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ORIGINAL ARTICLE

Efficacy of XP-endo Finisher-R in enhancing removal of bioceramic sealer from oval root canal: a micro CT study

ABSTRACT

Aim: *To investigate the efficacy of the XP-endo Finisher-R (XP-FR) and manual H-filing in enhancing the removal of Totalfill BC sealer from oval root canals.*
Methodology: *Forty mandibular incisors were prepared using ProTaper Next up to file X3 then filled with warm vertical condensation using Totalfill BC sealer. The volume of the root canal filling post-obturation and the remaining volume post-retreatment using Mani NRT-GPR system were assessed using Micro-CT (μ-CT). The total volume in 3 mm was calculated from the cervical line till the root apex using the CT-an software. Specimens were randomly divided into two equal groups n=20 according to the supplementary approach of gutta percha removal used; where Group I: XP-FR was used for 1 min, and Group II: size 30 H-file was used in a filing motion for 1 min. Specimens were again scanned using μ-CT and the remaining gutta percha volume was calculated. Data were statistically analyzed using Wilcoxon, Man-Whitney, Friedman tests with significance level of 5%.*
Results: *Significant reduction of the remining filling material was recorded post-retreatment with percentage of reduction of 63.34%, 78.53%, and 66.21% at the apical, middle, and coronal thirds respectively using Mani NRT-GPR system. Supplementary removal approaches significantly improved filling material removal (P<0.05). XP-FR removed significantly more filling material than manual H-filing with percentage of filling material reduction of 52.22%, 34.92%, and 40.60% compared to 21.89%, 18.43%, 31.72% in the apical, middle, and coronal thirds (Man-Whitney test, P<0.001).*
Conclusions: *Rotary retreatment files failed to totally remove the root canal filling material. Supplementary methods have improved root canal filling material removal; where XP-FR significantly removed more filling than manual H-filing.*

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Introduction

Persistent intracanal microorganisms following primary root canal treatment are causative factors of treatment failure (1, 2). Root canal system disinfection following total elimination of the root canal filling material is the main objective of nonsurgical root canal retreatment. Several techniques have been advocated for intracanal filling material removal using manual and engine-driven files (3). Moreover, supplementary techniques were introduced as lasers and ultrasonics with or without solvents (4-7).

Gutta percha and sealer removal from oval canals is quite challenging (8) as most endodontic files fail to touch all the root canal walls. Therefore, supplementary techniques following retreatment procedures would be beneficial.

Recently, bioceramic sealers (BCS) have been introduced as root canal sealers. BCS showed superior biocompatibility, physical properties, biomineralization, antimicrobial activity, and sealing ability (9-12). Totalfill BC sealer (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland) is a premixed, injectable, calcium silicate-based, containing zirconium oxide, calcium phosphate monobasic, calcium silicates, calcium hydroxide, as well as various filling and thickening agents. BCS use moisture within the dentinal tubules to complete its setting by forming hydroxyapatite resulting in dentin-sealer bond. Retrieval of BCS is considered a difficult task due to the formation of a strong chemical bond with hydroxyapatite (13-16).

Many engine-driven file systems were designed for gutta percha removal. Mani NRT-GPR system (Mani Inc, Tokyo, Japan) includes four rotary files with 0.04 taper. Two stainless steel files 1S and 2S with tip size 0.7 mm and 0.5 mm respectively designed to remove the root canal filling material from the coronal two thirds of the canal. Two NiTi files 3N and 4N with tip size 0.4 mm and 0.3 mm respectively used to the full working length of the root canal. Recently, XP-endo Finisher-R (XP-FR) (FKG Dentaire, La Chaux-de-Fonds, Switzerland) was introduced as a new variation of the XP Endo Finisher "MaxWire" Martensite-Austenite Electropolish Flex (FKG Dentaire, La Chaux-de-Fonds, Switzerland) to aid in the removal of gutta percha and sealer from the root canals. It has a tip size of 0.3 mm and a zero taper. The manufacturer claims it has the ability to expand in the root canal at body temperature which enables it to abrade the root canal walls (17). Micro-CT (µ-CT) allows for three-dimensional evaluation of the remaining intracanal filling material (18). The current study aimed to investigate the ability of XP-FR and manual H-filing in enhancing the removal of Totalfill BC sealer from oval root canals using µ-CT. The null hypothesis tested is that there is no difference between XP-FR and manual H-filing in removal of Totalfill BC sealer from oval root canals.

