

Evaluation of the Efficacy of EASYDO ACTIVATOR Irrigation Technique in Intracanal Smear Layer and Debris Removal from Mature Permanent Teeth

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Abstract

EASYDO ACTIVATOR (EA) is a continuously vibrational device for root canals irrigation, but its cleaning effectiveness has not been evaluated by any published reports. We were aiming to evaluate whether EA results in a greater intracanal smear layer and debris removal than conventional needle irrigation (NI) and passive ultrasonic irrigation (PUI). Twenty-seven single-rooted teeth were used. Canals were sized to R30 and irrigated with 3% sodium hypochlorite. Species were divided into three groups: Group 1: NI; Group 2: PUI; Group 3: EA. Canal walls were subjected to scanning electron microscopy. NI- and PUI-group canal cleanliness decreased from the coronal to apical direction ($P < 0.05$), except for EA group in the apical third. PUI removed more smear layer from the coronal and middle thirds than EA and NI ($P < 0.05$). PUI and EA were superior to NI regarding debris removal ($P < 0.05$). The smear layer and debris from the coronal and middle thirds were effectively removed with EA and PUI. More effective removal occurred from the apical third for EA compared with PUI ($P < 0.05$). Both methods removed smear layer and debris better than NI, providing a theoretical basis for the clinical application of EA.

Introduction

Cleaning and shaping procedures are the key principles of successful root canal treatment¹. Even with the use of rotary instrumentation, the nickel-titanium instruments currently available only act on the central body of the canal, leaving the apical canal root, canal fins, isthmi, and culs-de-sac untouched after completion of the preparation, which would leave necrotic debris and form a smear layer that prevents the rinsing fluid from entering dentinal tubules and promotes reinfection²⁻⁶. Irrigating solutions have a broad antimicrobial spectrum and capacity to dissolve organic tissue remnants⁷. Various irrigation protocols have been proposed to improve the efficacy of irrigation by delivering irrigants to untouched areas after instrumental preparation^{8,9}.

Syringe irrigation is the most basic flushing method, and the introduction of ultrasonic equipment has improved the effect of root canal irrigation so that irrigants penetrate widely into the root canal collateral to achieve a better irrigation effect^{9,10}. Studies have shown that compared with syringe irrigation, ultrasonic irrigation can remove the smear layer better due to the effect of cavitation and acoustic streaming^{11,12}. However, as the depth of the root canal system increases, the effectiveness of ultrasonic irrigation in removing the smear layer seems to decrease.

According to the manufacturer, the EASYDO ACTIVATOR (EA) system uses machine energy technology for root canal treatment. The driver works with the hand device, motor and needle tip to provide power for tip oscillation and vibration. Evidence-based endodontics have shown that cavitation and acoustic streaming can improve debridement and the disruption of the smear layer and biofilm¹². The activator helps the fluid stream enter the pulp chamber, root canal, lateral canal, connection of interroot canal and root apex to ensure deep cleaning and disinfection of root canal. This method is beneficial to complete the 3D filling of the root canal and ensures long-term success.

Although several studies have demonstrated the efficacy of ultrasonic systems on smear layers and debris, the efficacy of EA in removing the smear layer and superficial debris has not been documented. According to previous studies, the cleanness of the removal of the smear layer and superficial debris is typically evaluated by qualitative methods¹³⁻¹⁵. To assess the efficiency of different irrigation systems, scanning electron microscopy (SEM) is used to assess the cleanness of the contaminant layer in the root canals¹⁶⁻¹⁹.

The aim of this study was to compare the effect of EA with needle irrigation (NI) and passive ultrasonic irrigation (PUI) to remove the smear layer, evaluate the effectiveness of EA, and complete clinical research on EA. The null hypothesis of this study was that EA had no difference in the removal of smear layers and debris compared with PUI and NI.

Results

The removal of the smear layer is shown in Table 1 and Fig. 1, and the residual debris results are shown in Table 2 and Fig. 2. Figure 3 and Fig. 4 shows representative images of the middle and apical thirds for each of the groups analyzed. With regard to smear layer removal, significant differences were found between EA and all the instrumental groups in the apical third ($P < 0.05$). For the removal of superficial debris, activation with PUI or EA instruments guaranteed a better removal efficiency compared with NI at all root levels ($P < 0.05$).

Table 1

Mean scores in the evaluation of the residual smear layer in the different root canal thirds for each group

	NI	PUI	EA
Coronal	3.11 ± 0.60 ^{aA}	1.44 ± 0.40 ^{aB}	2.56 ± 0.56 ^{aA}
Middle	2.00 ± 0.54 ^{bA}	1.67 ± 0.39 ^{aA}	2.33 ± 0.55 ^{aA}
Apical	3.67 ± 0.77 ^{aA}	2.56 ± 1.34 ^{bB}	1.33 ± 0.39 ^{bC}
Different superscript letters indicate a significant difference at the 5% significance level ($P < 0.05$). (a, b and c for columns and n, m and l for rows) (NI, needle irrigation; PUI, passive ultrasonic irrigation; EA, EASYDO ACTIVATOR)			

Table 2
Mean scores in the evaluation of residual superficial debris in the different root canal thirds for each group

	NI	PUI	EA
Coronal	2.56 ± 0.77 ^{aA}	1.67 ± 0.39 ^{aB}	1.56 ± 0.40 ^{aB}
Middle	3.33 ± 0.55 ^{bA}	1.89 ± 0.26 ^{aB}	1.33 ± 0.39 ^{aB}
Apical	3.22 ± 0.64 ^{bA}	2.11 ± 0.60 ^{aB}	1.56 ± 0.40 ^{aB}
Different superscript letters indicate a significant difference at the 5% significance level ($P < 0.05$). (a, b and c for columns and n, m, and l for rows) (NI, needle irrigation; PUI, passive ultrasonic irrigation; EA, EASYDO ACTIVATOR)			

Smear layer (Fig. 1)

Significantly more smear layer was found in the apical portion than in the middle and coronal thirds of the root canals in all groups except for the EA group ($P < 0.05$). PUI removed significantly more smear layer in the coronal third than NI and EA ($P < 0.05$). However, more significant differences in the middle thirds among the groups were not obtained ($P > 0.05$). Moreover, compared to all other groups in the apical third, activation with the EA instruments removed significantly more smears ($P < 0.05$).

Debris (Fig. 2)

Both the EA group and PUI group removed significantly more debris compared to the NI group at all root levels ($P < 0.05$). However, significant differences between the EA group and PUI group were not obtained ($P > 0.05$). Canal cleanliness did not significantly differ between the apical and coronal portions of the root canals ($P > 0.05$), but more debris was found in the middle and apical thirds of the NI group ($P < 0.05$).

Discussion

Although many new endodontic treatments have been invented and used extensively, there are still more than 50% of the root canal wall remain untouched resulting in inorganic dentine chip, residual pulp tissue, microorganisms and necrotic products remaining in the variability of root canal anatomy^{9,20}. Thus, the development of agitation devices has been recognized during the last decade to promote the efficacy of cleaning and disfection of root canals through delivering irrigants and removing smear layer and debris.

Needle irrigation is a traditional and widely used methods but has its limitations to clean 1–2 mm area within the tip^{8,9}. Overall, new irrigation treatments have improved canal cleanness and disfection by irrigating the root canal thoroughly. The aim of this in vitro study was to evaluate the efficacy of a new irrigating instrument called the EA system with the NI and PUI systems for the removal of the smear layer and debris by SEM in single-rooted teeth.

In this study, the EA and PUI groups were statistically more effective than the NI group in the removal of superficial debris at all root levels, which was consistent to previous study. Van der et al. studied the mechanical cleaning efficiency of ultrasonic activation transferring irrigants²¹. Acoustic streaming and cavitation were reported to appear during the PUI treatment and the removal of dentin debris and smear layers was more effective than the NI treatment²². Furthermore, Al-Jadaa et al. found that PUI was able to increase temperature of irrigants, which effectively enhanced the tissue-dissolving capacity of NaOCl (chemical)²³. According to the manufacturer, EA creates a three-dimensional movement to trigger “cavitation” and “acoustic streaming”—two irrigation effects that until now have only been reported by PUI^{11,21}. Moreover, the EA devices have a DC motor control powered system to vibrate tips at 3,000–10,000 rpm, i.e., 3,000–10,000 Hz, which can also heat the fluid streaming and promote liquid transport. Therefore, with regard to the irrigation protocols, it is reasonable to consider that both EA and PUI have a positive impact on clinical performance.

Moreover, in the EA group, the apical part of the root canals exhibited less smear layer compared with the NI and PUI groups. As reported, automated instrumentation might produce thicker smear layer than manual preparation²⁴, which is contrary to our results. We speculated that is because the EA instrument is a cordless handpiece with a tip with highly flexible polyamide, which may decrease the risk of uncontrolled removal of root canal smear compared to the metal tip of PUI⁹. Nevertheless, further studies about the efficacy of manual and automated irrigation devices should be performed. According to our research, the null hypothesis was rejected.

In the present study, SEM was used for comparing the cleaning efficiency on the basis of a numerical evaluation scheme for debris and smear layers^{15,27,28}. However, SEM evaluations have some limitations as this method allows assessment of only limited areas of the canal wall. To overcome this potential limitation, after completely screening canal walls under SEM, the portions for each third of root canals with the greatest amounts of smear layer and debris was photographed and further analyzed. Another limitation of SEM evaluation is that the process of gold sputtering in the SEM process may have influenced the amount of smear layer and debris packing in root canal walls²⁹. Therefore, only one professionally trained operator was chosen to perform all procedures. However, the conditions in this study were more ideal than those encountered in the clinical situation. Thus, it is suggested these techniques before used in the mouth need to be assessed in clinical studies in vivo as well as in vitro

In conclusion, the results support the use of the EA instrument to guarantee effective cleanness of apical root canals, providing a theoretical basis for clinical application

Methods

Specimen preparation

The study design was approved by the Institutional Ethics Committee of the Second Xiangya Hospital, Central South University (LYE No. 2021023). All methods were performed in accordance with the relevant guidelines and regulations. Twenty-seven intact premolars extracted from orthodontic reasons were collected after informed consent from the patients or their parents or guardians. All specimen were radiographically confirmed the presence of a single root straight canal with a mature apex and excluded teeth with cracks or root fractures. Following the removal of superficial soft tissues with a brush, and the teeth were kept in 0.1% thymol solution (Sigma-Aldrich, Missouri, USA) at 4 °C until used.

Root canal therapy

The root canal preparation followed recognized studies, the Guide to Clinical Endodontics, published by the American Association of Endodontists^{30,31}. All samples were confirmed the working length (WL) by inserting No.10 K files (Dentsply Maillefer, Ballaigues, Switzerland) reaching the apical foramen and subtracting 1 mm from this point. Then, root canals were instrumented with nickel-titanium X-Taper Universal files (Easyin smile, Staten Island, NY, USA) up to F3 size³² following the WL by the same operator. Following the completion of canals enlargement, canals were rinsed with 2 mL of 0.9% NaCl for 1 min through an in-and-out motion with a 5 ml needle (NaviTip, Ultradent, South Jordan, UT) and dried with absorbent paper points.

Final irrigation procedures

The teeth were randomly divided to 2 experimental groups (n = 9) according to the final irrigation treatment; 9 additional teeth selected as a control group. Final irrigation protocol of each group was as follows:

Group 1 (needle irrigation, NI)

A total of 1.5 ml of 3% NaOCl was applied for the final irrigation^{19,33-35} by a needle (NaviTip, Ultradent, South Jordan, UT). The tip of needle was placed 2 mm short of the WL.

Group 2 (passive ultrasonic irrigation, PUI)

The final irrigation was performed using 1.5 ml of 3% NaOCl for 45 s but with passive ultrasonic activation. It was performed using an ultrasonic tip (size 25) that was placed 2 mm from the WL.

