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Original Article

In vitro effect of XP-Endo finisher on the amount of residual debris and smear layer on the root canal walls

Shahrzad Azimian[1], Hengameh Bakhtiar[2], Shahram Azimi[3], Ehsan Esnaashari[2]

[1]Dental Student, Faculty of dentistry, Tehran medical sciences, Islamic Azad University, [2]Assistant Professor, Department of Endodontics, Faculty of Dentistry, [3]Dental Material Research Center, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

ABSTRACT

Background: A successful endodontic treatment depends on efficient cleaning and shaping and effective irrigation of root canals. The irrigating solution may not be effective in some areas in the canal. The manufacturer of XP-Endo finisher claims that it can effectively clean the root canals with complex morphology. This study aimed to assess the effect of XP-Endo finisher on the amount of residual debris and smear layer on the root canal walls of mandibular second premolars.

Materials and Methods: In this *In vitro* study Fifty extracted mandibular second premolars with a root curvature <20° were collected. Root canals were prepared using BioRaCe rotary system. The root canals were in contact with the file and different irrigating solutions for 1 min. The teeth were then randomly divided into four experimental (n = 10) and one positive control group as follows: (1) XPF + saline, (2) XPF + ethylenediaminetetraacetic acid (EDTA), (3) XPF + sodium hypochlorite (NaOCl), (4) XPF + EDTA + NaOCl and (control) EDTA + NaOCl. The teeth were longitudinally sectioned into two halves and the amount of debris and smear layer remaining in the coronal, middle, and apical thirds of the roots was quantified and scored under an electron microscope. The Kruskal–Wallis test was used to compare the groups, and $P < 0.05$ was considered statistically significant.

Results: The highest mean amount of residual debris (2.9 ± 1.13) was noted in XPF + saline group ($P < 0.05$). XPF + saline and XPF + NaOCl (3.8 ± 0.60) had the lowest efficacy for smear layer removal ($P < 0.05$) with no significant within-group difference. No significant difference was noted between Groups 2, 3, and 4 with the positive control group regarding debris removal. Groups 2 and 4 had no significant difference with the positive control group regarding smear layer removal.

Conclusion: Use of XP-Endo finisher has no superiority to the standard protocol for the use of irrigating solutions (EDTA + NaOCl) for debris and smear layer removal, but in some cases, such as second appointment of regeneration treatment we cannot use NaOCl because of its destructive effects on stem cells; thus, we can benefit from the synergistic effects of XPF and EDTA for better smear layer removal.

Key Words: Debris, root canal, smear layer

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Address for correspondence:
Dr. Ehsan Esnaashari, Department of Endodontics, Dental Branch, Islamic Azad University of Medical Sciences, Tehran, Iran.
E-mail: ehsan_dmd@yahoo.com

INTRODUCTION

A successful endodontic treatment depends on the correct diagnosis, efficient cleaning and shaping, and effective irrigation of root canals and their filling.[1] Evidence shows that following root canal

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preparation, a layer known as the smear layer irregularly covers the root canal walls with 1–2 μ thickness.[2] The smear layer has a crystalline structure and includes pulp residues, dentinal debris, bacteria, and their products.[3] Despite the existing controversy on the effect of smear layer on the quality of root canal preparation and filling, researchers believe that the smear layer is infected and can preserve the bacteria present in dentinal tubules.[4] The smear layer prevents or delays the penetration of intracanal medicaments, irrigating solutions, and antimicrobial agents into the dentinal tubules, increasing the coronal and apical microleakage.[5,6] Moreover, the smear layer prevents the contact of sealer with the canal walls, which also increases microleakage.[7,8]

The common protocol for smear layer removal includes the use of sodium hypochlorite (NaOCl) followed by ethylenediaminetetraacetic acid (EDTA), each for 1 min.[2] However, penetration of solutions into the isthmus area and other hard-to-reach areas in the canal is influenced by the preparation size, degree of taper, and surface tension of the solution.[5] Furthermore, the irrigating solution may not be effective in some areas in the canal.[9-11] The FKG Dentaire SA company in Switzerland recently introduced the XP-Endo finisher, a new NiTi file, into the market. The manufacturer claims that this file can effectively clean the root canals with complex morphology or very narrow straight or highly curved canals. These properties are attributed to the small size of the central core (ISO 25 diameter), 0% taper, MaxWire NiTi alloy, molecular phase transformation of the file in body temperature, high flexibility of the file, and its ability to access the surrounding environment by 6 mm or 100 times it's primary volume.

