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Original research

EFFICACY OF ROTARY AND RECIPROCATING FILE SYSTEMS FOR GUTTA-PERCHA REMOVAL WITH SOLVENT IN ENDODONTIC RETREATMENT

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ABSTRACT

Background: *Effective removal of gutta-percha (GP) in endodontic retreatment is a significant factor to ensure a favorable outcome from failed procedures. The purpose of this study was to evaluate the efficacy of rotary and reciprocating file systems for GP removal from root canal systems, with and without the use of solvent.*

Methods: *Forty extracted single-rooted human mandibular premolars were prepared and obturated using a single cone technique. Specimens were randomly divided into four groups (n=10): Group 1 (Protaper Universal Retreatment (PUR) + Solvent), Group 2 (PUR without Solvent), Group 3 (Reciproc Blue (RB) + Solvent), and Group 4 (RB without Solvent). After retreatment, teeth were split longitudinally and photographed under a stereomicroscope with x50 magnification. Images were imported to the ImageJ software to measure the residual filling material in cervical, middle, apical thirds and the root canal space. The time to reach working length (WL) and total procedural time were recorded. Data were analysed using the Mann-Whitney test ($p < 0.05$).*

Results: *RB demonstrated significantly higher cleaning efficacy than PUR across total canal walls ($p < 0.05$) in non-solvent conditions. The addition of solvent leaded to increasing residual material in the middle and apical thirds for both systems ($p < 0.05$). PUR reached the WL and completed the procedure significantly faster than RB in non-solvent conditions ($p < 0.05$). Solvent reduced time to reach WL, but significantly increased total procedural time for both systems.*

Conclusion: *Reciprocating system provides better canal cleaning efficacy compared to rotary system when used without solvent, though rotary system is more time efficient. Solvent hinders filling material removal by creating a sticky residue that prolongs the procedure and prevents thorough canal cleaning.*

Keywords: *Endodontic retreatment, protaper universal retreatment, reciproc blue, reciprocating motion.*

I. INTRODUCTION

The main purpose of non-surgical root canal retreatment is to restablish healthy periapical tissues. This procedure requires complete removal of the pre-existent root canal filling material, reinstrumentation, redisinfection, and refilling of the root canal system. Effective removal of the obturation material is considered essential for the success of endodontic retreatment [1].

Although numerous materials have been prescribed for obturation of root canals, GP in combination with a sealer is most frequently used. The complete elimination of GP and sealer remains a significant clinical challenge. Residual GP acts as physical barriers that harbor bacteria and prevent irrigants from reaching apical ramifications, a leading cause of persistent apical periodontitis [2].

Several methods have been employed for removal of GP from the root canal system, ranging from traditional hand instrumentation and chemical solvents to advanced tools such as Nickel-Titanium (NiTi) rotary and reciprocating systems, heat-

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transferring instruments, ultrasonics and laser irradiation [3]. Retreatment rotary instruments, especially designed for retreatment, which rotate in continuous motion are practical options in such scenarios and may decrease patient and operator fatigue [4]. The PUR system (Dentsply Maillefer, Ballaigues, Switzerland) has long been a clinical standard, specifically developed for the retreatment that included three instruments D1, D2 and D3. It utilizes conventional NiTi alloy with active cutting tips to penetrate filling materials. These files have been found to be effective in removing root filling material when compared to manual procedures. However, recent evidence suggests that the stiffness of conventional NiTi alloy and its continuous rotary motion can lead to the retention of residual filling material within the root canal space and increase the risk of canal transportation [5].

The RB (VDW, Munich, Germany) system belongs to a new generation of single file systems and was recently introduced in the market. It is designed for cleaning and shaping root canal systems using reciprocating motion. The same technique is also indicated for retreatment purposes, in which the instruments are used with a brushing motion against the lateral walls of the canal to remove any residual filling material [6]. They have shown better mechanical behaviour in comparison with conventional rotary files. However, conflicting results were reported regarding their effectiveness in root canal retreatment [7].

