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Comparing the Effectiveness of Two Methods for Removing Residual Root Filling Materials in Retreatment

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ABSTRACT

Background and Objective: Non-surgical retreatment is the first choice for the treatment of persistent periapical diseases and failure of conventional treatments. Given the necessity of proper removal of gutta-percha and bioceramic root canal sealer for the success of retreatment, the aim of this study was to compare Ultrasonic (Ultra X) and M3 Max file techniques.

Methods: This laboratory study was conducted on 36 extracted human premolars that met the inclusion criteria (single-rooted, single-canal premolars, similar in root diameter, oval canal, with no branching and anatomical complexity). Two-dimensional radiographs were obtained to examine the root canals and standardize their diameters, and then, in order to standardize the samples, the crowns of the teeth were cut with a double-sided diamond disc at low speed. The canals were prepared with M3 rotary files and obturated with gutta-percha and bioceramic root canal sealer using the single cone technique. The teeth were placed in an incubator for one week, and root retreatment was performed using M3 files. The samples were randomly divided into three groups of 12 based on activation of irrigation solution, including the control group (side-vented needle as a comparison), the ultrasonic irrigation group, and the M3 Max activation group. The teeth were then divided into two halves, mesial and distal, and the area of residual filling material to total root area was examined in apical, middle, and coronal sections using a stereomicroscope and Image J software.

Findings: The results showed that in all three sections examined, the percentage of residual material in the control group (29.83±10.73% in the apical section, 19.19±11.13% in the middle section, and 6.94±3.51% in the coronal section) was significantly higher than Ultra X and M3 Max groups ($p<0.001$).

Conclusion: Based on the results of this study, the use of ultrasonic and M3 Max techniques can significantly remove residual root canal filling material and lead to successful root canal retreatment.

Keywords: *Root Canal Filling Materials, Ultrasonic, Retreatment, Gutta-Percha, Bioceramic Sealer.*

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Introduction

Nonsurgical retreatment is recommended as the first treatment option for persistent periapical disease and failure of conventional treatments because it helps eliminate microorganisms. The ultimate goal of treatment is to eliminate microorganisms and their byproducts by re-preparing and sealing the root canal with biocompatible materials. To achieve this goal, complete removal of the previous root canal filling material is required (1, 2).

Gutta-percha, as one of the most common materials for canal filling, is not able to adhere properly to the dentinal walls of the canal and achieve the desired three-dimensional filling (3). Therefore, the use of a sealer along with gutta-percha is necessary to achieve a better seal (4). The most common sealers used in endodontic therapy are zinc oxide eugenol (ZOE)-based sealers. In recent years, bioceramic materials have also been developed as root canal sealers. These sealers are based on calcium silicate with the addition of several oxide components and bioactive properties, which can stimulate tissue repair and induce mineralization.

Therefore, they are suitable for root canal filling (5). There are different methods for root canal filling. The two important methods are cold lateral compaction and single cone. The cold lateral compaction method using gutta-percha and sealer is one of the most widely used filling techniques with good long-term results, requiring lateral compaction pressure. The single cone method uses a gutta-percha cone and a sealer without the need for lateral or vertical pressure, thereby reducing the risk of root fracture and thermal damage to the periodontal membrane. However, since the filling process does not involve compaction pressure, the root canal contains a larger volume of sealer compared to cold lateral compaction method (6).

Different methods are used for root canal retreatment, such as the use of solvents, manual files, NiTi rotary systems or combination systems. NiTi rotary systems have shown high efficiency, but Micro-CT studies show the failure of any retreatment technique to completely remove residual material from the root canal system (3). Also, the best-known material as a gutta-percha solvent is chloroform, which some therapists are reluctant to use due to its nephrotoxicity and carcinogenicity (7). The presence of residual material acts as a mechanical barrier between the intracanal disinfectant and the inaccessible microorganisms present in the dentinal tubules, lateral canals and isthmuses. Therefore, in order for the irrigant and medications to reach all parts of the root canal system, all residual filling material must be removed.

Ultrasonically-activated irrigation (UAI) is also known as passive ultrasonic irrigation. This technique is based on cavitation and acoustic current at a frequency of 30 kHz, generated by the vibration of a thin, smooth metal tip, and can reach inaccessible (approximately 35%) and complex areas of the root canal (2). The XP-endo Finisher R file is also made with Max Wire, an alloy that undergoes a phase change (martensitic to austenitic) when exposed to body temperature, which causes the distal millimeters of the instrument to assume a spoon-like shape (8, 9). When rotated in the root canal system, it can reach an area of up to 6 mm in diameter (100 times larger than the instrument), which creates a whip-like action against residual material (10). This spoon-like shape allows the instrument to reach irregular areas without changing the original shape of the canal. Recent studies have shown its effectiveness in removing filling materials after root canal retreatment (9). The M3 Max file is similar to the XP-Endo Finisher in terms of use and properties. This nickel-titanium file scrapes the root canal walls, thereby removing the smear layer or biofilm (11).

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Since bioceramic sealers have been used extensively in endodontic treatment in recent years, proper removal of these sealers during retreatment has received attention (8, 12). Therefore, given the lack of studies on bioceramic sealer removal methods, the present study was conducted to evaluate the efficacy of two techniques, ultrasonic and M3 Max, in removing root canal filling materials.

Methods

After approval by the Ethics Committee of Mashhad University of Medical Sciences with the code IR.MUMS.DENTISTRY.REC.1401.086, this laboratory study was conducted from May 2022 to April 2023 in the Dental Materials Laboratory of Mashhad Dental School using the materials and equipment presented in Table 1. Extracted human mandibular premolar teeth with single-root and single-canal characteristics, oval canal, fully formed roots, canal without branching or any anatomical complexity, and similarity in root canal diameter were included in the study. Roots with open apex, calcified canals, roots with internal or external resorption, roots with fractures or previous root treatment, teeth with root surface caries, cracks on the root surface, the presence of additional canals, and teeth that fractured or cracked during the work process were excluded from the study.

Table 1. Materials and equipment used in the study

Materials and equipment	Details of the manufacturer
M3 max rotary file	Udg, China
Rotary file M3, #10-30, 6%	Udg, China
M3 Retreatment Rotary File #20, 7% #25, 8% #30, 9%	Udg, China
Diamond Burs	Meisinger Dental Burs, Germany
Irrigation syringe	Cerkamed
Sodium hypochlorite	Cerkamed
Bio-C Sealer	Sure Dent Corp., Gyeonggi-do, Korea
Manual K-File	Mani Inc., Tochigi-Ken, Japan
Gutta-percha	Sure-endo, Sure Corp., Korea
Paper cone	MetaBiomed, South Korea
EDTA 17%	Cerkamed, Stalowa Wola, Poland
Dino Light Microscope	Dino-Lite, AnMo Electronics Corporation, Taiwan
X-Smart Rotary Machine	Dentsply Maillefer, Ballaigues Switzerland
Diamond disc	D&Z, Diamant, Germany

Thirty-six extracted human mandibular premolars were collected and two-dimensional radiographs in the mesiodistal and buccolingual directions and CBCT were obtained to examine the root canals and standardize their diameters. To standardize the samples, the crowns of the teeth were cut with a low-speed double-sided diamond disc to standardize the length of the samples to 13 mm. The working length was determined using a K file No. 15 (Mani Inc., Tochigi-Ken, Japan) to a distance of 1 mm from the apical foramen. The canals were prepared with M3 Pro Gold (Udg, China) 6% rotary files with numbers 10, 15, 20, 25 and 30 at a speed of 300 rpm and a torque of 2 N/cm using an X-Smart rotary motor (Dentsply Maillefer, Ballaigues, Switzerland).

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Canal preparation was performed in a crown-to-apex direction by inserting the file into the canal in three in-and-out strokes, using a brushing action on the exit. After each 3-stroke cycle, debris on the instrument was cleaned with gauze soaked in 70% alcohol. This procedure was repeated until the files reached working length.

Patency was maintained during preparation by placing a K-file No. 10 one millimeter away from the working length. During preparation, the canals were irrigated with 20 mL of 2.5% NaOCl solution using a disposable syringe and a 30-gauge side-vented needle positioned 2 mm from the working length. After canal preparation, the canals were irrigated with 2 mL of 17% EDTA solution to remove the smear layer to a distance of 2 mm from the working length. A final irrigation was performed with saline and the canals were dried with a paper cone. Finally, the canals were obturated with gutta-percha No. 30 with a 6% taper and Bio-C sealer using the single cone technique. The injection syringe was positioned in the middle third. The sealer paste was introduced into the canal and the middle and apical thirds were filled. The gutta-percha was covered with sealer and immediately and gently inserted into the canal to the working length. The residual gutta-percha was removed with a hot plugger and cold lateral compaction was performed. The samples were cleaned with cotton soaked in 70% alcohol and then covered with a temporary restoration and radiographed. Samples with inadequate obturation were removed and replaced. To ensure the sealer set, the teeth were kept in an incubator (100% humidity and 37°C) for one week.

Retreatment was performed after removing the dressing using the M3 Retreatment Rotary Files (Udg, China) system with files 20.0.07, 25.0.08 and 30.0.09. The instrument was inserted into the canal with three 3 mm in-and-out cycles using a brushing motion. After performing all three cycles, the file was cleaned with 70% alcohol-soaked gauze and the tooth canal was rinsed with 2.5% NaOCl solution. This procedure was performed until the file reached the working length and maintained the patency of K-file No. 10. If patency was not achieved, the sample was removed and replaced. Since no filling material was observed on the instrument using a Loupe Magnifier (BoNew-Oral, China) at 3.5x magnification, and considering complete retreatment, radiographs were taken and the canals were dried with paper points.

The samples were then randomly divided into three groups of 12. In the control group, irrigation was performed using a syringe and 2 ml of 2.5% NaOCl solution was used to irrigate the root canal. In the second group, irrigation material was transferred to the canal with a 30-gauge side-vented needle, and the root canal was irrigated with 2 ml of 2.5% NaOCl solution and 2 ml of 17% EDTA using a silver tip size 25 (2%) with a length of 18 mm and an Ultra X ultrasonic device (Eighteenth, Orikam). In the third group, irrigation material was transferred to the canal with a 30-gauge side-vented needle and an M3 Max file was used according to the manufacturer's settings at 800 rpm with a torque of 1 N/cm using an X-Smart rotary motor. Then, a buccolingual superficial groove was created on the occlusal surface of each sample using a disk (D&Z, Diamant, Germany) and a longitudinal groove on both buccal and lingual sides of the tooth, and care was taken to ensure that the grooves did not encroach on the canal space. Then, in order to better observe the overall view of the tooth and to accurately divide the root canal into three coronal, middle, and apical parts, the samples were observed under a stereomicroscope at x25 magnification. The amount of residual material was extracted for 36 human premolars and examined in accordance with the inclusion and exclusion criteria. Images of three coronal, middle, and apical sections were prepared at x50 magnification and the images were evaluated using Image J software. Statistical analysis of the findings was performed in SPSS 20 and using the ANOVA test, and $p<0.05$ was considered significant.

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Results

The results showed that in all three sections examined, the percentage of remaining sealer in the control group was significantly higher than in the X Ultra and M3 Max groups ($p<0.001$). In the apical section, the highest and lowest amount of residual filling material was in the control group and the M3 Max group, respectively. Also, in the middle and coronal sections, the highest amount of residual material was in the control group (Table 2).

Table 2. Amount of residual filling material at each section according to root canal cleaning method

Section and cleaning method	Number	Mean±SD	p-value
Apical			
M3 Max	12	1.15±1.12	<0.001 F=78.308
UltraX	12	2.21±2.23	
Control	12	29.83±10.73	
Middle			
M3 Max	12	0.52±0.66	<0.001 F=34.237
UltraX	12	0.51±0.73	
Control	12	19.19±11.13	
Coronal			
M3 Max	12	0.76±1.55	<0.001 F=33.504
UltraX	12	0.18±0.094	
Control	12	6.94±3.51	

Also, in all three sections, the amount of residual material in the Ultra X and M3 max groups did not differ significantly from each other, but was significantly lower than the control group. In each group, the amount of residual material in the three sections was compared with each other. In the M3 Max group, the amount of residual material in the sections did not differ significantly. However, in the Ultra X group, the amount of residual material in the apical section was significantly higher than the coronal section. In the control group, the amount of residual material in the apical section was significantly higher than the coronal and middle sections, and the amount of residual material in the middle section was significantly higher than the coronal section.

Discussion

The results of this study showed that in all three sections, the amount of residual material in the Ultra X and M3 Max groups was not significantly different from each other, but was significantly lower than the control group. Therefore, the use of ultrasonic techniques and M3 Max can be used as two complementary cleaning methods to remove gutta-percha and bioceramic sealer after retreatment. In addition, although the two methods did not differ from each other at different sections, cleaning using M3 Max at three apical, middle, and coronal sections produced more uniform results.

A study by Da Silva et al. showed that the use of XP-endo and Reciproc can remove some of the residual root canal sealers (8). In line with the present study, Roshdy et al. also used a stereomicroscope and Image-J software to measure the amount of gutta-percha and residual sealer (3). After retreatment of teeth

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that had been obturated with Sure Dent bioceramic sealer, they used Endovac, UltraX, and passive ultrasonic irrigation as a complementary technique. The results regarding the amount of residual material using a side-vented irrigation needle in the apical, middle, and coronal sections were similar to the findings of the present study.

In a study by Kim et al., the amount of residual filling material following retreatment of single- and double-rooted teeth and C-shaped canals after obturation with BC Sealer was shown to be similar (13). However, the other sealers used (EndoSeal MTA and EndoSequence BC) left the most residual material in C-shaped canals.

In a study by Colombo et al., the amount of Bio-C sealer remaining in the canal wall following ultrasonic cleaning was evaluated (12). The volume of Bio-C sealer remaining was greater than that of AH Plus sealer after using the Reciproc system, but no significant difference in the volume of residual material was observed after ultrasonic cleaning. Consistent with the findings of the present study, ultrasonic cleaning improved the removal of root filling materials, but the results showed that no technique is able to completely remove root filling materials.

A study by Volponi et al. showed that the XP-endo Finisher R method was more effective than passive ultrasonic irrigation and active ultrasonic irrigation with EndoActivator (1). Özyürek et al. also showed that compared to EndoActivator, Irrisafe, and irrigation syringe, XP-endo Finisher left less residue after retreatment of teeth that had been rehydrated with AH Plus sealer (14). In a study by Navabi et al., which used a stereomicroscope to examine the amount of residue, similar to the present study, the XP-endo Finisher R file significantly reduced the amount of residual sealer (AH Plus and N-ZOE sealers) in the apical and mid-canal regions (15). In a study by Crozeta et al., ultrasonic irrigation was found to be more effective than XP-endo Finisher R in removing AH Plus and BC Sealer (16). A study by Li et al. showed that the use of M3 Max compared to EndoActivator and passive ultrasonic irrigation showed greater efficiency in removing the smear layer in the coronal area due to its flexibility and ductility (11). Studies have shown that bioceramic sealers leave more residual material than other sealers, such as the Gold Standard AH Plus sealer (17). Therefore, mechanical cleaning seems to be necessary to remove this layer. Mechanical cleaning also seems to remove residual material more uniformly than ultrasonic cleaning. On the other hand, the higher residual material in the apical than coronal section in the UltraX group, unlike the M3 Max, may be because the M3 Max was used throughout the canal, while the Ultra X was placed up to 2 mm from it. Therefore, the use of an instrument that can be activated throughout the canal is important in the retreatment process of bioceramic sealers.

In addition to the ability of ultrasonic and M3 Max to remove residual sealer due to the aforementioned properties, the properties of EDTA, which acts as a chelating solution, may contribute to the effectiveness of these methods as well as syringe irrigation (control group). EDTA can remove inorganic components of dentin, calcium ions (2). Since bioceramic sealers react with dentin calcium, EDTA may affect the bond strength of bioceramic sealers and may cause them to detach from dentin (18, 19).

Although the amount of residual material in the root canal, especially in the middle and coronal sections, was reduced after retreatment in both intervention groups, in line with many other studies, none of the methods were able to completely remove residual material (1, 20, 21). Therefore, further studies in this area are needed to design new methods for retreatment.

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