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Efficacy of Endodontic Files with Different Metallurgical Characterization in Removing Root Canal Filling Material

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Abstract

Statement of problem: Safe and efficient removal of all root filling materials from the canal system is essential for optimal nonsurgical retreatment, because it provides effective cleaning, shaping, and re-filling of the root canal system.

Objectives: This study compares the effectiveness of Reciproc Blue, HyFlex CM, Reciproc, and ProTaper Universal retreatment files (PTUR) in removing root canal filling material (RCFM).

Materials and methods: Sixty human upper central incisors were shaped with Revo-S files up to apical size 40 and were obturated using the cold lateral compaction technique. After two weeks, the RCFMs were removed with Reciproc Blue, HyFlex CM, Reciproc, or PTUR (ProTaper Universal Retreatment) files. Teeth were cleaved longitudinally, and digital images were then captured. The amounts of RCFMs in the obtained images were analyzed using ImageJ software, and the time required to remove the RCFM was recorded. Data were analyzed using a one-way of variance (ANOVA) test.

Results: There was no significant difference among the files in the coronal third ($P>0.05$). In contrast, in the middle and apical thirds, the amount of remaining RCFM was significantly higher in HyFlex CM and Reciproc Blue groups than that of PTUR and Reciproc groups ($P<0.05$); however, there is no significant difference between the HyFlex CM and Reciproc Blue groups ($P>0.05$). Furthermore, there is no difference between the Reciproc and PTUR files regarding the amount of remaining RCFM ($P>0.05$). The Reciproc file removed the RCFM in a shorter time than the other groups ($P<0.05$). However, there is no difference among the other three groups ($P>0.05$).

Conclusions: None of the tested files could completely remove the RCFM. Under the limitation of this study, the files with shape memory (Reciproc and PTUR files) exhibited better performance than the files with reduced shape memory (Reciproc Blue) and controlled memory (HyFlex CM) in removing the RCFM.

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Introduction

Nonsurgical endodontic retreatment procedures are performed as the first choice to eliminate or reduce the microbial infection when the initial root canal treatment fails [1]. Safe and efficient removal of all root-filling materials from the canal system is essential for optimal nonsurgical retreatment, because it provides effective cleaning, shaping, and re-filling of the root canal system [2]. Mechanical removal of root canal filling material (RCFM) is routinely performed by using hand files, rotary files, ultrasonic tips, or heating devices [3]. In particular, nickel-titanium (NiTi) rotary files are often used in endodontic retreatments because of their safety, efficiency, and ability to remove RCFM faster than hand files [4]. In many previous studies, the efficacy of traditional rotary NiTi files have been tested for removing RCFM and determined that the rotary NiTi files are effective in removing RCFM [5, 6]. Some of them are Reciproc (VDW, Munich, Germany), HyFlex CM (Coltène Whaledent, Altstätten, Switzerland), Reciproc Blue (VDW, Munich, Germany), and PTUR (Dentsply Maillefer, Ballaigues, Switzerland). Reciproc Blue (VDW) has been one of the new generations of Reciproc-instruments introduced recently. The manufacturer of this new file claims that it is much more flexible, and has an even lower fracture risk than the Reciproc file. Because of the special temperature protocol, the Reciproc Blue file can also be present to better access curved canals. The ProTaper Universal Retreatment system (Dentsply, Maillefer) was specifically developed for removal of root canal filling material and includes three instruments as follows: D1 (size 30/.09 taper), D2 (size 25/.08 taper) and D3 (size 20/.07 taper) [7]. The PTUR instruments have a convex cross-section design [8]. Several studies have determined that ProTaper retreatment instruments are more effective in removing root-filling material when compared to hand files [6, 9]. A new reciprocating motion approach was introduced for instrumentation using nickel–titanium instruments with an M-Wire alloy, which is considered more resistant than conventional alloys. Reciproc (VDW) is based on this motion. The Reciproc system consists of three files: R25 (25/0.08 in the first millimeters), R40 (40/0.06 in the first millimeters) and R50 (50/0.05 in the first millimeters) [10]. The effectiveness of instruments that work with a reciprocating motion in the removal of root canal filling material have been evaluated and determined to be effective [4]. Several studies have evaluated the amount of apically extruded debris during removal of root canal filling material using hand files, rotary and reciprocating systems [11-13]. The findings of these studies showed that all techniques caused apical extrusion of debris during the removal of canal filling material. HyFlex CM (Coltène Whaledent) files are manufactured from a CM alloy using a special thermomechanical method, which increases their resistance to cyclic fatigue by conferring extreme flexibility on the files [14, 15]. HyFlex CM contains a smaller percentage of nickel than other systems [16]. The reduction of nickel content generates a metal that is softer, i.e., exhibits lower hardness [17]. The processing of these files also affects the metal properties, such as the thermal changes that occur during the manufacturing of the HyFlex CM file, which results in a martensitic metal phase. The martensitic phase is a more flexible form of yarn that results in greater elasticity and resistance to cyclic fatigue [18].

It has been stated that thermomechanical treatment (M-wire, CM-wire, or Blue technology) of the NiTi files compared to traditional NiTi files provides significant benefits with regard the efficacy and safety of endodontic files [19, 20]. However, there are limited studies about the efficacy of M-wire and CM-wire files in removing the RCFM [21-23]. Moreover, there has been no study evaluating the efficacy of Reciproc Blue and HyFlex CM files manufactured with Blue technology and CM-wire, respectively. Therefore, this study evaluates of the effectiveness of the Reciproc, HyFlex CM, Reciproc Blue, and PTUR files in removing RCFM.

Materials and Methods

Based on data from a previous study [24], power calculations indicated that the sample size for each group must be a minimum of 12 specimens. Thus, 60 extracted single-rooted human upper central incisors were selected for this study and were stored at 4°C in distilled water up to experimental procedures. Preoperative radiographs were taken to verify the presence of a single canal, and the

criteria for tooth selection included a completely formed apex and the absence of previous root filling, resorption, or calcifications. The length of the teeth was standardized to 21 mm by trimming the crowns of teeth with silicon carbide abrasive paper. The teeth were completely not decoronated, and the crowns served as a reservoir for the irrigation solution. Endodontic access cavities were prepared using diamond burs (Dentsply Maillefer, Ballaigues, Switzerland) with a high-speed handpiece under water-cooling. A K-file (#10, Dentsply Maillefer) was inserted into each canal until its tip was just visible at the apical foramen, and the length was then measured. The working length (WL) was established by subtracting 1 mm from this measurement, and the root canals were instrumented to a master apical size 40 with using SC1, SC2, SCU, AS30 and AS40 Revo-S files (Micro-Mega, Besancon, France) respectively. SC1 was used to enlarge the coronal two-thirds of the canal. SC2, SCU, AS30, AS35, and AS40 instruments were used to the WL. The canals were then irrigated with 1 mL 2.5% sodium hypochlorite (NaOCl) between each file size by using a syringe and a 29-G needle (NaviTip; Ultradent, South Jordan, UT). After the instrumentation, the canals were irrigated with 2 mL 17% EDTA for 1 minute and subsequently rinsed with 2 mL distilled water. Then all root canals were dried with paper point.

Root Canal Obturation

Sixty root canals were obturated with a resin-based sealer (MM-Seal; Micro-Mega, Besançon, France) and gutta-percha cones by using the cold lateral compaction technique. MM-Seal was introduced into the root canal by using a lentulo spiral filler (Dentsply Maillefer), and a # 40/0.02 taper master gutta-percha cone with good tug-back was coated with the sealer and slowly inserted into the canal until the WL was reached. Then, accessory cones were inserted in the same manner and laterally compacted using a # 25 finger-spreader. Excess material was seared and condensed with a plugger 1 mm below the canal opening, and the root canal openings of all specimens were sealed with temporary filling material (Cavit; 3M ESPE, Seefeld, Germany). Radiographs were then taken from the buccolingual and mesiodistal directions to ensure quality of the obturation, and the specimens were then stored at 37°C in 100% humidity for two weeks to allow complete setting of the sealer.

Experimental Groups and Retreatment Procedures

All rotary NiTi files were used with a torque and speed controlled motor (X-Smart Plus, Dentsply Maillefer), and the files were used at the torque and speed recommended by the manufacturer for each specific system. Sixty extracted single-rooted human upper central incisors were randomly divided into four groups. Root filling materials were then removed using the following techniques.

ProTaper Universal Retreatment (Dentsply Maillefer, Ballaigues, Switzerland) (PTUR) Group (n = 15)

RCFMs were removed using the D1 (#30/0.09 taper), D2 (#25/0.08 taper), and D3 (# 20/0.07 taper) retreatment files at 2-Ncm torque and 500-rpm speed. The files were used with a brushing action against the canal walls in a crown-down direction until the WL was reached. D1 was used in the cervical third, D2 in the middle third, and D3 throughout the entire WL. Finally, apical preparation was performed with a ProTaper F5 file (#50/0.05 taper) at 300 rpm. The root canals were irrigated after each file size using 2.5% NaOCl for 30 seconds.

Reciproc Group (n = 15)

RCFMs were removed using the Reciproc R25 (#25/0.08 taper, VDW, Munich, Germany) file at RECIPROC mode of endodontic motor (X Smart Plus; Dentsply Maillefer). Reciproc R25 was used in a slow in-and-out pecking motion with a 3-mm amplitude limit, and gentle apical pressure was combined with a brushing motion against the lateral walls of the root canal. After three complete pecking movements, the file was removed from the canal, and its flutes were cleaned. R25 file was then used for removing the filling material until the WL was reached followed by apical enlargement with R40 (#40/0.06 taper) and R50 (#50/0.05 taper) files. The root canals were irrigated after the pecking motion and each file size using 2.5% NaOCl for 30 seconds.

Reciproc Blue Group (n = 15)

In this group, RCFMs were removed with the same procedure as the Reciproc group, but the Reciproc Blue R25 (#25/0.08 taper, VDW, Munich, Germany) file was used to remove the root canal filling material. Final apical enlargement was completed by then using Reciproc Blue R40 (#40/0.06 taper) and R50 (#50/0.05 taper) files. The root canals were irrigated after the pecking motion and each file size using 2.5% NaOCl for 30 seconds.

HyFlex CM Group (n= 15)

RCFMs were removed using HyFlex CM (Coltène Whaledent, Altstätten, Switzerland) at a speed of 500 rpm and at 2.5 Ncm torque. HyFlex CM files were used in a crown-down sequence using #25/0.08 taper (at 2/3 of the WL), #20/0.06 taper, #30/0.06 taper, and #40/0.06 (at full WL). Additional apical preparation was performed using HyFlex CM (#45/0.04 and #50/0.04 taper) files, and the root canals were irrigated after each file size using 2.5% NaOCl for 30 seconds.

RCFM removal was conducted by one operator, and each instrument was used in one canal in all groups. Irrigation was performed using a total of 15 mL of 2.5% NaOCl for each tooth using a syringe and a 29-G side-port needle (NaviTip; Ultradent). The removal RCFM procedure was deemed complete when no debris of gutta-percha and sealer was invisible on the file surfaces and when canal walls were smooth. Working time for removal of RCFM was recorded and irrigation times were subtracted from total working time. A final rinse was performed with 2 mL 17% EDTA for 1 minute followed by 2 mL distilled water for 1 minute, and the canals were dried with paper points (Dentsply Maillefer). A dental operating microscope (Zeiss Opmi; Carl Zeiss, Jena, Germany) was used throughout the RCFM removal procedure.

Evaluation of the Removal of Canal Filling Material

Grooves were prepared with a water-cooled diamond bur on the buccal and lingual tooth surfaces, and teeth were split along their long axis in a buccolingual direction using a hammer and chisel. Digital images of the both halves were captured at 8x magnification using a digital camera (DP-70; Olympus, Tokyo, Japan) attached to a stereomicroscope (BX60; Olympus). The images were then transferred to imaging software (ImageJ; Wayne Rasband, NIH, MD, USA). The remaining RCFM on the root canal walls were measured using ImageJ software (Figure 1), and the specimens were evaluated by one operator blinded to groups tested for the removal of RCFM. The measurements were repeated to ensure reproducibility, and mean values were determined and compared. The percentage of RCFM remaining (A) was calculated using the following equation: A = (area of the remaining x 100)/area of the root canal [25].

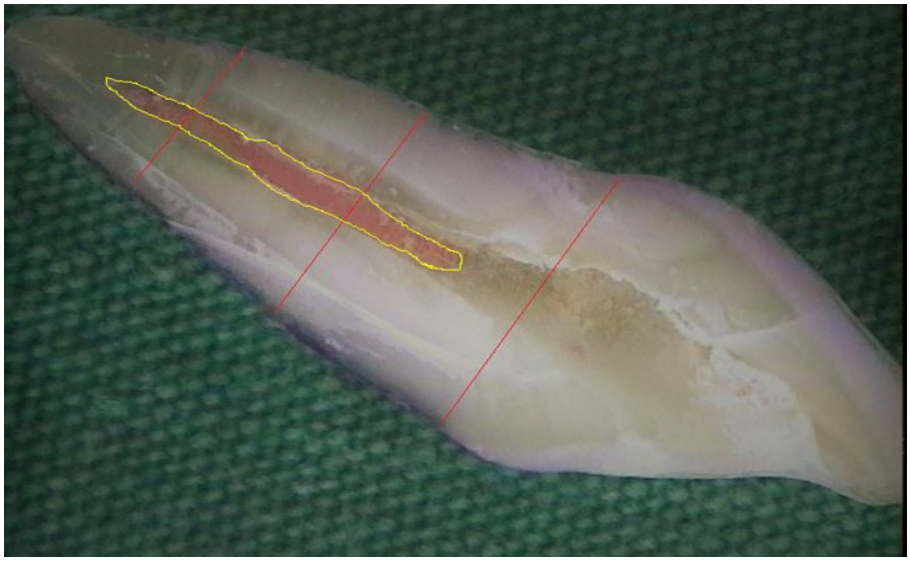

Figure 1: An image obtained to measure the amount of remaining canal filling material on root canal walls

Statistical Analysis

The data were normally distributed (Shapiro-Wilk test, p > .05) and homogeneity of variance (Levene test, p > .05). Thus, the area of the remaining RCFM and were analyzed with one-way ANOVA and Tukey post hoc tests to determine the working time. Statistical analysis was performed with SPSS Statistics Version 20 for Windows (IBM, Chicago, IL, USA), and a p value lower than 0.05 was regarded as statistically significant.

Results

The means of the percentage of remaining RCFM are shown in Table 1. None of the files could completely remove the RCFM, but statistical analysis showed the percentage of remaining RCFM was the lowest at the coronal third in all groups (P<0.05). However, there was no significant difference among the files in the coronal third (P>0.05). In the middle and apical thirds, HyFlex CM and Reciproc Blue groups exhibited higher percentages of remaining RCFM than PTUR and Reciproc groups (P<0.05), but there is no significance difference between HyFlex CM and Reciproc Blue groups (P>0.05). Reciproc and PTUR files had similar values regarding the remaining RCFM (P>0.05).

The Reciproc file reached the WL significantly faster than the other systems (P<0.05). In addition, the required total time to remove the RCFMs was shorter with the Reciproc group compared to the other groups (P<0.05). There is no significant difference among Reciproc Blue, HyFlex CM, and PTUR files regarding the required time to reach the WL and to remove the RCFM (P>0.05).

Discussion

The complete removal of RCFM is necessary to allow an effective cleaning, disinfection, and re-obturation of the root canal when initial endodontic therapy fails. However, several studies have shown that it is impossible to remove the RCFM completely, regardless of the different instruments and protocols already proposed for the non-surgical endodontic retreatment [26]. The review of the endodontic literature shows there are few studies evaluated the performance of files with different metallurgical characterizations during the removal of the RCFM [27]. Therefore, this study compared the effectiveness of the files with different metallurgical characterization in removing the RCFM.

In the current study, maxillary central incisors with similar length were used to simplify the standardization of the specimens and were initially prepared to a #40/0.06 file. During the removal of the RCFM, no solvents were used to allow for sole evaluation of the effect of the different files. The RCFM removal procedure was performed using new files in each tooth to avoid instrument separation. None of the files separated during the removal of the RCFM. Teeth were split longitudinally for evaluation, which is similar to previous studies that used single-rooted and canalled teeth [28]. Maciel *et al* [29] stated that measurements that are more accurate could be obtained with longitudinal sectioning method when compared with conventional radiographs, because

Table 1: Mean percentages and standard deviations of remaining canal filling material in each section and time to perform the procedure

Group	Apical	Middle	Coronal	T1	T2
Reciproc	15.2 ±2.4^{a}	14.3 ±4.6^{a}	8.2 ± 1.3^{a}	34.52 ± 3.2^{a}	62.44 ± 5.1^{a}
Reciproc Blue	24.1 ±4.1^{b}	25.6 ±6.3^{b}	7.4 ±2.6^{a}	48.17 ± 3.5^{b}	91.73 ± 4.3^{b}
PTUR	12.4 ± 4.6^{a}	12.5 ±2.1^{a}	9.2 ± 3.1^{a}	50.22 ± 2.4^{b}	87.38 ± 3.2^{b}
HyFlex CM	28.3 ±3.2^{b}	24.6 ±3.5^{b}	11.1 ±2.4^{a}	51.37 ± 4.8^{b}	89.56 ± 4.4^{b}

T1: time to reach the working length, T2: time to remove the canal filling material. Values with the same superscript letters show that there is no statistical difference.

the latter may be subject to magnification or distortion. In the present study, images were traced using ImageJ software to assess the presence of the remaining RCFM on the canal walls quantitatively. In addition, no attempt was made to distinguish between remaining sealer and gutta-percha [28].

It has been stated that after retreatment procedures, the apical part generally has a greater percentage of the RCFM than the middle and coronal parts of the root canal because of the increased anatomic variability and the difficulty of instrumentation in the apical part of the root [30]. Therefore, in the present study, the additional instrumentation was performed to #50 file in all the groups.

The current study determined that none of the tested files could produce canal walls completely free of the RCFM. This finding is compatible with several studies comparing the efficacy of the rotary NiTi files in removing the RCFM [31, 32]. However, there is no consensus regarding whether the motion type of the endodontic files is an important factor in removing the RCFM. Several previous studies showed that the motion type of the files could not be an important factor when the efficacy of files is evaluated in removing the RCFM. Zuolo *et al* [32] evaluated the efficacy of files working with rotary (TRUShape) or reciprocating (Reciproc) motion in removing the RCFM and determined that there is no significant difference between the two files. Rios Mde *et al* [3] assessed the efficacy of the two reciprocating systems compared with a rotary system in the removing the RCFM in maxillary incisor teeth. They also found that the reciprocating systems (Reciproc and WaveOne) were as effective as rotary file (PTUR file).

In contrast, a few studies showed that motion type might be an important factor in removing RCFM. Capar *et al* [33] determined that the use of PTUR files with adaptive motion left significantly less RCFM than the rotational motion. In addition, Bernardes *et al* [27] evaluated the amount of remaining RCFM after the use of different techniques (Hand files, Reciproc, and PTUR files) and found that Reciproc file removed more RCFM than the other techniques. Reciproc and Reciproc Blue files employ a reciprocating motion, whereas HyFlex CM and PTUR files employ a rotational motion. The findings of the current study showed that in the middle and apical part of the root canal, Reciproc and PTUR files removed more RCFM than Reciproc Blue and HyFlex CM files. Based on these findings, the motion types of the files may not have affected the results in the current study.

In the current study, given that the two files (Reciproc and Reciproc Blue) have the same cross-sectional exhibited different retreatment efficacy, the alloy type of the file (M-wire or Blue technology) should be considered as a significant factor when the performances of the files in the retreatment process are evaluated. Reciproc Blue and HyFlex CM files are more flexible than Reciproc and PTUR files. According to the findings of this study, Reciproc Blue and HyFlex CM files showed similar abilities to removing RCFM during retreatment procedures of teeth with straight canal. Under the limitations of this study, as the flexibility of the files increases, their performance in removing the RCFM could decrease.

Considering the time needed to remove the RCFM, Reciproc was shown to take shorter retreatment times than other systems in straight root canals when removing the RCFM, because fewer files in the Reciproc group were used compared to other groups (HyFlex CM and PTUR file). However, more time is required in the Reciproc Blue group compared to the Reciproc group because of the different metallurgical properties of the Reciproc file.

Conclusions

Based on the findings of this study, none of the files could completely remove the RCFM. In addition, Reciproc and PTUR files had better performance than Reciproc Blue and HyFlex CM files regarding the removal of the RCFM in the middle and apical sections.

Conflict of Interest: None declared.

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