Original Research Article

An in vitro evaluation of a supplementary step in cleaning apical third area of oval canals using micro-computed tomography

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Abstract

Background: High resolution micro-computed tomography (micro-CT) is pioneering, non-destructive, and reproducible equipment that produces very thin sections and an accurate three dimensional reconstruction of the object with cubic voxels and isotropic resolution. To the best of our understanding, no research has so far tested the removal efficacy of XP-F and XP-FR in obturated oval canals using micro-computed tomography.

Aim: This study aimed to assess and relate the efficacy of XP-F and XP-FR as a supplementary step during re-treatment in apical third area of oval canals through micro-CT analysis.

Materials and methods: Root canals of forty human extracted maxillary premolars were prepared with ProTaper Universal (PTU) and obturated using F3 ProTaper single cone and AH Plus Sealer. The surface area and volume was analyzed using micro CT imaging. The canals were re-treated with ProTaper Universal retreatment files (PTUR). Post re-treatment surface area and volume were evaluated with micro CT imaging. Supplementary re-treatment was done with XP-endo Finisher (XP-F) and XP-endo Finisher R (XP-FR). The roots were scanned again in the micro CT device and the remaining volumes of the filling material were quantified. Data was analyzed by means of Mann-Whitney test with a significance threshold of 5%.

Results: The remaining filling material after re-treatment with PTR files in both the groups was not statistically significant for both volume and surface area ($p > 0.05$). For XP-F group, the elimination of filling material was 83.2% in volume and 89.4% in surface area in apical 5 mm. For XP-FR group, the elimination of filling material was 72.3% in volume and 78.7% in surface area in apical 5 mm. The percentage of filling material removed by XP-F was statistically significant as compared to the XP-FR group ($p < 0.05$).

Conclusion: In the apical 5 mm of oval shaped canals XP-F showed better re-treatment efficiency

than XP-FR. However, neither of both instruments could eliminate all remaining filling material.

Key words

Apical third,Maxillary premolars, Micro-computed tomography, Oval canal, Retreatment, XP-endo Finisher, XP-endo Finisher R.

Introduction

Successful outcome of any re-treatment depends upon the effective disinfection of the root canal system and elimination of necrotic tissues and microorganisms that may be responsible for endodontic failure [1]. The elimination of former root canal filling substance is imperative in order to achieve complete disinfection of root canal by allowing access to the antimicrobial agents. The presence of bacteria in apical third area leads to persistence of periradicular inflammation [2]. Various studies [3, 4] have enumerated that regardless of re-treatment technique, complete elimination of filling material is not attained especially in apical-third area.

XP-F (FKG Dentaire) is a new NiTiMaxWire alloy instrument of size 25 developed for enhanced cleaning of the root canal. It is straight in martensitic phase (below 30°C) but once placed at body temperature, there is transition to austenitic phase. Thereby it adopts a spoon shape which leads to an increase in diameter of 3mm in the last 10 mm [5]. As per manufacturer, when the instrument is placed inside the canal in rotation mode, the A-phase shape allows the file to access and clean areas that might be missed by other instruments without damaging dentin or altering the original canal shape. There is limited data regarding the use of XP-F in re-treatment. It appears that the XP-F instrument can possibly be applied as an extra technique in re-treatment cases to escalate filling removal.

XP-FR (FKG Dentaire) is an innovative variant of the XP-F file. Conferring to the manufacturer, it is designed for re-treatment and exhibits a larger core diameter (size 30). It can expand and contact the dentin surface with an enhanced reach of 6mm in diameter. Its design aids in removal of necrotic tissue, dentin mud and smear layer along with the irrigant [6].

Throughout this course, the anatomy of the root canal system should consistently be considered in light of the fact that the cross-sectional shape of canal has been accounted for significant impact on successful outcome of re-treatment [7]. The re-treatment of oval-shaped canals requires further techniques as extra enlargement can lead to root perforation or canal transportation [8].

Cone-beam computed tomography provides needed three-dimensional visualization in failed endodontic cases. However, their reduced resolution and enormous radiation exposure makes it a constraint in daily endodontic follow-up. High resolution micro-computed tomography (micro-CT) is pioneering, non-destructive, and reproducible equipment that produces very thin sections and an accurate three dimensional reconstruction of the object with cubic voxels and isotropic resolution [9]. To the best of our understanding, no research has so far tested the removal efficacy of XP-F and XP-FR in obturated oval canals using micro-computed tomography. Hence, the aim of this study was to evaluate and compare the efficacy of XP-F and XP-FR as a supplementary step during re-treatment in apical third area of oval canals through micro-CT analysis. The null hypotheses was that there will be no difference in the removal of filling material after the use of XP-F and XP-FR.