In addition to mechanical instrumentation, chemical solvents are frequently employed to soften GP and facilitate initial apical penetration [8]. While solvents are traditionally believed to increase efficiency, their impact on final canal cleanliness remains a subject of debate [9]. Some researchers suggest that solvents may transform solid GP into a viscous membrane that adheres to dentinal walls and anatomical irregularities, potentially complicating the final debridement phase and extending total procedural time [10]. Therefore, the aim of this study was to evaluate the cleaning efficiency of rotary and reciprocating systems during the removal of root canal filling material, both with and without the use of solvent.

II. MATERIALS AND METHODS

2.1. Specimen preparation

A total of 40 extracted single-rooted mandibular premolar teeth were selected and cleaned ultrasonically for removing calculus and debris.

The teeth were radiographically confirmed to have a single straight canal with curvature less than 10° according to the Schneider's method; those without calcification, internal resorption, previous root canal treatment and fully formed apices were selected. Teeth were stored in a 0.9% physiological saline solution until use [11].

2.2. Initial root canal treatment

To standardize the samples, all roots were decoronated to obtain a standardized root length of 18 mm with a working length (WL) of 17 mm. Canal preparation was carried out by the sequential use of Protaper (Dentsply Tulsa Dental Specialties, USA) files in the crown down technique up to size 25/0.06 at WL in combination with a torque controlled engine (NSK, Japan) operated at 300 rpm according to the manufacturer's instructions. During instrumentation, root canals were irrigated with 2 mL NaOCl 3% between each file. After completion of preparation, a final rinse with 2 mL EDTA 17% was performed and the root canals were dried with paper points.

Obturation was performed using single cone technique with GP (DiaDent, Canada) and cortisomol (Pierre Rolland Acteon, France). The adequacy of root canal filling was radiographically confirmed. Excess GP was removed at the canal entrance with heated instruments. Access cavities were sealed with Cavit (ESPE Dental, Germany) and the specimens were stored at 37°C in 100% humidity for 1 month to allow complete setting of the sealer [12].

2.3. Root canal retreatment

After the removal of the temporary filling, a total of 40 teeth were categorized into 4 experimental cohorts (n=10 each) using a simple randomization technique, ensuring that each group was representative and statistically comparable prior to further testing. Retreatment was performed according to the following groups: Group 1: PUR + Solvent, Group 2: PUR, Group 3: RB + Solvent, Group 4: RB

Figure 1: Protaper Universal Retreatment and Reciproc Blue system

Group 1: The PUR files were used in a crown down approach in combination with a torque controlled engine at 500 rpm, according to the manufacturer's instructions. Root canal filling was gradually removed using light apical pressure until the pre-established WL was reached. The D1 instrument (30/0.09) was first used to create a pilot hole into the GP at the cervical; after using D1, 0.2 mL of orange oil was injected into the coronal part of the canal for 3 minutes to soften the filling material. The D2 instrument (25/0.08) was used in the middle third of the root canal and the D3 instrument (20/0.07) in its apical part until the WL was reached [13].

Group 3: Gates Glidden (Dentsply Maillefer, USA) size 3 was used to remove 2mm coronal GP and create a reservoir for orange oil for 3 minutes to soften the filling material. The root canals were reinstrumented using the RB R25 (25/0.08). The file was introduced into the canal and applied in a reciprocating motion. It was then moved towards the apex using an in and out pecking motion with an amplitude of approximately 3 mm. After three pecking motions, the file was removed from the canal and cleaned with sterile gauze. This procedure was repeated until the file reached original WL [14].

In non-solvent groups (Group 2 and Group 4), the method of removing root canal fillings was the same as that for the with solvent groups, except that no orange oil was used.

In all groups, NiTi instruments were discarded after four uses or if a visible deformation occurred. Irrigation was performed with 2 mL NaOCl 3% after each instrument or after three pecks with the reciprocating files. Final irrigation was performed with 5 mL EDTA 17% and 5 mL NaOCl 3%, and root canals were dried with paper points. The retreatment procedure was considered completed when the WL was reached and no residual filling material could be seen on the surface of the last used file or in the irrigation solution [14].