Materials and Methods

Sample selection

After approval from the local Ethics Committee (Protocol No 037-01-19), forty human mandibular mature incisors were selected. Teeth with oval root canals, completely formed apices, tooth length ranging from 19 to 21 mm and root curvature <20° calculated using Schneider method (19) were included. Teeth were cleaned then immersed in 2.5% sodium hypochlorite (NaOCl) for 24 hours then kept in 10% formalin till use. Teeth were subjected to digital radiographs in mesiodistal and buccolingual directions. The canal is considered oval when its buccolingual dimension is at least double its mesiodistal dimension. Teeth with more than one root canal, calcification, accessory root canals, or previous root canal treatment were excluded.

Root canal preparation

One operator (the first author) performed all the procedures. Diamond round burs mounted on high-speed handpiece were used to prepare access cavities. Working length (WL) was calculated by subtracting

0.5 mm from the tooth length. Teeth were placed in silicone mount to facilitate positioning for the µ-CT scan. Root canals were prepared using ProTaper Next (Dentsply Tulsa Dental; Tulsa, OK, USA) with rotational speed of 300 rpm and torque 2 N/cm using X-Smart endodontic motor (Dentsply Tulsa Dental; Tulsa, OK, USA) till X3 (30, 0.07). Root canal irrigation was done using 3 ml of 2.5% NaOCl. Final irrigation was done using 10 ml of 2.5% NaOCl followed by 1 ml of 17% Ethylenediamine Tetraacetic Acid (EDTA) MD-cleanser, (MetaBiomed, Chungcheongbuk-do, Republic of Korea) to remove the smear layer. Final rinse using 5 ml of distilled water was done followed by canal drying using paper points X3 (Dentsply Tulsa Dental; Tulsa, OK, USA).

Root canal obturation
Warm vertical condensation technique was used. Thin layer of TotalFill BC sealer was applied using paper point X2. Master gutta percha cone X3 (Dentsply Tulsa Dental; Tulsa, OK, USA) was selected and inserted into the canal, tug-back was ensured, and down packing was performed using System B (Analytic Technology, Redmond, WA). Fine medium plugger was selected for the down pack procedures. Temperature was set at 200 ºC and power at 10. Gutta percha was cut off at the root canal orifice. Plugger was reactivated at the same temperature to compact the gutta percha till reaching 5 mm of the WL. Gentle pressure was maintained for 10 seconds. Backfill of the canal was performed to the root canal orifice level.
Access cavities were temporized using Coltosol (Coltene, Altstätten, Switzerland). Obturation quality was evaluated using periapical radiographs in mesiodistal and buccolingual projections. Teeth were kept in incubator at 37 ºC and 100% humidity for 30 days to ensure maximum setting of the root canal sealer.

Post-obturation micro-CT scanning
Following obturation, teeth were scanned using micro-CT (SkyScan 1172 Kontich, Belgium). Teeth were placed in silicone mold to allow each tooth to be scanned during all stages of evaluation in the same position. During acquisition, teeth were rotated 360 degrees around the vertical axis with 0.6 step-size rotation, with 100 kV,100 mA, and 13.7 µm voxel resolution, and a cupper aluminum filter. Scanning time was 40 minutes in average for each tooth. Images were saved as 16-bit raw data TIFF files. Raw data were reconstructed to bitmap files using software (NRecon v.1.6.7.2; Bruker-microCT, Kontich, Belgium). Total volume in mm3 of gutta percha was calculated from the cementoenamel (cervical) line till the root apex by integration of the regions of interest in all cross sections using the CT-an software (Bruker-micro CT).

Root canal retreatment procedures
Following Coltosol removal, gutta percha was removed using Mani GPR Files. These files were operated at 1000 rpm and no torque control, as recommended by the manufacturer. Gutta percha was removed using the 1S file 3 mm from the canal orifice followed by the 2S instrument in the coronal third for 1 to 2 seconds. The 3N instrument was used in the coronal two thirds of the canal followed by the 4N instrument to the WL and operated for 1 to 2 seconds. Root canal preparation was then expanded using X3 (30, 0.07) and X4 (40, 0.06).
All files were used in 3 mm vertical strokes with light apical pressure. Retreatment was considered complete when the WL could be reached and there was no gutta percha or sealer on the instruments. All instruments were used for 5 root canals and then discarded. Root canals were irrigated using 2.5% NaOCl during the procedure.