Materials and methods

Specimen selection and initial preparation

Forty human extracted maxillary premolars were collected. Samples were soaked in 5.25% sodium hypochlorite (NaOCl) for 1 hour. The inclusion criteria’s were a radiographically mature apex

and Vertucci's type IV classification. The exclusion criteria's were internal calcifications, evidence of previous endodontic treatment, immature apex, blocked canals and resorbed roots. All procedures were performed by an Endodontist having 8 years of experience.

Root canal preparation and obturation

A high speed diamond bur was used for access through the crown and working length (WL) set at 0.5 mm short of apex. A size 15 K-file was used for establishing the glide path. Canals were shaped using PTU rotary instruments (Dentsply) in a crown-down manner.2 ml of 5.25% NaOCl solution were used for irrigation. 5 ml of 17% ethylenediaminetetraacetic acid (EDTA) followed by 5 ml of 5.25% NaOCl for 1 minute were used as final irrigant. Paper points (Dentsply) were used to dry the canals. A size F3 ProTaperguttapercha and AH Plus Sealer (Dentsply) were used to obturate the canals. Periapical radiographs were taken to confirm the adequate quality of obturation. Access cavities were sealed with Cavit (3M) and the specimens were stored at 37°C for 14 days.

Post-obturation micro CT imaging analysis

The Skyscan 1172 (Bruker Micro CT, Kontich, Belgium) was used for the micro CT scans of all specimens. Three dimensional image reconstruction was done with the help of NRecon program (version: 1.6.1.3). The data was viewed by using Data viewer Program (version 1.5.2.4; Bruker Micro CT). Image analysis was done using morphometry software CTAn (CT analyzer) version 1.17.7.2. CT Vol version 2.3.2.0 was used for calculation of volume in mm^3. For standardization purpose, volume analysis was restricted to apical 5mm of filling. Preand postoperative volumes of filling materials were calculated in mm^3, and the mean values were recorded.

Re-treatment with PTUR

The temporary filling was removed using round burs. Re-treatment was done by removing the coronal third of obturation with Gates-Glidden drills size 2 taken up to 3 mm apical to canal orifice. The root canal fillings were removed using PTUR files (Dentsply Maillefer, Ballaigues, Switzerland) in an X-Smart motor (Dentsply Maillefer) at a torque of 2 N cm and speed of 500 rpm using minimal apical pressure.D1 30/ .09 rotary file was used to remove the coronal third part. D2 25/.08 rotary file was used in the middle third. The D3 20/.07 rotary file was introduced till the working length and 5.25% NaOCl was used for irrigation. The completion of the re-treatment procedure was considered by absence of any remaining filling material on the file flutes and smooth canal walls.

Post re-treatment micro CT imaging analysis

After re-treatment procedure, the roots were imaged once more in the micro CT device and the remaining volumes of filling material were calculated.

Supplementary re-treatment with XP-F and XP-FR

The teeth were randomly divided into two experimental groups:

Group1- 20 teeth treated with XP-F

Group2- 20 teeth treated with XP-FR

Each sample was soaked in a hot water bath (37°C) to simulate clinical conditions. Supplementary warm water bath was used to store the irrigant solution and the files at 37°C during the experiment.

In group 1, the stopper was placed at 1 mm from the WL. An endodontic motor (X-Smart Plus, Dentsply Maillefer) was set at 800 rpm speed and 1-Ncm torque and was operated for 1 minute with a gentle up and down motion. The canals were flushed with a total of 10 ml of 5.25% NaOCl at 37°C followed by a final flush using 5 ml of 17% EDTA. In between each solution, the flutes were cleaned of the debris using an alcohol soaked gauze.

In group 2, the stopper was placed at 1 mm from the WL. The XP-FR file was cooled with a Endo-Ice via the tube. An endodontic motor (X-

Smart Plus, Dentsply Maillefer) was set ata speed of 1000 rpm and a torque of 1-Ncm in rotation mode for 30 seconds while applying slow, gentle longitudinal movements of 7-8 mm, so that the entire length of the canal was covered according to manufacturer's instruction. However, we did not use any solvent. Canals were flushed with a total of 10 ml of 5.25% NaOCl at 37°C followed by a final flush using 5 ml of 17% EDTA. In between each solution, the flutes were cleaned of the debris using an alcohol soaked gauze.