At room temperature, the file is straight and in martensite phase (20°). When entered into the canal at body temperature (35°), it transforms to austenite phase considering its molecular memory. On cooling, it transforms back to the martensite phase and its straight form.[12] The manufacturer claims that the XP-Endo finisher file can remove dentin from the root canal surface and guide chemical solutions to the hard-to-reach areas. By doing so, it enhances the dissolution of biofilm and microorganisms.

This study aimed to assess whether the use of this file accompanied by the standard irrigation protocol can yield a cleaner canal surface.

MATERIALS AND METHODS

Sample preparation

In this *In vitro* study Fifty extracted human mandibular second premolars were collected and immersed in 0.1% thymol solution (Ogna, Muggio, Italy) for 1 h. After cleaning of the root surfaces from debris and tissue residues using a sterile gauze, the teeth were stored in saline until the experiment. The roots were inspected for cracks, fractures, root caries or external root resorption, and the teeth with such defects were excluded from the study. The teeth were then standardized regarding length by measuring the tooth length from the buccal cusp tip to the root end and the teeth with 18–22 mm length were included in the study.

The canal curvature was measured by introducing a #15 K-file (Maillefer, Dentsply, Ballaigues, Switzerland) into the canal to the working length and taking a buccolingual radiograph using the parallel technique with the help of Endo-Ray film holder and photostimulable phosphor plate sensor (Soredex, Helsinki, Finland). The canal curvature was determined using the Schneider's method[13] and the teeth with canal curvature <20° were included in the study. Access cavity was prepared using high-speed hand-piece (W and H Dentalwerk GmbH, Burmoos, Austria) operating at 20,000 rpm and 008 cylindrical bur (Tizkavan, Tehran, Iran). Straight access was created. A #10 K-file was introduced into the canal to ensure canal patency. Apical canal diameter was checked using a #15-K file (file could not pass the apical foramen). Roots not meeting these conditions and teeth with a lateral apical foramen were excluded. A #15 K-file was introduced into the canal until its tip was visible at the apex. Working length was determined 1 mm short of this length. The teeth were then coded and randomly divided into four experimental (n = 10) and one positive control group.

Canal preparation

Canals were prepared using BioRaCe rotary system (FKG Dentaire SA, Switzerland) up to size 40 (4%) operating at 600 rpm and 1.5 Ncm torque driven by an electric motor (NSK, Japan). Canals were rinsed with 2 mL of 2.5% NaOCl (Cerkamed, Poland) with a 30G needle (Transcodent GmbH and Co Kiel, Germany) after using each file. After completion of root canal preparation, each canal was rinsed with 5 mL of saline. In the four experimental groups, XPF file operating at 800 rpm was used with up and down

movement for 1 min before canal irrigation with saline, NaOCl, and 17% EDTA (Cerkamed, Poland) solutions using a 30G needle. The needle was reached to the apical third for irrigation. The study groups were as follows:

1. XPF + 2 mL of saline (1 min)
2. XPF + 2 mL of 17% EDTA (1 min)
3. XPF + 2.5% NaOCl (1 min)
4. XPF + 17% EDTA (30 s) +5 mL of saline and XPF + 2.5% NaOCl (30 s)
5. 17% EDTA (1 min) +5 mL of saline + 2.5% NaOCl (1 min).

Finally, all canals were rinsed with 5 mL of saline. Next, canals in all five groups were dried with paper points (Dentsply-Maillefer, Konstanz, Germany).

Electron microscopic analysis

The teeth were cut at the cementoenamel junction and then two superficial grooves were created on the external buccal and lingual root surfaces by a diamond bur (Tizkavan, Tehran, Iran) under copious irrigation. Using a chisel, each root was longitudinally sectioned into two halves in buccolingual direction. The teeth were then gold-palladium sputter-coated (Agar Sputter Coater B7340; Agar Scientific Ltd., Stansted, UK) and observed under a scanning electron microscope (SEM 5600; JEOL Ltd, Tokyo, Japan) at ×3000 magnification. The coronal, middle, and apical thirds were evaluated and the amount of debris and the smear layer on the root canal surfaces was quantified. The obtained photographs were evaluated by three experienced, blinded endodontists, and the amount of residual debris was scored using the Hulsmann scoring system as follows:[14]

1. Clean canal walls with only a few debris particles
2. Small masses of debris
3. High amounts of debris covering <50% of the canal wall
4. Debris masses covering more than 50% of the canal wall
5. Almost the entire canal wall is covered with debris.

The amount of residual smear layer was also scored using the same scoring system as follows:[14]

1. Absence of smear layer and open dentinal tubules
2. Small amounts of smear layer and only a few open dentinal tubules
3. Uniform smear layer covering almost the entire canal wall with only a few open dentinal tubules
4. Uniform smear layer covering the entire canal walls with no open dentinal tubules
5. Heavy, irregular smear layer covering the entire canal walls.