Post-retreatment µ-CT scanning
Teeth were scanned post-retreatment using the same initial parameters for scanning, reconstruction, and calculation of the remaining gutta percha volume in the root canals. Total volume in mm3 of filling material was calculated from the cementoenamel (cervical) line till the root apex by integration of the regions of interest in

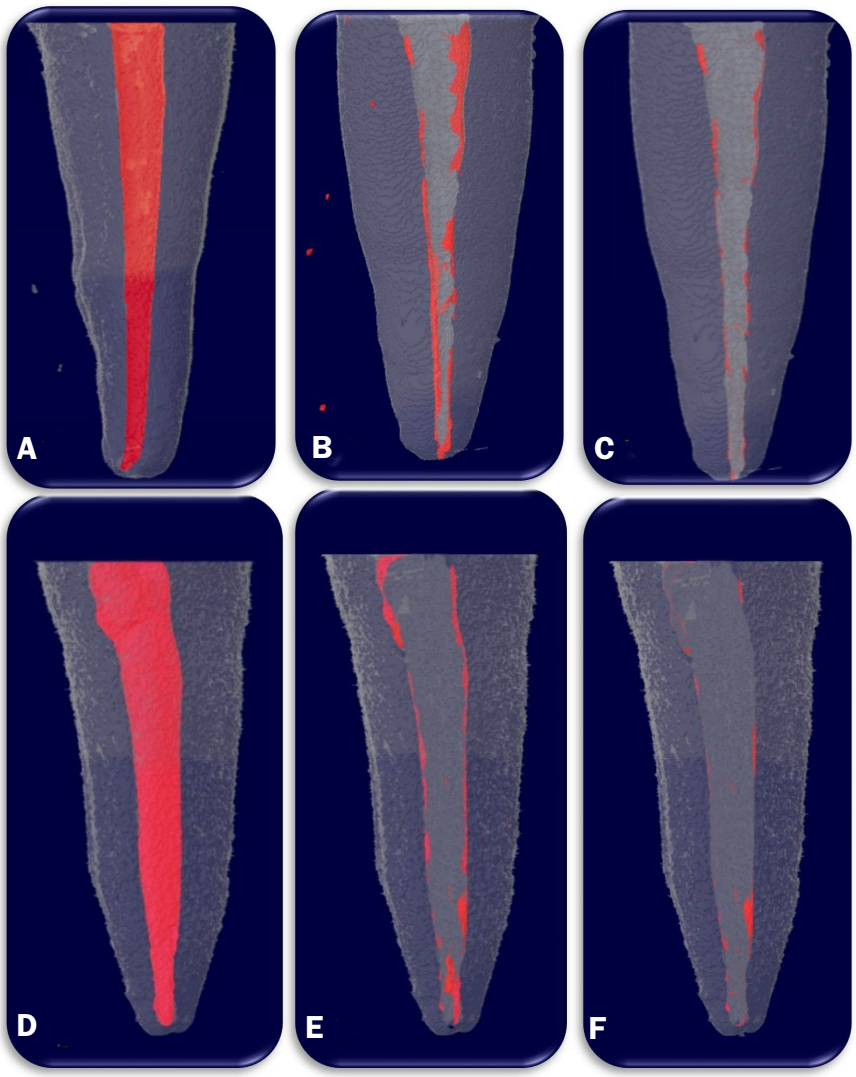

Figure 1
Micro-CT images of representative samples before (**A** & **D**), after re-treatment procedure (**B** & **E**), after supplementary approach XP-FR (**C**) and H-file (**F**).

all cross sections. Volume (mm 3) of root filling material removed was calculated as the difference between initial (post-obturation) and final readings (post-retreatment). Percentage of reduction in filling material was also calculated. Teeth were randomly divided into two equal groups (n=20) according to the supplementary root canal cleaning method used.

Supplementary cleaning methods

XP-endo Finisher-R

For group I, XP-FR was removed from the plastic tube in rotation motion by lateral movement.