Supplementary re-treatment micro CT imaging analysis

After supplementary re-treatment procedures, the roots were imaged again in the micro CT device and the remaining volume and surface area of filling material were calculated.

Statistical Analysis

The Kolmogorov-Smirnov test tested normality of the results. Data analysis was carried out with the assistance of Statistical Package for Social Sciences Version 22 (SPSS Inc., Chicago, IL, USA). The Mann-Whitney test was used to determine if the initial volume and surface area of filling material varied substantially in both groups and to compare the percentage of filling material removed in both groups. The level of significance was set at 5% for all statistical tests ($p< 0.05$).

Results

The remaining filling material after re-treatment with PTR files in both the groups was not statistically significant for both volume and surface area ($p > 0.05$). The mean volume and mean surface area of remaining filling material in apical 5 mm of root canals subsequent to the use of XP-F file was significantly lower than XP-FR ($p < 0.05$) (**Table – 1, 2**).

Table - 1: Mean volume (mm^3) of remaining filling material with the standard deviation (SD) in apical 5 mm of root canals before and after the use of XP-F and XP-FR file. Different superscript uppercase letters in the same column indicate a statistically significant difference ($p< .05$). Different superscript lowercase letters in the same row indicate a statistically significant difference ($p< .05$).

Group	n	Mean Volume ±SD (before)	Mean Volume ±SD (after)
XP-F	20	0.97 ± 0.18^{Aa}	0.02 ± 0.03^{Ab}
XP-FR	20	0.98 ± 0.18^{Aa}	0.32 ± 0.20^{Bb}

Table - 2: Mean surface area (mm^2) of remaining filling material with the standard deviation (SD) in apical 5mm of root canals before and after the use of XP-F and XP-FR file. Different superscript uppercase letters in the same column indicate a statistically significant difference ($p< .05$). Different superscript lowercase letters in the same row indicate a statistically significant difference ($p< .05$).

Group	n	Mean Surface area ±SD (before)	Mean Surface area ±SD (after)
XP-F	20	8.79 ± 0.96^{Aa}	0.37 ± 0.48^{Ab}
XP-FR	20	8.94 ± 0.88^{Aa}	2.92 ± 0.74^{Bb}

For XP-F group, the elimination of filling material was 83.2 % in volume and 89.4 % in surface area in apical 5 mm (**Figure - 1**). For XP-FR group, the removal of filling material was 72.3 % in volume and 78.7 % in surface area in apical 5 mm (**Figure - 2**). The percentage of filling material eliminated by XP-F was statistically significant as compared to the XP-FR group ($p < 0.05$ for both volume and surface area).

Discussion

Poor endodontic outcome is associated with bacterial persistence in the complex root canal system. Hence, complete elimination of root canal filling substance is essential for a successful re-endodontic outcome [10].

Figure - 1: Three-dimensionally reconstructed micro-CT images in apical 5 mm of a same samplein a row (I) after obturation (II) after use of XP-F files.

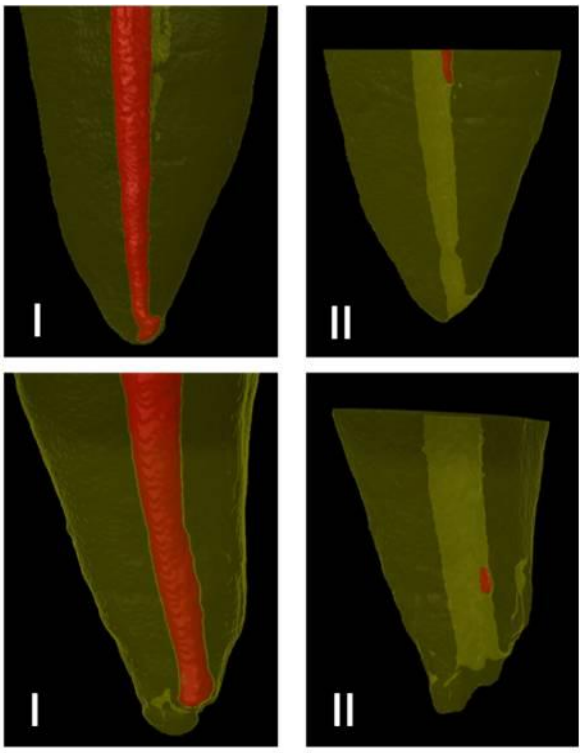
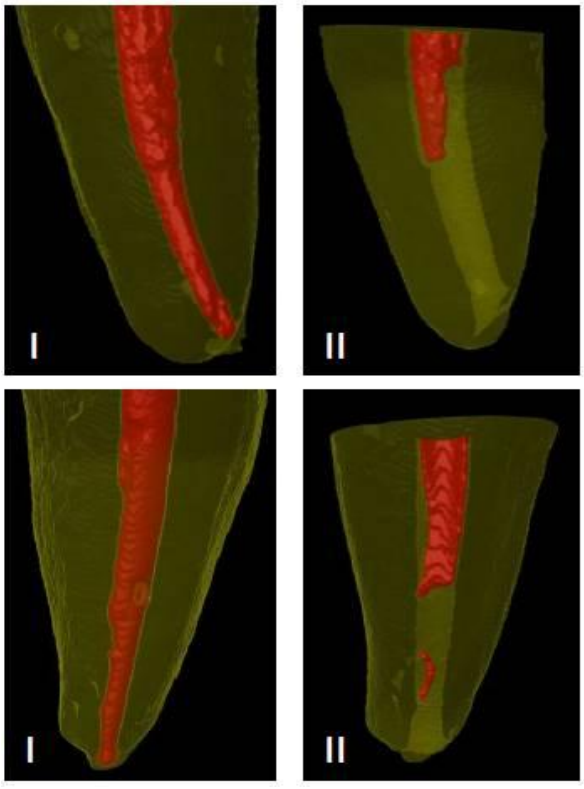


Figure - 2: Three-dimensionally reconstructed micro-CT images in apical 5 mm of a same sample in a row (I) after obturation (II) after use of XP-FR files.



In this study, we used three dimensional, high-resolution micro-CT scans to quantify the amounts of the filling material after re-treatment procedures. Since its advent in dentistry in the late 1990's, micro-CT technology has been used in many domains of dental research because it is a non-destructive technique that provides three-dimensional information on the root canal filling material [11].

The study was carried out on mandibular premolars that have oval-shaped canals. There noncircular anatomy scientifically poses a challenge during re-treatment [12] and hence the explanation for selection in this research. Regardless of the re-treatment technique, ample studies have demonstrated that that complete removal of root canal fillings, specifically in the apical portion is not commonly accomplished [3, 4].

Therefore, in the current study we evaluated the efficacy of two new instruments: XP-F and XP-FR in apical third area which is the most difficult area to remove the filling material. We found that both files were efficient in eliminating filling material, with a significant volume reduction by 83.2 % and 72.3% respectively by using XP-F and the XP-FR files ($p < 0.05$). The efficacy of the XP-F and XP-FR in removing residual materials from the canal walls might be referred to its metallurgy and elliptical movement in the canal. This drives the file to reach inaccessible parts of the canal. Our findings are in corroboration with Silva, et al. [13].

However, the percentage of filling material removed by XP-F was significant higher as compared to the XP-FR group ($p < 0.05$). This might be attributed to the speed and design of the instrument. Azim, et al. [14] found that when increasing the speed of XP instruments to 3000 rpm, its penetration capability and re-treatment efficiency was increased without any untoward events. However, in the present study, we used a speed of 800 rpm according to manufacturer instructions. Also, XP-FR has a thicker core design as compared to XP-F. These factors might

be responsible for poor performance of XP-FR in the present study.

Also, we found that remaining filling material existed in all samples, regardless of the instrument used. The results of our study are consistent with literature which shows that no re-treatment technique has been capable of making root canals entirely free of filling material [15-17].

The manufacturer advise the use of solvent with XP-FR. However, we did not use solvent so as to standardize the experimental set-up. Solvents are believed to produce a fine coating of softened gutta-percha which highlights the difficulty in removing the same during re-treatment [18, 19].

While the actual effect of the volume of filling material remaining subsequent to endodontic re-treatment is unclear, research using histological examination of teeth with post-treatment apical periodontitis identified several cases in which the filling material could have kept bacteria sheltered. Consequently, it is rational to believe that filling material remnants compromise the successful outcome especially during apical periodontitis, and complete root canal disinfection should be targeted.

Conclusion

Within the parameters set in the current study, it can be concluded that in the apical 5 mm of oval shaped canals:

- Both XP-F and the XP-FR files efficiently eliminated there maining root filling material.
- XP-F showed better re-treatment efficiency than XP-FR.
- Neither instruments were able to eliminate all residual filling substance.

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