Statistical analysis

The Kruskal–Wallis test was used for the comparison of groups, and $P < 0.05$ was considered statistically significant.

RESULTS

Variable amounts of debris and smear layer were noted on canal walls. Removal of the smear layer and debris was equal in the coronal, middle, and apical thirds with no significant difference ($P > 0.05$). Table 1 shows the order of groups regarding the amount of residual debris. The results showed that the saline group had the highest mean amount of residual debris. The highest amount of residual debris was noted in saline group (2.9 ± 1.13; $P < 0.05$). XPF + saline and XPF + NaOCl had the lowest efficacy for smear layer removal (3.8 ± 0.60; $P < 0.05$) with no significant within-group difference.

Table 2 shows the order of groups regarding the amount of residual smear layer. The XPF + saline and XPF + NaOCl groups showed the lowest removal of the smear layer compared to all other groups ($P < 0.05$) with no significant within-group difference. Regarding debris removal, no significant difference was noted between Groups 2, 3, and 4 with the positive control group. Regarding smear layer removal, no significant difference was noted between the Groups 2 and 4 with the positive control group.

Figure 1 shows representative scanning electron microscope photomicrographs (×3000) of debris and smear layer in different groups at the coronal, middle, and apical thirds.

Table 1: Comparison of *P* value between groups for residual debris

Canal level	Study group	Significance
Coronal	Saline+XPF. NaOCL+XPF	0.007
	Saline+XPF. EDTA+XPF	0.001
	Saline+XPF. EDTA+NaOCL+XPF	0.001
	Saline+XPF. control	0.004
Middle	Saline+XPF. NaOCL+XPF	0.004
	Saline+XPF. EDTA+XPF	0.000
	Saline+XPF. EDTA+NaOCL+XPF	0.008
	Saline+XPF. control	0.000
Apical	Saline+XPF. NaOCL+XPF	0.043
	Saline+XPF. EDTA+XPF	0.028
	Saline+XPF. EDTA+NaOCL+XPF	0.001
	Saline+XPF. control	0.001

The significance level is 0.05

Table 2: Comparison of *P* value between groups for residual smear layer

Canal level	Study group	Significance
Coronal	Saline+XPF. NaOCL+XPF	1.000
	Saline+XPF. EDTA+XPF	0.026
	Saline+XPF. EDTA+NaOCL+XPF	0.000
	Saline+XPF. control	0.000
Middle	Saline+XPF. NaOCL+XPF	1.000
	Saline+XPF. EDTA+XPF	0.000
	Saline+XPF. EDTA+NaOCL+XPF	0.015
	Saline+XPF. control	0.000
Apical	Saline+XPF. NaOCL+XPF	1.000
	Saline+XPF. EDTA+XPF	0.005
	Saline+XPF. EDTA+NaOCL+XPF	0.002
	Saline+XPF. control	0.000

The significance level is 0.05

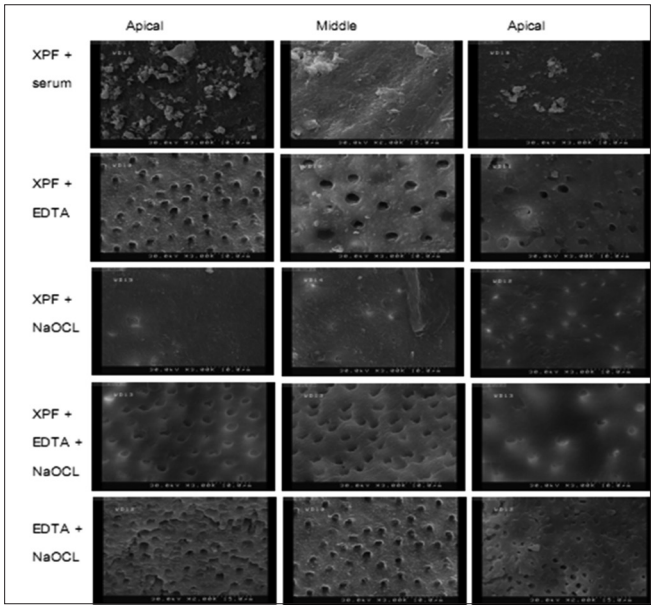

Figure 1: Representative scanning electron microscope photomicrographs (×3000) of debris and smear layer in different groups at the coronal (C), middle (M) and apical (A) thirds.

DISCUSSION

The main goal of endodontic treatment is cleaning and preparation of root canal walls to ensure removal of necrotic and vital pulp tissue, bacteria, debris, and smear layer and prevent re-contamination of the canal.[15]

Use of NiTi files is increasing in endodontic treatments. These files are elastic and adapt to the canal wall due to their low modulus of elasticity. Compared to stainless steel files, NiTi files have lower frequency of procedural errors such as ledge formation, zipping, and canal transformation and are less susceptible to fracture.[16] The BioRaCe rotary file used in the current study prepares the apical region to larger sizes (#40) and thus, provides a larger space for the activity of solutions in the apical region.[17-19] Previous studies confirmed that NiTi rotary files contact the canal walls by 40%–45% during root canal preparation and thus, a great part of the canal walls remains unprepared.[20,21] One unique property of XPF file is molecular phase transformation at body temperature. In Austenite phase, this file better adapts to the canal wall and results in more efficient cleaning.[12]

In this study, ×3000 magnification was used because although high amounts of smear layer can be seen in lower magnifications, the debris, and dentinal tubules are only seen at higher magnifications.[22] To quantify the amount of residual debris and smear layer, the Hulsmann scoring system was used, which is reliable and reproducible.[14]

In this study, removal of debris and smear layer by the XPF file was the same in the coronal, middle, and apical thirds and was not significantly different. However, Slavoljub *et al.*[23] and Elnaghy *et al.*[24] stated that the removal of debris and smear layer by the XPF file was greater in the coronal and middle thirds compared to the apical third. Most previous studies have not mentioned the location of needle for canal irrigation[23-26] while in the current study, the needle was in the apical third and 30G needle was used, to improve the irrigation of the apical region. This increases the efficacy of irrigating solutions.[27,28]

The amount of residual debris in different regions of the canal in this study showed that XP + saline group had the highest amount of residual debris. It indicates that XPF file accompanied by NaOCl, EDTA, or a combination of both better removes debris; this has also been reported in previous studies and is due to the chelating effect of EDTA and dissolution of necrotic tissues as well as the antimicrobial effect of sodium hypochlorite.[24-29]

The amount of residual smear layer in different parts of the canal in this study revealed that XP + saline and XP + NaOCl groups had the highest amount of residual smear layer. XPF plus EDTA alone or EDTA and NaOCl better removed the smear layer, which may be due to the chelating action of EDTA for smear layer removal. This was in agreement with the results of the previous studies.[24-26,30,31] In contrast to some studies, this study showed that XPF combined with NaOCl solution alone had lower efficacy for smear layer removal.[23,27,32] This difference may be

due to the volume, concentration or frequency of use of irrigating solutions. Considering different protocols for the use of irrigating solutions, 2 mL of 2.5% NaOCl was used for canal irrigation along with XPF in the current study while Wigler *et al.*[27] used 5 mL of 4% NaOCl for canal preparation and 5 mL of 4% NaOCl and 5 mL of 17% EDTA after canal preparation for smear layer removal. Also, 5 mL of 4% NaOCl was used with XPF. Bao *et al.*[32] used 5.25% NaOCl and 17% EDTA for smear layer removal at first and then used XPF along with 1 mL of 3% NaOCl. They performed three-step irrigation. In this method, NaOCl irrigating solution is changed three times.

Moreover, final canal rinse and flushing can also help in effective removal of the smear layer. For this purpose, 5 mL of saline was used in this study while Slavoljub *et al.*[23] used 5 mL of 2% NaOCl and Elnaghy *et al.*[24] used 1 mL of 2.5% NaOCl solution for 1 min plus 5 mL of saline. Wigler *et al.*[27] used 5 mL of 4% NaOCl and Bao *et al.*[32] used 1 mL of saline for 30 s as well as 4 mL of 17% EDTA for 2 min.

Canal preparation size by the rotary system is also important in this respect because widening of the apical third of the canal results in better contact of XPF file as well as NaOCl and EDTA solutions with the canal wall. As the result, greater amounts of debris and smear layer are removed. In the current study, BioRaCe system with 4% taper was used while Leoni *et al.*[29] used WaveOne rotary system with 6% and 8% taper, Bao *et al.*[32] used Vortex Blue rotary system with 4% and 6% taper, and Elnaghy *et al.*[24] used BT Race rotary system with 4% and 6% taper.

CONCLUSION

According to the current results, use of XP-Endo finisher has no superiority to the standard protocol of irrigating solutions (EDTA + NaOCl) for debris and smear layer removal.

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Department of Endodontics, Faculty of dentistry, Tehran medical sciences, Islamic Azad University, Tehran, Iran

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

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