2.4. Evaluation

To reduce inter-operator variability variability, a single operator carried out all endodontic procedures. Evaluation of GP remnants was carried out by a second examiner who was blind to group assignment. The following parameters were evaluated.

* Residual GP and sealer

The teeth were grooved buccolingually using a diamond disc and then split into halves. The tooth half with a greater amount of residual filling material was photographed under a stereomicroscope (USB Digital Microscope Mega Pixel, China) at x50 magnification as JPEG images [15]. Assessment of the residual filling material was performed by transferring the images to ImageJ 1.33 software (National Institutes of Health, Bethesda, USA) used to measure the areas of residual filling material in the cervical, middle and apical thirds of the root canal and root canal periphery [16]. For each section measurements were repeated 3 times, and the means were calculated and compared. The amount of residual filling material was expressed as a percentage of the total area of each third of the root canal [17].

Figure 2: Measurement of residual filling material on canal walls

* Operating time

Time to reach WL: The time elapsed from entering the canal with the first instrument until reaching the WL was measured.

Total time for retreatment: The time elapsed from entering the canal with the first instrument until retreatment was completed.

Time was recorded in seconds with a stopwatch. Time for instrument changes and irrigation was not included [14].

2.5. Data analysis

The data were statistically analyzed using SPSS software version 20.0 (IBM Corporation, Armonk, USA) and tested using analysis of variance followed by Mann-Whitney test for two group comparison. A value of $p < 0.05$ was considered to be statistically significant.

III. RESULTS

3.1. Efficacy of root canal filling material removal by each file system

All roots showed residual filling material inside the canals. The mean amount of residual filling material in each group is shown for each third in Table 1.

Group I showed more residual filling material than Group II in the total canal (20.4 ± 5.0% vs. 15.3 ± 4.8%) and in the middle and apical thirds ($p < 0.05$), with no significant difference in the cervical third. Similarly, Group III left more material than Group IV in the total canal (16.1 ± 5.7% vs. 10.5 ± 4.0%) and in the middle and apical thirds ($p < 0.05$), while no significant difference was found in the cervical third.

The use of a solvent significantly increased the amount of residual filling material in the middle third, apical third, and total canal walls for both file systems ($p < 0.05$). No significant differences were observed in the cervical third across all groups ($p > 0.05$) (Table 1).

Table 1: Percentage of the residual filling material (Mean ± SD) on the canal walls after retreatment of each file system

Group	Cervical (%)	Middle (%)	Apical (%)	Total (%)
I: PUR + Solvent	21.3 ± 4.8	24.2 ± 7.4	31.0 ± 19.0	20.4 ± 5.0
II: PUR	17.0 ± 5.8	18.3 ± 4.9	15.0 ± 7.2	15.3 ± 4.8
p-value	p > 0.05	p < 0.05	p < 0.05	p < 0.05
III: RB + Solvent	16.4 ± 7.0	18.6 ± 8.9	21.5 ± 9.0	16.1 ± 5.7
IV: RB	12.2 ± 6.6	9.6 ± 6.3	13.0 ± 6.7	10.5 ± 4.0
p-value	p > 0.05	p < 0.05	p < 0.05	p < 0.05

3.2. Efficacy of root canal filling material removal between the two file systems

With solvent use (Groups I and III), no significant differences were found in residual filling material at any location ($p > 0.05$), although the RB system (Group III) left less material than the PUR system (Group I). Without solvent use (Groups II and IV), the RB system showed significantly better cleaning efficiency than the PUR system in the middle third (9.6 ± 6.3% vs. 18.3 ± 4.9%, $p < 0.05$) and overall canal walls (10.5 ± 4.0% vs. 15.3 ± 4.8%, $p < 0.05$). No significant differences were observed in the cervical or apical thirds ($p > 0.05$) (Table 2).

Table 2: Percentage of the residual filling material (Mean ± SD) on the canal walls after retreatment of two file systems.