Speed was set at 800 rpm and torque 2 N/cm and a 16:1 reduction-gear contra-angle handpiece was used. Each root canal was filled by 2 ml of 2.5% NaOCl and XP-FR was used in a gentle vertical motion 7-8 mm strokes up to the WL. XP-FR was used in a brushing motion against the walls for one minute inside the canal. XP-FR instrument was discarded after preparation of 4 canals.

Manual filing

For group II, Hedstrom file number 30 was placed to the WL and used in a brushing motion against the walls for one minute. Final irrigation was performed using 2 ml of 2.5% NaOCl.

Post-supplementary retreatment µ-CT scanning

Teeth were scanned with µ-CT using the same parameters to evaluate the volume of the remaining filling material. Volume (mm3) of filling material removed after using both supplementary approaches was calculated. Percentage of reduction in the filling material was also calculated.

Statistical analysis

Primary observation for the normality of recorded data took place using Kolmogorov-Smirnov and Shapiro-Wilk tests. Data failed to pass normality test and presented non-parametric (not-normal) distribution. Based on this, non-parametric tests were used for analysis namely; Wilcoxon and Man-Whitney.

Wilcoxon test was used to evaluate the assumption that the baseline volume (post-retreatment) is similar between tested groups. Man-Whitney test was used to evaluate whether the difference of volume of root canal filling material is similar after both supplementary approaches (post-supplementary retreatment).

Additional intra-group analysis was performed using Friedman test to evaluate and compare the amount of root filling material removed from root canal thirds (coronal, middle, and apical) by each supplementary approach.

The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results

Remaining filling material was observed post-retreatment and after both supplemen-

Table 1

The mean, median, and standard deviation (SD) values of root filling material volume in mm 3 post-obturation, post-retreatment, and percentage of reduction in each anatomical third

	Apical			Middle			Coronal			Total		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Post-obturation	0.81	0.73	0.25	1.94	1.57	0.72	4.16	3.6	1.03	6.86	5.91	1.77
Post-retreatment	0.32	0.24	0.21	0.42	0.34	0.21	1.37	1.29	0.21	2.12	1.86	0.62
% reduction	63.34	66.09	12.28	78.53	79.61	5.90	66.21	65.52	4.42	69.13	70.01	4.37
p-value	<0.001*			<0.001*			<0.001*			<0.001*		

**significant (p<0.05)*

tary approaches as shown in Figure 1. While Table 1 shows the means, medians and standard deviations of the initial volume of root canal filling material (post-obturation), volume of remaining gutta percha (post-retreatment) and percentage of reduction at root canal thirds after retreatment. Significant reduction in the amount of filling material was shown when compared to the baseline (post-obturation) (Wilcoxon test, P=0.001), Also, significant reduction was recorded (P<0.001) with a median of 66.09%, 79.61%, and 65.52% at the apical, middle, and coronal thirds respectively.

Comparing the supplementary removal methods, XP-FR was more effective than H-filing (Man-Whitney test, P<0.001), as it removed a median of 43.83% compared to 22.28% for manual H-filing (Table 3).

Additional intra-group analysis revealed that XP-FR significantly reduced the remaining filling material at all root canal thirds (Freidman test, P=0.004). It removed 57.27%, 38.75 % and 42.86% from the apical, middle, and coronal thirds respectively, compared to H-filing which removed 22.31%, 19.23%, and 32.09 % from the apical, middle, and coronal thirds respectively. Mean, median and standard deviation values of the root filling material volume and the percentage of reduction post-supplementary approaches are presented in Tables 2 and 3.

Discussion

BCS retrieval is not easy due to the strong chemical bond formed with hydroxyapatite (13-16). Although BCS could be used in obturation with a single cone (20), continuous wave of condensation was used in this study to achieve maximum contact with dentin. Oval-shaped canals represent another challenge for intracanal filling material removal due to minimal contact between the endodontic file and the root canal wall (21). Therefore, the aim of this study was to compare two supplementary methods used in the removal of gutta

Table 2

The mean, median, and standard deviation (SD) values of percentage of gutta percha reduction following use of supplementary method for both groups

	Apical			Middle			Coronal			Total		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Group I	0.18	0.09	0.2	0.28	0.19	0.2	0.81	0.72	0.2	1.28	1	0.6
Group II	0.27	0.28	0.18	0.37	0.38	0.2	0.96	0.91	0.22	1.72	1.57	0.65
p-value	0.004*			0.005*			0.003*			0.004*		

**significant (p<0.05)*

Table 3

The mean, median, and standard deviation (SD) values of remaining gutta percha volume in mm^3 post-supplementary approaches for both groups

	Apical			Middle			Coronal			Total		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Group I	52.22	57.27	22.74	34.92	38.75	11.77	40.6	42.86	5.02	40.21	43.83	8.75
Group II	21.89	22.31	9.51	18.43	19.23	9.18	31.72	32.09	4.01	22.31	22.28	5.24
p-value	<0.001*			<0.001*			<0.001*			<0.001*		

**significant (p<0.05)*

percha and BCS from oval root canals. Microcomputed tomography is a good, accurate, reliable, and noninvasive method for evaluation of the root canal system qualitatively and quantitatively (22). The data can be represented as 2D or 3D images (23). Microcomputed tomography has already been shown to be the gold standard for testing filling material retrieval (17). This technique enables the 3D calculation of the remaining root canal filling material without splitting the root which may cause loss of some of the gutta percha (24). In our study, the retreatment procedure was expanded using X3 (30, 0.07) and X4 (40, 0.06) in an attempt to achieve better removal of intracanal filling material. Yet, Mani GPR files failed to completely remove intracanal filling material from oval root canal, with the median total percentage of reduction recorded of 70.01%. This comes in agreement with Rubino et al. who showed 74% reduction in intracanal filling material using Mani GPR Files (25).

In order to achieve complete removal of root canal filling material, two supplementary approaches were compared; engine-driven XP-FR and manual H- filing. Results showed significant reduction in the total amount of remaining filling material using both techniques. XP-FR removed significantly more intracanal filling material with reduction percentage of 43.83% compared to only 22.28% for manual H-filing. Therefore, the null hypothesis was rejected in this study.Our results are in full agreement with Alves et al. (26), Machado et al. (27), De-Deus et al. (17), Campello et al. (28), and Silva et al. (17) who also showed significant reduction of remaining intracanal filling material using XP-FR. This could be attributed to expansion of the file within the oral cavity temperature together with its spiral movement intracanal which promotes remaining filling material displacement (26). Yet, these studies have tested XP-FR on gutta percha and resin-based sealers. Silva et al. showed that XP-FR decreased the total volume of remaining intracanal filling material by 59.4% using resin-based sealer compared to 43.83% in the current study using bioceramic sealer. This is a logic finding as bioceramic sealers are more difficult to remove than resin-based sealers due to the strong chemical bond they form with hydroxyapatite (13, 14, 29).

Manual H-filing is capable of removing intracanal filling material (30, 31); however, it was used as a reference for comparison as a supplementary technique in the current study. Borges et al. used H-filing in an oscillatory motion and compared it to XP-endo Shaper. XP-endo Shaper removed significantly more intracanal filling material due to the ability of Max-Wire novel files to expand and contract touching and abrading the walls more effectively compared to the linear motion of H-filing (32).

The use of different supplementary approaches for intracanal filling removal is deemed mandatory. Especially, XP-FR that showed superior ability of intracanal filling material removal. However, being an in-vitro study, extrapolation of these results into the clinical setting needs further investigation as identification of the remaining intracanal filling material using µ-CT is not applicable in the clinical setting.

Preoperative, intraoperative and postoper-

ative factors lead to root canal treatment failure (33). Persistence of microorganisms is considered one of the major causes of root canal treatment failure (34). Removal of root canal filling material is considered the key of success for root canal retreatment. Presence of root canal filling material may harbor microorganisms that affects the disinfection procedures (35). Numerous studies have reported that complete removal of intracanal filling material, especially the apical third, is nearly impossible (36-39). Therefore, the use of supplementary techniques has been advocated to allow more contact with dentin and forcing irrigation laterally to reach inaccessible areas (40, 41).

Conclusions

Based on this in-vitro study, it could be concluded that rotary files are not efficient in complete removal of bioceramic sealer and gutta percha from oval root canals. The use of supplementary removal methods has improved intracanal filling material removal. XP-FR significantly removed more intracanal filling material than manual H-filing.

Clinical Relevance

Supplementary methods following rotary retreatment files improve bioceramic sealer and gutta percha removal from oval root canals.

Conflict of Interest

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

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