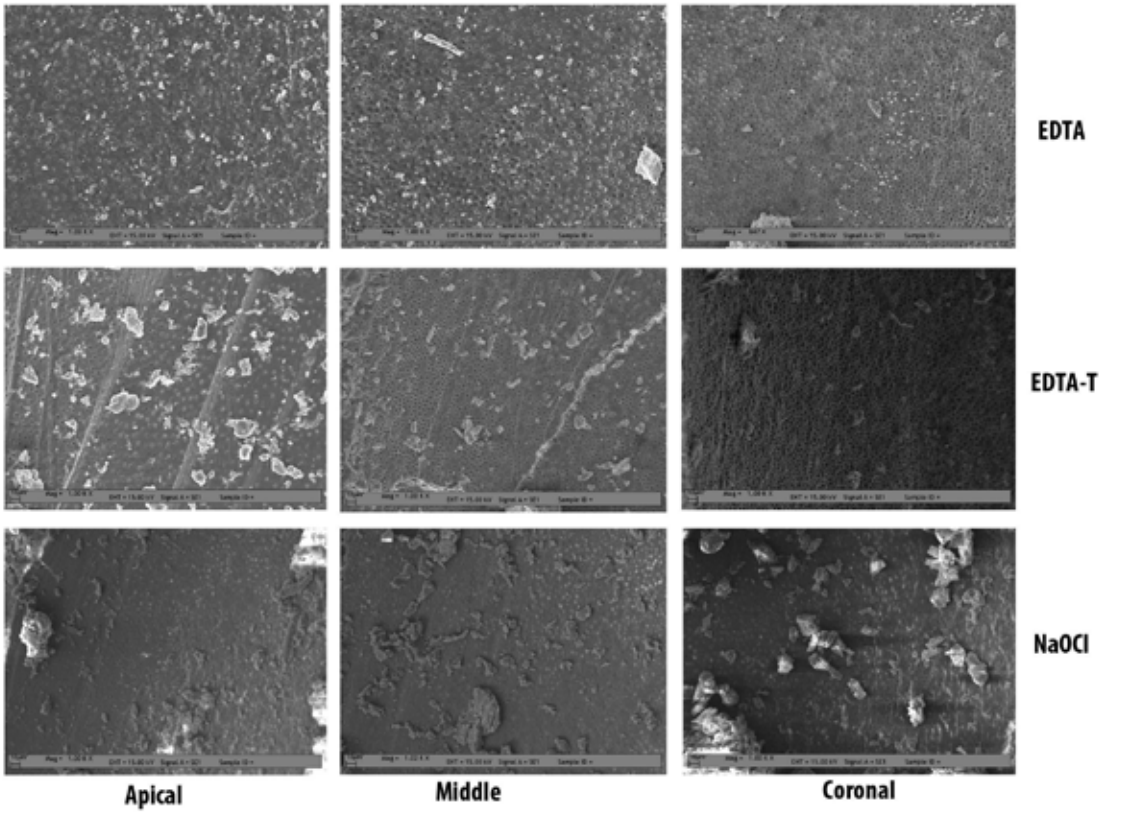

Fig. 1. *Representative SEM photomicrographs showing the apical, middle, and coronal levels of root canal dentin surface in EDTA, EDTA-T and NaOCI groups (1,000x).*

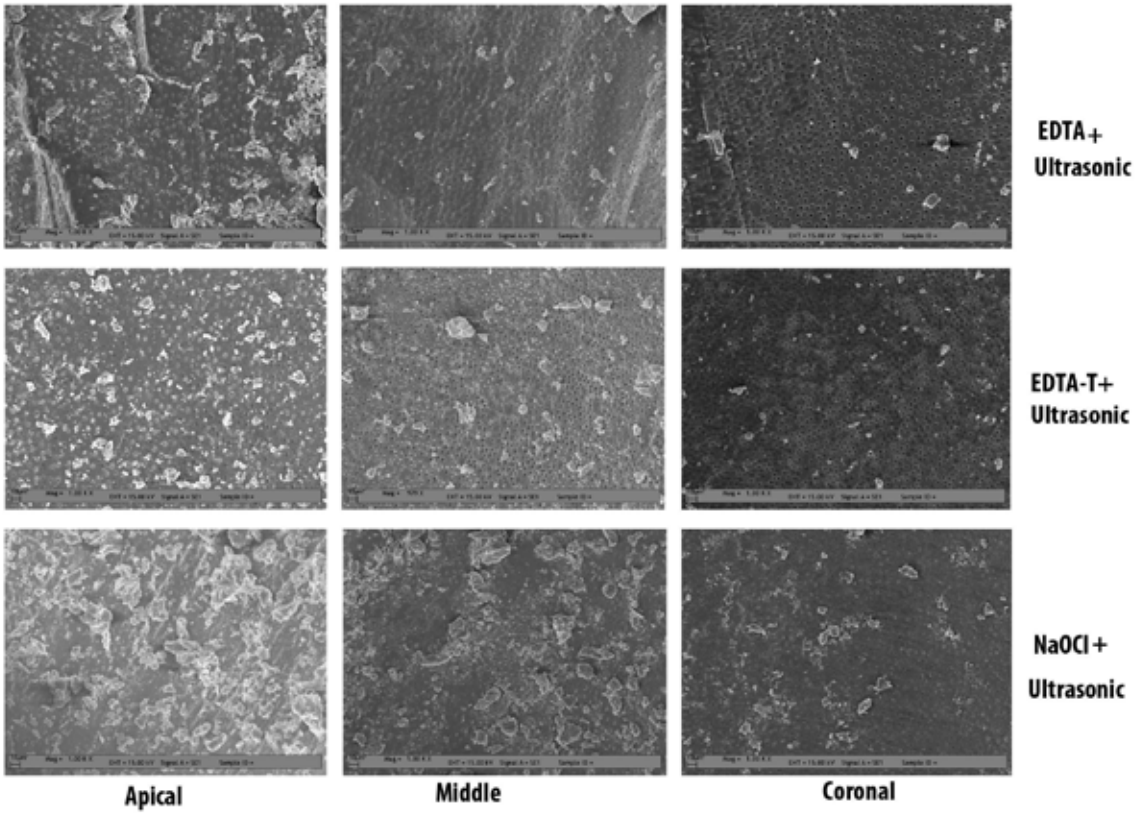

Fig. 2. *Representative SEM photomicrographs showing the apical, middle, and coronal levels of root canal dentin surface in EDTA + ultrasonic, EDTA-T + ultrasonic and NaOCI + ultrasonic groups (1,000x).*

can be possible that low-surface-tension EDTA solutions might improve the adhesion properties of root canal dentin. However, our experiments showed that adding a detergent failed to improve the performance of EDTA in terms of smear layer removal. This finding is in accordance with a recent study (6) which demonstrated that addition of surfactants to EDTA did not result in better smear layer removal compared to EDTA alone. According to Zehnder et al (21) calcium chelating ability of an endodontic chelator did not improve with addition of a surfactant to reduce the surface tension. According to Zehnder's study it may not be necessary to add a wetting agent to a chelator solution to improve its effectiveness in removing inorganic smear layer components. Sampaio *et al* (22) showed that sodiumlaurylsulphate was ineffective in removing the smear layer alone compared to EDTA groups. Another study by Sampaio demonstrated no significant difference between EDTA and EDTA-T groups (23). Although use of detergents seems beneficial to remove bacteria and toxins from the root surface, they do not play a major role for removal of smear layer (24). In a study by Scelza *et al* (25), higher debris scores were found with EDTA-T groups regardless of application time.

In general, analysis of the dentinal wall of all the specimens in the experimental groups demonstrated that cleaning of the coronal and middle thirds of these surfaces had been effective. When compared with the apical third, it is possible that the size of the canals in these thirds, allowed better circulation and action of the irrigating solution, making complete removal of the smear layer possible. Such results are in agreement with those of various authors (26,27) who have also observed an effective cleaning action on these thirds even when different quantities of solutions and times of irrigation were employed. Due to the small diameter of root canals, it is often difficult for the irrigating solutions to reach the apex of the tooth.

In the present study, ultrasonic activation of the irrigation did not have any additional effect on the smear layer removal and dentinal tubule opening. This result was in accordance with the findings presented by Hulsmann *et al* (16) and Xin-Hua Gu *et al* (14) who reported that ultrasonic activation could not improve the cleaning effect of irrigation. However, other researchers reported that ultrasonic activation had a supportive effect on smear layer removal during endodontic treatment (6,8,29). These different effects of ultrasonic activation might be caused by the different diameters of the post space and the root canal (14). Ultrasonic activation might have only limited influence on the radicular dentin surface of the post space, which had a larger diameter than the root canal. As a result of the small diameter of the post space, it may be difficult for the irrigating solutions to reach the apical root region and action of ultrasonic.

With the limitations of this study, results show that irrigation with EDTA without ultrasonic activation could effectively remove the smear layer and open dentinal tubules after post space preparation. However, addition of surfactants to EDTA in EDTA-T did not result in better smear layer removal, when compared with EDTA alone. Ultrasonic activation did not have any additional effect on smear layer removal.

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