Group	Cervical (%)	Middle (%)	Apical (%)	Total (%)
I: PUR + Solvent	21.3 ± 4.8	24.2 ± 7.4	31.0 ± 19.0	20.4 ± 5.0
III: RB + Solvent	16.4 ± 7.0	18.6 ± 8.9	21.5 ± 9.0	16.1± 5.7
p-value	> 0.05	> 0.05	> 0.05	> 0.05
II: PUR	17.0 ± 5.8	18.3 ± 4.9	15.0 ± 7.2	15.3 ± 4.8
IV: RB	12.2 ± 6.6	9.6 ± 6.3	13.0 ± 6.7	10.5 ± 4.0
p-value	> 0.05	< 0.05	> 0.05	< 0.05

3.3. Evaluation of treatment time efficiency between the two file systems and the impact of solvent

The use of a solvent significantly reduced the time required to reach the WL for both systems ($p < 0.05$). When solvent was used, the PUR (169.2 ± 25.2s) reached the WL faster than RB (219.4 ± 67.0s), although this difference was not statistical significance ($p > 0.05$). In the absence of solvent, the PUR system reached the WL significantly faster than the RB system ($p < 0.05$) (Table 3).

Table 3. Time required (Mean ± SD) to reach the WL for two file systems

Solvent	PUR (s)	RB (s)	p-value
With solvent	169.2 ± 25.2	219.4 ± 67.0	p > 0.05
Without solvent	280.5 ± 68.0	356.8 ± 63.2	p < 0.05
p-value	p < 0.05	p < 0.05	

In the presence of a solvent, there was no statistically significant difference between the two file systems regarding the total removal time ($p > 0.05$). However, when no solvent was used, the PUR (428.6 ± 74.8s) was significantly faster in completing the retreatment procedure than the RB (494.3 ± 52.8s) ($p < 0.05$). For both the PUR and RB systems, the use of solvent resulted in a significant increase in the total time ($p > 0.05$) (Table 4).

Table 4. Time required for retreatment (Mean ± SD).

Solvent	PUR	RB	p-value
With solvent	589.2 ± 101.8	615.6 ± 102.2	p > 0.05
Without solvent	428.6 ± 74.8	494.3 ± 52.8	p < 0.05
p-value	p < 0.05	p < 0.05	

IV. DISCUSSION

4.1. Efficacy of root canal filling material removal by each file system

Our study demonstrated that the efficacy of root canal filling removal is significantly influenced by the use of solvents. For both systems, no significant difference was observed in the cervical third between solvent and non-solvent groups ($p>0.05$). However, in the middle and apical thirds, as well as for the total canal area, the absence of solvent resulted in significantly cleaner canal walls ($p<0.05$). It is important to note that regardless of file system used with or without solvent, none of the groups achieved complete removal of the filling material, reinforcing the inherent challenge of endodontic retreatment.

The results of our study are consistent with several previous studies. Subbiya et al. (2020) reported that the PUR system was significantly more effective when used without orange oil solvent ($p<0.05$) [17]. Similarly, Eldemerdash (2019) utilized scanning electron microscopy (SEM) and concluded that the Reciproc system performed more effectively without a solvent when removing GP [18]. Rossi-Fedele et al. (2017) highlighted a critical clinical trade-off: while solvents may facilitate initial instrument penetration, they concurrently hinder the thorough cleaning of the canal space [18].

The increased difficulty in achieving clean canal walls when using a solvent can be attributed to the chemical interaction with GP. The solvent softens and partially dissolves the GP, transforming it into a thin, viscous, and highly adhesive layer [11]. This layer is strongly attached to the dentinal wall and also can be forced into complex canal anatomies (isthmuses, lateral canals and irregularities) under the mechanical action of the rotary or reciprocating files. This makes the removal of filling material even more difficult and time-consuming compared to the removal of solid, brittle GP debris produced in non-solvent condition [19].

Additionally, residual filling material acts as a physical barrier that reduces the efficacy of intracanal medicaments, such as calcium hydroxide and compromise the bond strength and adaptation of the new sealer and obturation material during subsequent filling [13]. Therefore, while solvents may be useful for bypassing difficult obstructions or initial penetration of hard GP, non-solvent approach appears superior for achieving maximum canal cleanliness.

