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Evaluation of filling material removal in curved canals after different protocols: an ex vivo study with micro-computed tomography

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ABSTRACT

Complete removal of the filling material is essential to the success of endodontic retreatment. However, this step can be challenging due to anatomical difficulties, the nature of the sealer, or operational factors. ***Aim:*** *To evaluate the efficacy of filling removal using ProDesign R and Reciproc Blue retreatment, with supplementary irrigation step with XP-Endo Finisher R.* ***Materials and Method:*** *Twenty mandibular molar mesial canals were prepared using ProTaper Next, and filled using the single-cone technique (n=10). The fillings were subsequently removed using either ProDesign R (25/0.06) or Reciproc Blue (25/0.08 in the 3 mm from the tip of the file, decreasing towards the cervical, with average taper varying from 0.06 to 0.05 along the instrument). The XP-Endo Finisher R system was used for supplementary cleaning for both systems. Micro-computed tomography was used to assess filling material volume and reduction percentage. The significance level was set at 5% (p< 0.05).* ***Results:*** *It was found that ProDesign R and Reciproc Blue removed 91.2% and 82.7% of the filling material, respectively (p > 0.05), and after use of XP-Endo Finisher R, there was a significant increase in filling removal by 42.7 and 27.7%, respectively.* ***Conclusion:*** *ProDesign R and Reciproc Blue were equally effective, but neither system completely removed the filling material from the mesial canals of mandibular molars.*

Keywords: *endodontics - mandibular molar - micro CT - root canal therapy.*

Avaliação da remoção de material de obturação em canais curvos após diferentes protocolos: um estudo ex vivocom microtomografia computadorizada.

RESUMO

A remoção completa do material de obturação é essencial para o sucesso do retratamento endodôntico. Contudo, esta etapa pode ser desafiadora devido a dificuldades anatômicas, à natureza do cimento ou a fatores operacionais. ***Objetivo:*** *Avaliar a eficácia da remoção de materiais de obturação utilizando os sistemas ProDesign R e Reciproc Blue para retratamento, com limpeza adicional empregando o sistema XP-Endo Finisher R.* ***Material e métodos:*** *Vinte canais mesiais de molares mandibulares foram preparados usando o sistema ProTaper Next e obturados pela técnica de cone único (n=10). Os materiais de obturação foram subsequentemente removidos utilizando ProDesign R (25/0.06) ou Reciproc Blue (25/0.08 nos 3 mm da ponta da lima, diminuindo em direção ao terço cervical, com conicidade média variando de 0.06 para 0.05 ao longo do instrumento). O sistema XP-Endo Finisher R foi utilizado para limpeza suplementar em ambos os grupos. A microtomografia computadorizada (Micro-CT) foi empregada para avaliar o volume do material de obturação remanescente e sua porcentagem de redução. O nível de significância estatística foi estabelecido em 5% (p<0.05).* ***Resultados:*** *Constatou-se que ProDesign R e Reciproc Blue removeram 91,2% e 82,7% do material de obturação, respectivamente (p > 0.05). Após o uso do XP-Endo Finisher R, houve um aumento significativo na remoção do material de obturação em 42,7% e 27,7%, respectivamente.* ***Conclusão:*** *ProDesign R e Reciproc Blue apresentaram eficácia similar, mas nenhum dos sistemas removeu completamente o material de obturação dos canais mesiais de molares mandibulares.*

Palavras-chave: *endodontia - molar mandibular - micro CT - tratamento do canal radicular.*

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INTRODUCTION

Complete removal of filling material is essential to the success of endodontic retreatment[1]. Reciprocating instruments are used in endodontic retreatment because of their safety in extremely curved canals and their efficiency in removing filling material compared to continuous rotation systems or hand files[2,3]. A systematic review analyzed the effectiveness, efficiency, and apical extrusion of two continuous rotation systems (Protaper Universal and Mtwo retreatment systems) and two single-file reciprocating systems (Wave One and Reciproc) to determine which was the most efficient and effective and which extruded less filling material during endodontic retreatment. The authors concluded that all systems were equally time-efficient, but none completely removed the filling materials from straight root canals. In terms of apical extrusion, more material extruded towards the periapical tissues with the reciprocating systems than with the continuous rotation tested systems[4].

Various studies have shown that complete removal of root canal filling material is not achieved[5-7]. Additional methods have been suggested to improve the removal of the remaining filling material, including passive ultrasonic irrigation and XP-endo finisher instruments[8-11].

Many studies have demonstrated that micro-computed tomography (micro-CT) can be used to quantify filling material remaining in the root canal system before and after endodontic retreatment[12-14]. This technology provides accurate qualitative and quantitative three-dimensional analysis of root canal and filling material volume[5].

Reciproc Blue (VDW GmbH, Munich, Germany) is a reciprocating single file system with a similar design to Reciproc, with an S-shaped cross-section and two cutting edges[15,16]. These files are available in sizes with tip diameters ranging from R25 to R50, all with a taper of 0.08 in the first 3 mm from the tip of the file, decreasing towards the cervical, with the average taper varying from 0.06 to 0.05 along the instrument. The technical features of Reciproc Blue provide superior performance in reciprocating movements, ensuring precision and safety during endodontic procedures[17]. It is made of blue thermomechanical-treated alloy, making it more flexible and resistant to flexural fracture[15]. Although initially developed for primary root canal treatment, its use for retreatment has been suggested[18].

ProDesign R (Bassi/Easy, Belo Horizonte, Brazil) is an instrument designed for use in reciprocating motion. Featuring a double helix cross-section and CM thermal treatment for enhanced flexibility, it is available in lengths of 21 mm and 25 mm. Operating at 400 RPM with a 270° angle to the left and 30° to the right, its nickel-titanium alloy ensures precision and safety in dental procedures.

XP-Endo Finisher R (FKG Dentaire) is a 30-mm size non-tapered instrument, made of a NiTi MaxWire alloy. When inserted in the canal and exposed to body temperature, a martensitic-austenitic transformation occurs, and the instrument assumes a 'spoon shape' in the 10 mm segment from its tip. The instrument's expansion has the potential to reach anatomical areas that are inaccessible to conventional rotary instrumentation[19]. Recent studies have shown that the supplementary use of XPEndo Finisher R (FKG) significantly reduced the amount of filling material in oval and curved canals re-treated with different systems[19,20].

The aim of this study was to evaluate the efficacy of ProDesign R (PDR) and Reciproc Blue (RECB), followed by XP-Endo Finisher R, for filling material removal. The null hypothesis was that there would be no significant difference between the two systems in filling removal efficacy, and no significant difference in the amount of filling material remaining using the XP-Endo Finisher R.

MATERIALS AND METHOD

G*Power 3.1 software (Heinrich Heine College, Duesseldorf, Germany) was used to calculate power with a power of $\beta = 95\%$ and $\alpha = 5\%$, and a t test for independent samples was applied. The ideal sample size for each group was found to be at least 10 teeth. Five additional samples per group were added to compensate for possible loss.

The study protocol was approved by the São Leopoldo Mandic Dental School Research Institute research ethics committee (CEP #2.332.649).

Ten human mandibular molars (n=10) were obtained from a recently extracted tooth collection and stored in a 0.1% thymol solution. The inclusion criteria were teeth with two fully formed, independent mesial root canals, with separate foramina, and root curvature angles between 10° and 20°, confirmed by digital analysis of radiographs taken in the mesiodistal and buccolingual directions (Image J software,

Maryland, USA). Teeth with previous endodontic treatment, root resorptions, root fractures, or pulp calcifications were excluded. Specimen length was standardized to 18 mm using a diamond disk (FKG, La Chaux-de-Fonds, