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Endodontic Irrigants and Their Activation Efficacy on Cleansing Post-Space Root Canal Walls

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Abstract: The aim of this study was to evaluate the efficacy of activated irrigants (EDTA e NaOCL) during the cleansing of root walls, of the smear layer, of the debris, and gutta-percha after the preparation of the restorative space. Twenty single and multi-rooted (n = 20) have been collected. All samples were prepared by the same operator, using Nickel-titanium rotating instruments (Mtwo) through the Simultaneous Shaping Technique. The continuous-wave of condensation technique of obturation was used. To all specimens, the restorative space has been made, leaving 5 mm of apical gutta-percha, and postoperative periapical X-rays were performed. The samples were randomly divided into two groups: Group (A): cleansing of the root walls with ultrasonic activation of the irrigants (NEWTRON P5 XS; Satelec Acteon); Group (B): radicular walls wash without ultrasonic activation of endodontic irrigants (NaOCl 5.25% and EDTA 17%). Both dental sample groups were cut longitudinally with a low-speed saw (Isomet); the samples were observed by using a scanning electron microscope (Jeol, Jsm-6060LV) in order to evaluate: (1) the amount of debris/smear layer; (2) the mount of obstruction of dentinal tubules found in the two groups; and (3) evaluation of the presence of gutta-percha. Then, the other five samples each group (with and without ultrasonic activation) were prepared following the same protocol. Then, a universal bonding system (G-Praemio Bond, GC) and a layer of a flowable resin composite (Gaenial Flow, GC) were light-cured and used on top of the prepared root canal walls. The samples were cut in two pieces along the long axis of the root. Then, half sample teeth were kept in an acidic solution (37% HCl) for 48 h in order to completely dissolve dental structures and to have a direct view of resin tags formation under SEM. The other half was prepared to observe the adhesive interface under SEM. The amount of debris was not satisfactory in 9 out of 10 cases in Group B, while in Group A, which has been treated with ultrasounds, the result was either good or great in most of the samples. For the sample group treated with ultrasound, the tubules were evaluated as perfectly clean in 9 out of 10 cases, instead, the results are unsatisfactory for 9 out of 10 cases of group B not treated with ultrasound. Differences between Group A and B were statistically significant. With respect to the presence of debris and tubules obstruction treatment with ultrasonic activation, it offers with no doubt better results. When ultrasonic activation is used in combination with endodontic irrigants, a clean dentin substrate is be obtained for the adhesion of restorative materials, but in order to confirm the findings of this study, further in vivo trials are needed.

Keywords: post space; cleaning root canal; ultrasonic activation

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1. Introduction

Intracanal posts are often necessary for the restoration of endodontically treated teeth after the tooth deterioration due to extensive carious lesions, the endodontic root canal treatment, previously extensive restorations, or teeth fractures.

For radicular post cementation, the resin-based types of cement are the material of choice [1–5]: in the literature, good clinical performances and high rates of success for teeth restored with fiber posts in conjunction with several resin types of cement and adhesive systems have been reported [6–8]. Despite that, the evidence gathered from clinical trials shows that post cement removal is one of the most common failure modes [8]. Most of the time, the dentin–resin–cement interface is the weakest point and, consequently, more frequently subject to failure. The above-mentioned interface could be influenced by several factors, such as the dentine state, the dentinal tubules orientation, the irrigation solution used, depth of the intra-radicular area, the type of adhesive system, and the type of endodontic cement used.

The adhesives are currently available on the market to use in fiber post-cementation ranges from total-etch and self-etch to self-adhesive systems.

There has been a long debate in the literature on which one method the best irrigation solution for the cementation of fiber posts. What is utilized as an irrigation solution can affect the bond strength of the cement with the root canal dentin. Although manufacturers recommend sodium hypochlorite (NaOCl) as a primer for the space for the post, the above-mentioned procedure, according to several authors, can adversely affect resin–cement bond strength [9].

Based on other studies, instead, alternating irrigation with NaOCl and ethylenediaminetetraacetic acid (EDTA) can completely remove the smear layer, increase the adhesive penetration, and increase the bond strength of the post cement to the dentin in the end [10,11].

The study objective is to evaluate the role of activated irrigants (EDTA and NaOCL) on the cleansing of root walls, of the smear layer, of the debris, and gutta-percha after the preparation of the restorative space.

The null hypothesis tested was that irrigants' activation can better clean root canal walls from the endodontic smear layer after being prepared.

2. Materials and Methods

2.1. Samples Preparation

Twenty dental elements, both single and multi-rooted (n = 20), have been collected. Extraction was performed for periodontal reasons, and preoperative periapical X-rays were performed. Teeth preservation was conducted by using a physiological saline solution. The access cavity was performed with a cylindrical diamond bur 206, an endodontic probe (DG16 Hu-Friedy) was used to locate the canal openings, and lastly a patency file K-file 08/10/15 has been utilized for reaching the working length and maintaining root canals' patency. The endodontic treatment was performed by using a disinfection protocol chemo-mechanical standard with proper irrigants (11). All the samples were prepared by the same operator, using Nickel-titanium (Ni-Ti) rotating instruments (Mtwo, Sweden & Martina, Le Due Carrare, Italy) through the Simultaneous Shaping Technique where four instruments were used in a sequence:

- 10.04 at WL;
- 15.05 at WL;
- 20.05 at WL;
- 25.06 at WL.

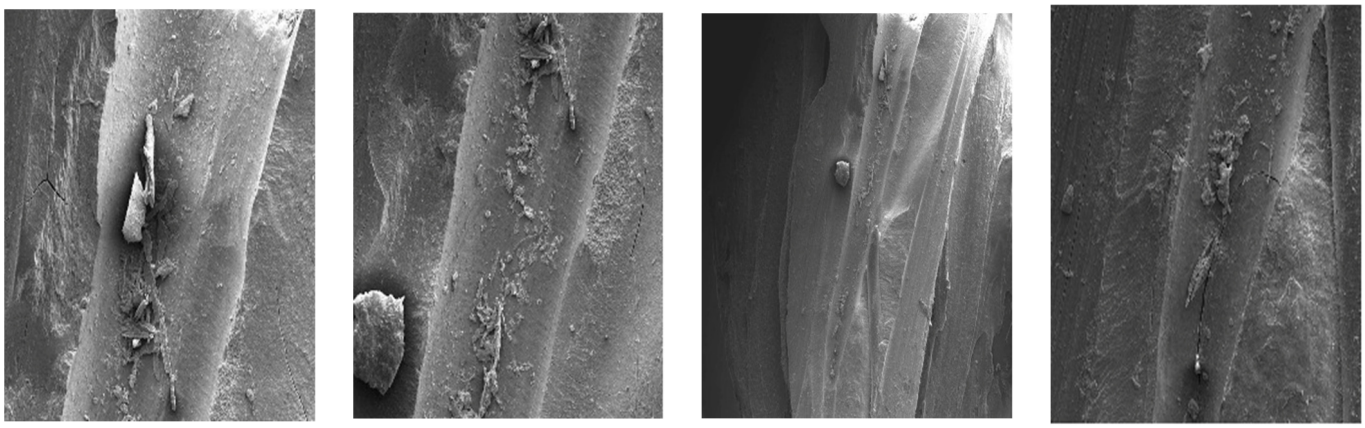
The use of mechanical instruments was alternated with irrigation cycles with 2 mL of NaOCl al 5.25% at room temperature, then apical gauging was performed utilizing a Ni-Ti hand K-file (NiTiflex Maillefer, Bailague, Switzerland) with the same size as the last apical rotating instrument used. At the end of the procedure, 5 mL of EDTA 17% (OGNA Pharmaceutical Laboratories, Milano, Italy) was used to irrigate the canal and left

for two minutes. The final rinse was performed with 5 mL di NaOCl at 5, 25% (OGNA Pharmaceutical laboratories, Milano, Italy); afterwards, the gutta-percha cone-fit was performed with dedicated gutta-percha cones (Mtwo, Sweden & Martina, Le Carrare, Italy). The root canals were dried out by using paper points and three dimensionally obturated with gutta percha and a ZOE sealer (Argoseal, Ogna, Milano, Italy) as cement, with the continuous-wave of condensation technique of obturation using a SytemB/Sybron Endo as a device for the down filling, for the backfilling of the middle third and coronal third has been utilized the Obtura Syringe (Metasystems EQ-V). With respect to all specimens, post-operative periapical X-rays were performed. Subsequently, the restorative space has been made with cutters Gates Glidden N° 2, N° 3, leaving 5 mm of apical gutta percha, and post-operative periapical X-rays were performed once more. Based on the treatment used, the samples were randomly divided in two groups:

- Group (A): cleansing of the root walls with ultrasonic activation of the irrigants (NEWTRON P5 XS; Satelec Acteon, Merignac, France) is based on the following scheme:
  - NaOCL 5.25% + US × 20 s;
  - EDTA 17% + US × 20 s;
  - NaOCL 5.25% + US × 10 s;
  - EDTA 17% + US × 20 s, as final wash;
  - Final drying made with paper cones.
- Group (B): radicular walls wash following the below scheme:
  - EDTA 17% × 60 s;
  - NaOCL 5.25% × 20 s;
  - EDTA 17% × 20 s, as a final wash;
  - Final drying made with paper cones.

Both dental sample groups were cut longitudinally with a low speed saw (Isomet, BUEHLER Co., Lake Bluff, IL, USA); the samples were not completely cut and then fractured with a blad in order to avoid any contamination of the root canal space. The selected sections were mounted on matrices and gold-sputtered using a sputtering device (EMITECH K550); after that, the samples were observed using a scanning electron microscope (Jeol, Jsm-6060LV Scanning Electron Microscope) at different magnifications: 10×, 33×, 500×, and 1000×.

One hundred and twenty images at 10× (Figure 1a), 33× (Figure 1b–d), 500× (Figure 2), and 1000× (Figure 3) magnifications were observed separately according to the following criteria:



(**a**) (**b**) (**c**) (**d**)

Figure 1. (**a**) Root canal preparation (×10); (**b**) root canal preparation: coronal third (×33); (**c**) root canal preparation: medium third (×33); (**d**) root canal preparation: apical third (×33).

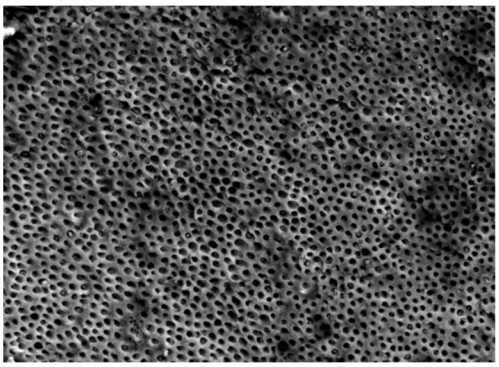


Figure 2. Root canal preparation. Group A: higher magnification of dentinal wall (×500).

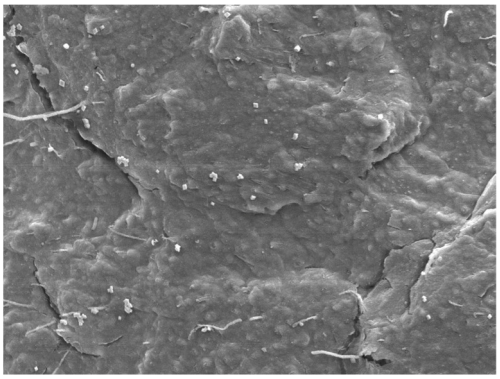


Figure 3. Root canal preparation. Group B: higher magnification of dentinal wall (×1000).

2.2. Amount of Debris/Smear Layer

- The amount of smear layer or plugs on the tooth surface has been evaluated by the researcher on the basis of observation of pictures taken using a microscope at different degrees of magnification (500×), where the rating scale is between 1 and 5.
    - 1: more or equal to 50%;
    - 2: less or equal to 40%;
    - 3: less or equal to 30%;
    - 4: less or equal to 20%;
    - 5: less or equal to 10%.

2.3. Amount of Obstruction of Dentinal Tubules Found in the Two Groups

The researcher, through observational studies, has evaluated the amount of obstructed tubules with a rating scale from 1 to 5; the scale is the same as the one utilized previously for debris evaluation.

- The 'amount of obstructed dentin tubules' was divided from 1 to 5:
    - 1: more or equal to 90%;
    - 2: less or equal to 70%;
    - 3: less or equal to 50%;
    - 4: less or equal to 20%;
    - 5: less or equal to 10%.

The microscopic observations were made by two calibrated expert operators: in the case of different evaluations, the two operators re-evaluated the microscopic picture together and found an agreement.

Then, 5 samples each group (with and without ultrasonic activation) were prepared following the already described protocol. Then, a universal bonding system (G-Praemio Bond, GC Co., Tokyo, Japan) was used following the manufacturer's instruction to bond

prepared root canal walls. After setting the bonding material, a layer of a flowable resin composite (Gaenial Flow, GC, Tokyo, Japan) was light-cured using Valo LED Cordless light curing device (Ultradent) on top following manufacturer's instructions. The samples were cut into two pieces along the long axis of the root. Then, half of the sample teeth was kept in an acidic solution (37% HCl) for 48 h in order to completely dissolve dental structures and to have a direct view of resin tags formation under SEM. The other half was prepared in order to observe the adhesive interface under SEM.

2.4. Statistical Analysis

Collected data were analyzed by using a statistical test (Wilcoxon and Fisher) and setting the *p*-value at $p < 0.01$ in order to evaluate possible differences among tested groups with respect to the amount of obstructed tubules.

3. Results

The results of the sample treated with or without ultrasounds are reported below.

The amount of debris was not satisfactory in 9 out of 10 in Group B, while in Group A, which has been treated with ultrasound, the result was either good or great in most of the samples (Figure 4). When increasing the level of details, the median value of the ultrasound treated group increased. The Wilcoxon *p*-value test for the differences between the two groups is a method of refusing the hypothesis of both treatments being equal. The results showed that the use of ultrasounds to clean root dentinal walls of post space is very useful, significantly improving the dentin surfaces without debris and with open tubules. The SEM observations of resin tags penetration showed that when ultrasounds were used and tubules were consequently opened, the adhesive can penetrate deeply into the tubules, creating a resin tag network; however when the ultrasound was not used, the resin tags were very short (Figures 5–8).

For the sample group treated with ultrasound, the tubules were evaluated as perfectly clean in 9 out of 10 cases; instead, the results are unsatisfactory for 9 out of 10 cases of group B, which was not treated with ultrasound. When the level of detail increases, the researcher's assessment does not change substantially. The differences between the scores of the two groups are statistically significant (*p*-value Wilcoxon test < 0.01).

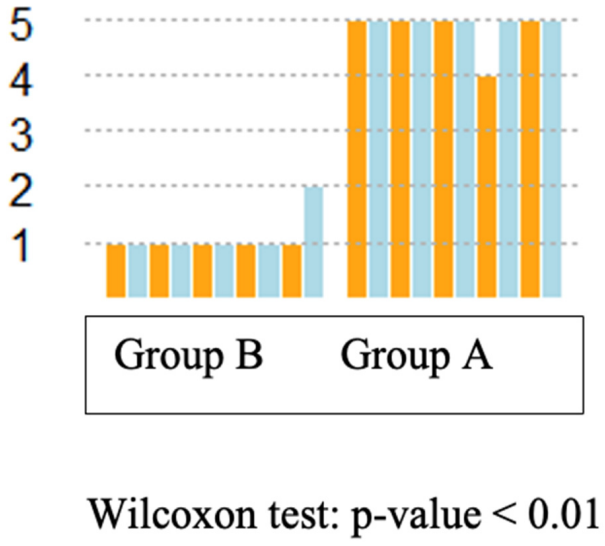


Figure 4. Evaluating cleaning of tubules: when an ultrasonic device was used (Group A), they were much better opened than when ultrasonic device was not used (Group B).

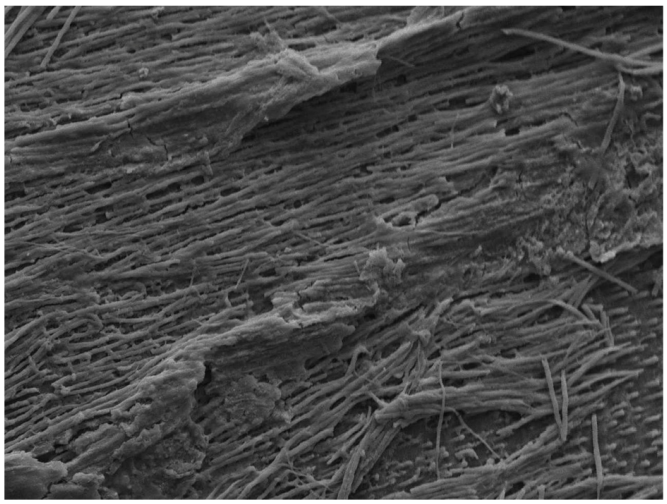


Figure 5. Group A: long resin tags formed into opened and cleaned tubules (×1000).

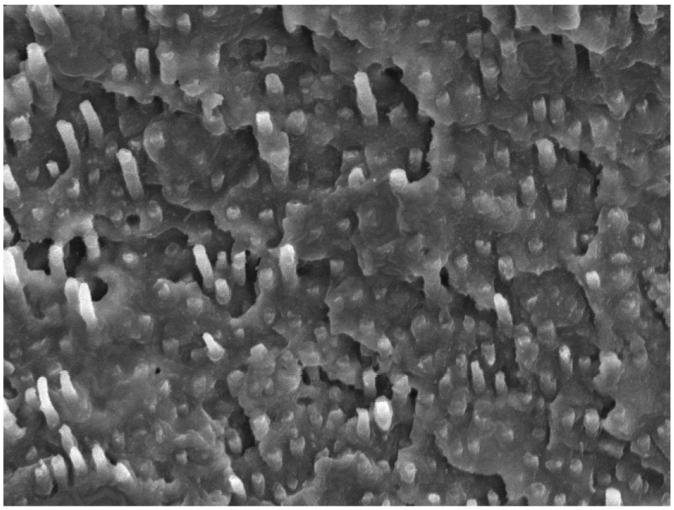


Figure 6. Group B: short resin tags formed into opened and cleaned tubules (×1000).

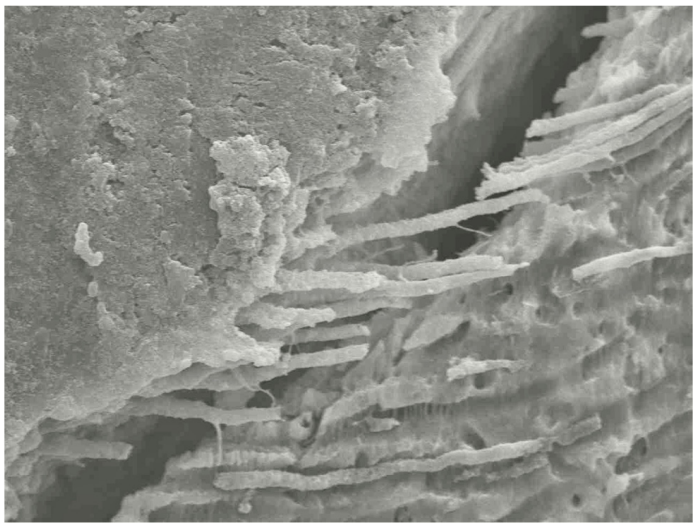


Figure 7. Group A: Adhesive interface (×1000).

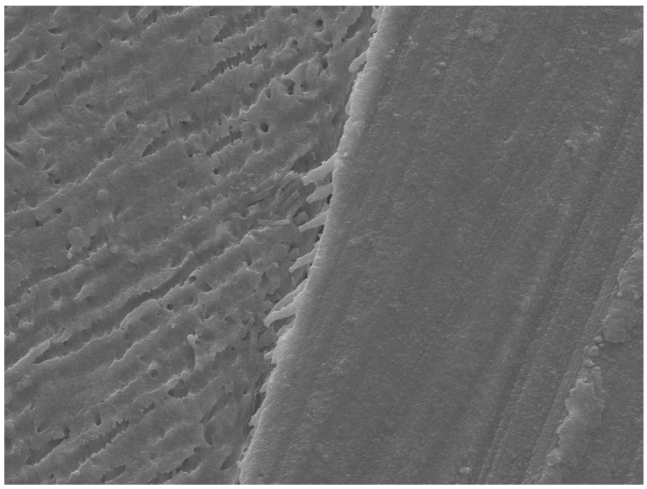


Figure 8. Group B: Adhesive interface (×1000).

The SEM evaluation of dissolved teeth in acid solution showed that, in Group A, the adhesive (resin tags) penetrated into the dentinal tubules deeply (Figure 5) whilst in penetration of adhesive into the dentinal tubules of Group B was limited or mainly absent (Figure 6).

The observations of the adhesive interfaces pointed out that the hybrid layer and resin tags formation in Group A was much more evident (Figure 7 than in Group B, Figure 8).

4. Discussion

The restoration of a non-vital tooth with or without the insertion of a fiber post and resin materials is a common clinical procedure in dentistry. The adhesion to the dentinal tissue is due to micromechanical retentions made on the demineralized surface and through the formation of a hybrid layer and resin tags [12]; therefore, post-space cleansing is really important and can influence the bond strength of the post to the dentin [13].

There are several adhesive systems available in the market; some authors argue that using self-etch has advantages over the total-etch ones, because they do not require a moist dentine substrate that is difficult to control within the canal [14]. Furthermore, the self-etch adhesive strength is not affected by the post-space's depth [15–17]. However, after the preparation of the post-space, the canal walls are characterized by the presence of the thick and sticky smear layer, and inserting the self-etch system will not be straight forward [18]; that is why total-etch systems are considered better in the adhesion process of the fiber post due to the etching effect of orthophosphoric acid while removing the smear-layer from canal walls [18].

Some studies have suggested that EDTA is effective in removing the smear layer both from the tubules and from the dentinal surface along the entire post-space [12,19–21], but in deeper areas of post-space, it is more difficult to obtain a clean dentinal surface. Some studies reported that the use of EDTA combined with sodium hypochlorite [22,23] has been shown to cleanse the canal walls of the post-space, but NaOCl causes the release of oxygen, which can inhibit the polymerization of resinous materials [24,25]; therefore, the acid etching of dentine is still an essential step for obtaining clean canal walls and a greater adhesion force of the post-bond strength, which can be further obtained with the use of ultrasonic tools during the cleansing of the post-space, as shown in this study, and this appears to produce a better dentine substrate for adhesive post cementation.

During irrigation, the ultrasound action is due to the capability of making minimal caving, which is minimal and just limited to the tip of the instrument, and acoustic streaming instead appears to be more significant. The ultrasounds, when near the liquid molecules, create positive and negative pressure bubbles, which became unstable, and will collapse and create an implosion similar to a decompression vacuum; the explosion and implosion

of the bubble will release impact energy with a cleansing effect, and it has been shown that the hypochlorite that has been previously activated with ultrasound cleans the root canal space more efficiently because there will be an increase in the flow of the irrigant further improving antibacterial proprieties and washing inorganic and organic debris removal powders. However, with respect to EDTA activity, ultrasounds seem to be less effective, but in any case they will allow improved smear layer removal [26].

5. Conclusions

With respect to the presence of debris and tubules obstruction treatment with ultrasonic activation, the studied material offers with no doubt better results. When ultrasonic activation is used in combination with endodontic irrigants, a clean dentin substrate is be obtained for the adhesion of restorative materials, but in order to confirm the findings of this study, further in vivo trails are needed.

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