4.2. Efficacy of root canal filling material removal between two file

Our study found that while both systems performed similarly with a solvent, the RB system removed significantly more filling material than PUR without solvent in the middle third and total canal walls ($p<0.05$). These findings align with Silva EJNL et al. (2018) and De-Deus G et al. (2017), who attribute this to RB's superior flexibility and cyclic fatigue resistance. Unlike the stiffer NiTi files in PUR that follow a narrower path, RB's centeredness allows it to sweep canal walls more comprehensively, reducing debris in lateral extensions [7].

Additionally, the RB system's reciprocating kinematics act as a mechanical excavator; its asymmetric oscillation bites into and coronally displaces GP. This efficiency is enhanced by an S-shaped cross-section, providing ample chip space for debris transport. Conversely, the PUR system's continuous rotation generates frictional heat which, without solvent, can soften the GP and smear it into dentinal tubules or undercuts, leading to higher residue.

Regarding canal regions, no significant difference was found in the cervical third ($p>0.05$), likely due to its straightness and accessibility. However, the apical third remained the most difficult to clean for both systems ($p>0.05$), as inherent anatomical complexities limit the reach of even advanced mechanical instrumentation like RB [20].

Notably, the introduction of a solvent (Group I vs. Group III) eliminated the statistical disparity between the two systems ($p>0.05$). By converting solid GP into a viscous and adhesive slurry, the chemical agent reduces the inherent cutting advantages of specific file designs. In this plasticized state, both reciprocating and rotary instruments tend to smear the softened material against the canal walls. These findings are supported by Rodrigues CT et al. (2016), who also concluded that reciprocating motion without a solvent was more effective at removing GP than traditional rotary systems [21].

4.3. Evaluation of treatment time efficiency between two file systems and the impact of solvent

The time required for filling removal is clinically important because it affects patient comfort and operator fatigue. As shown in Table 3.4, solvent use significantly increased retreatment time for both PUR and RB systems ($p<0.05$). Under dry conditions, PUR (428.6±74.8s) completed the procedure significantly faster than RB (494.3±52.8s) ($p<0.05$), while no significant difference was observed when solvent was used ($p>0.05$).

Our study shows that while solvents hasten reaching the working length ($p<0.05$), they significantly extend total retreatment time. This occurs because solvents transform solid GP into a viscous slurry that adheres to canal walls and instrument flutes. As noted by Hormati et al. (1982) and Eldemerdash (2019), clearing this softened residue requires more supplemental irrigation and repeated passes than removing solid, brittle fragments [22].

Without solvent, the PUR system was more time-efficient than RB ($p<0.05$). Its sequence of three specialized files (D1,D2,D3) and continuous rotary motion create a screwing force and active cutting that facilitate faster apical penetration. In contrast, while the RB system's reciprocating motion is safer and effective for debris removal, its back-and-forth oscillation results in slower excavation compared to the aggressive, continuous rotation of PUR (Silva et al., 2018; Gu et al., 2008) [12].

V. CONCLUSION

Within the limitations of this in vitro study, neither rotary nor reciprocating file file systems were able to completely remove all filling material from the root canal. The apical third remains a significant clinical challenge for total debridement, indicating that mechanical instrumentation alone is insufficient and must be supplemented with advanced irrigation protocols to improve cleanliness.

Reciprocating system demonstrated superior cleaning efficiency compared to the continuous rotary system in total canal area in non-solvent conditions. The Protaper Universal Retreatment system proved to be more time efficient than the Reciproc Blue system when operating without a solvent due to its active cutting tips and continuous rotary motion.

While the use of a solvent significantly facilitates the initial penetration of instruments and reduces the time required to reach the working length, it negatively impacts both the total procedural time and the final cleanliness of the root canal.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the research, authorship, and publication of this article.

Ethical Considerations

The protocol for this study was reviewed and formally approved by The Institutional Ethics Committee of Hue University of Medicine and Pharmacy.

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