Group 3 (EASYDO ACTIVATOR, EA)

Similarly, 1.5 ml of 3% NaOCl was delivered but with an EA system with a power setting of 2. The EA tip was applied 2 mm short of the working length and moved in 2 mm amplitudes from the WL.

SEM preparation and analysis

After the intracanal procedures, teeth were marked 2 longitudinal grooves at buccolingual direction with a diamond-coated high-speed bur (TF-14; SHARK, Boston, USA) as reported by Wu and Wesselink³¹. A mallet and a chisel were used to split root canals and care was noticed so that decreased the grooves penetrating into canals. To clearly and objectively distinguish the sections of each root canals, horizontal signs were made at the coronal, middle, and apical sections from apex using a sharp scalpel inside the canals. All sections of teeth were subjected to critical point drying and coated for later examined under SEM. The root canal surface of all sections was examined using a scanning electron microscopy (JSM-IT100; Jeol, Tokyo, Japan). Following screening of all canal walls, photomicrographs at 1000× and 2000× magnification were taken to visualize three portions at the levels previously marked by a scalpel scratch.

The smear layer was recognized as the surface film of debris produced by root canal instrumentation, which may become a barrier and increase bacterial invasion into dentinal tubules³². Scoring of the presence of a smear layer was analyzed using a ×1000 magnification, and the scores were proposed by Hülsmann et al.¹⁷ on a grade from 1 to 5 as follows: score 1: no smear layer, all orifice of dentinal tubules open; score 2: slight smear layer, some dentinal tubules obstructed by debris; score 3: homogeneous amount of smear layer covering the canal wall, only a few dentinal tubules clean and open; score 4: whole root canal wall covered by heterogeneous smear layer, no patent orifice of dentinal tubules; score 5: the root canal wall obstructed by heavy, nonhomogeneous smear layer completely.

Debris was defined as inorganic dentine chips, pulp tissues residue, microorganisms and necrotic products and **remnant** attached to canal walls closely^{17,32}. × 2000 magnification images were analyzed for the presence of debris. The images were graded followed to the criteria reported by Hülsmann et al. [1]: score 1: root canal wall clean and smooth, few small debris remnants present; Score 2: dense debris packing part of root canal wall; Score 3: less than 50% of the root canal wall packed by agglomerations of debris; Score 4: over 50% of the root canal wall covered by uneven debris; Score 5: whole root canal wall covered by a great number of debris nearly.

Statistical analysis

The smear layer and debris score data were analyzed using the Pearson chi square test by SPSS software (SPSS v. 23, IBM, Armonk, NY, USA) to verify the assumption of normality. The level of significance was set at $p \leq 0.05$.

Declarations

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The authors deny any conflicts of interest related to this study.

Author contributions

Shao-Hui Zhang: Investigation, Writing - Original draft preparation, Formal analysis. Zheng-Rong Gao: Investigation, Writing - Original draft preparation, Formal analysis. Dusenge Marie Aimee, MB: Conceptualization, Methodology, Software. Yao Feng: Conceptualization, Methodology, Software. Jing Hu: Formal analysis. Jie Zhao: Formal analysis. Ya-Qiong Zhao: Data curation. Yun Chen, MD, PhD: Data curation. Qiong Liu, MB: Data curation. Qin Ye: Visualization. Ying-Hui Zhou, MD, PhD: Visualization. Li Tan: Writing - Review & Editing. Yue Guo, MD, PhD: Project administration, Funding acquisition. Yun-Zhi Feng, MD, PhD: Project administration, Funding acquisition.

Competing interests

The author(s) declare no competing interests.

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Figures

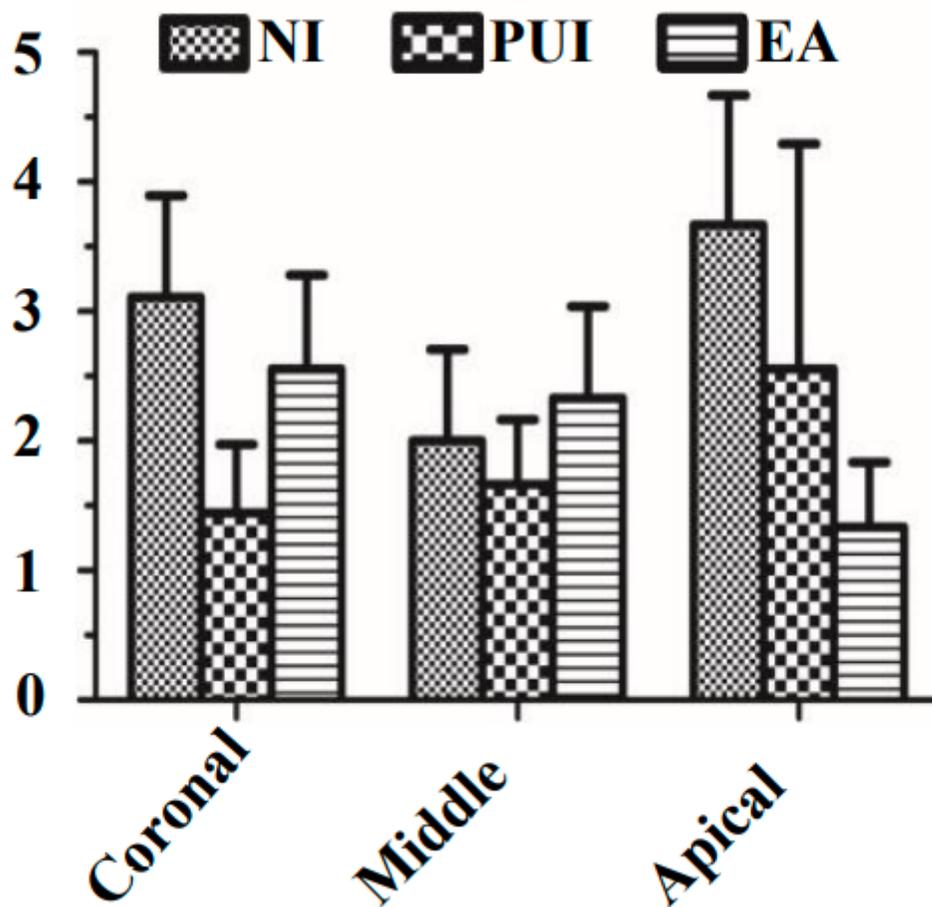


Figure 1

Histogram representing the mean scores in the evaluation of the residual smear layer in the different root canal thirds for each group. (NI, needle irrigation; PUI, passive ultrasonic irrigation; EA, EASYDO ACTIVATOR)

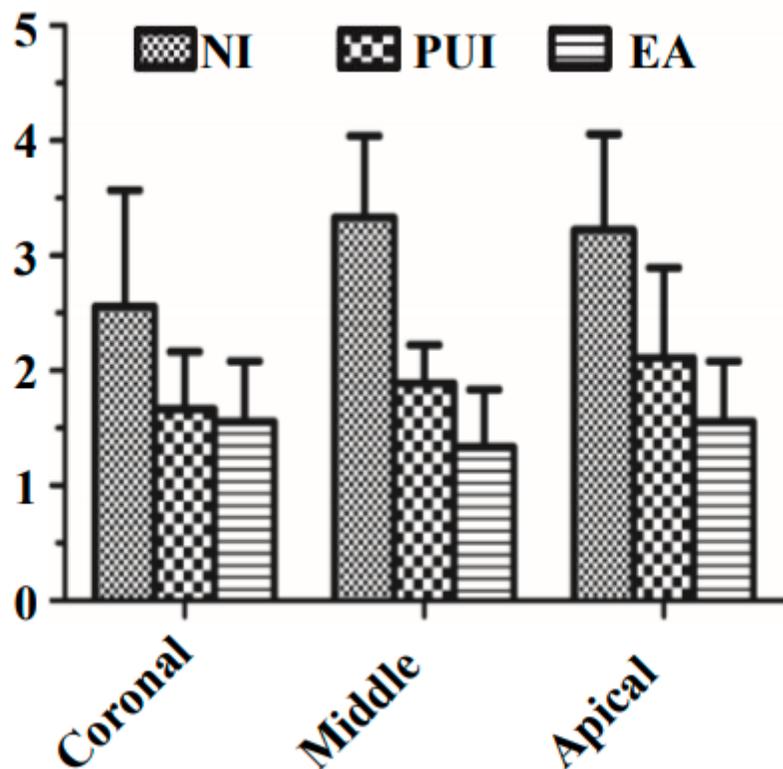


Figure 2

Histogram representing the mean scores in the evaluation of residual superficial debris in the different root canal thirds for each group. (NI, needle irrigation; PUI, passive ultrasonic irrigation; EA, EASYDO ACTIVATOR)

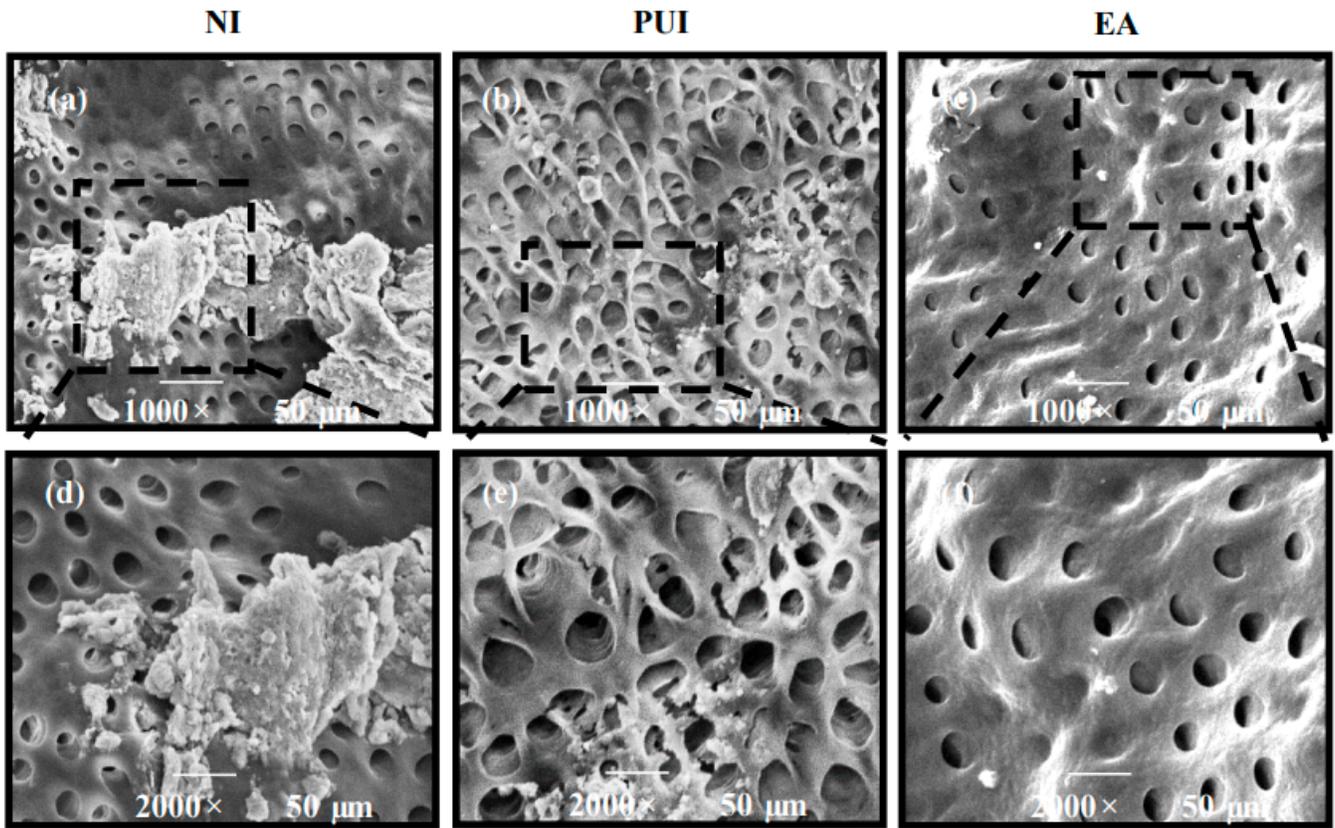


Figure 3

SEM smear layer, debris of dentinal wall at the coronal third. Above column: 1000× magnification. Below column: same sample at 2000× magnification. a and d: group NI (needle irrigation). b and e: PUI (passive ultrasonic irrigation). c and f: group EA (EASYDO ACTIVATOR).

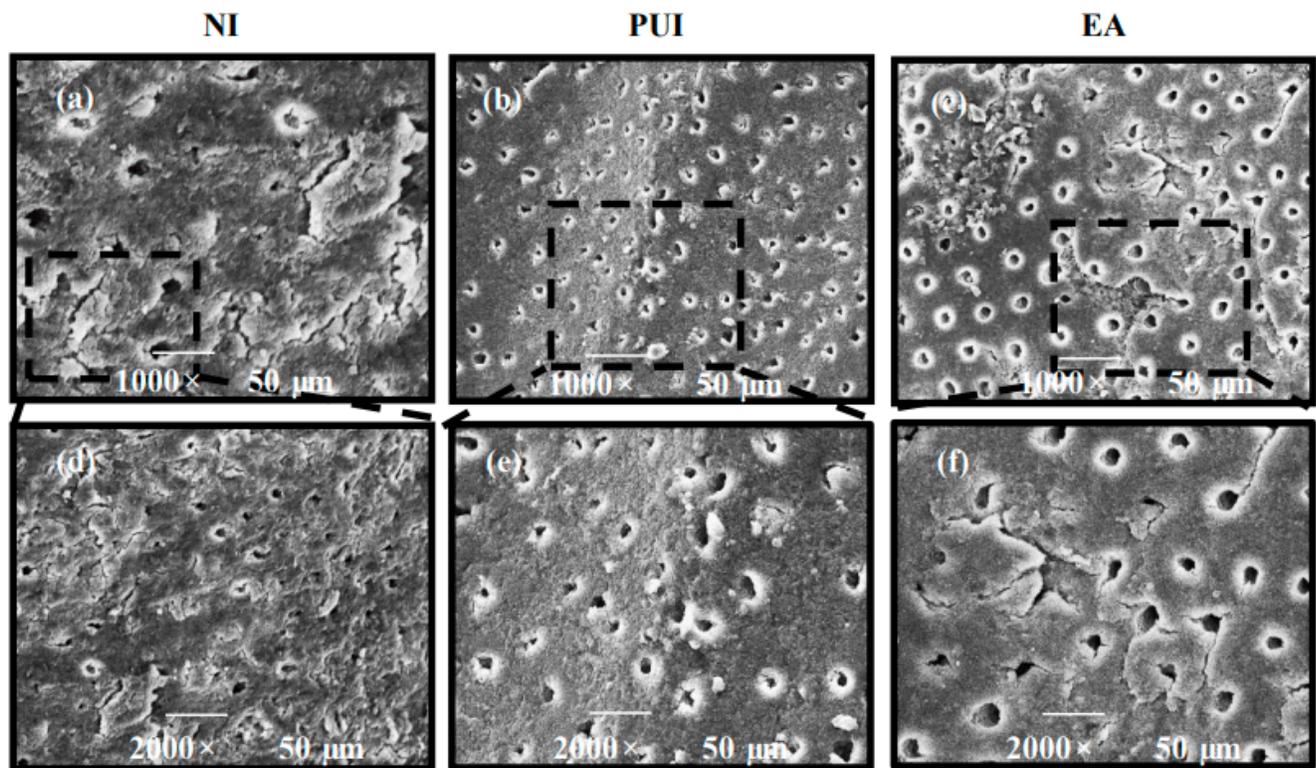


Figure 4

SEM smear layer, debris of dentinal wall at the apical third. Above column: 1000× magnification. Below column: same sample at 2000× magnification. a and d: group NI (needle irrigation). b and e group PUI (passive ultrasonic irrigation). c and f: group EA (EASYDO ACTIVATOR).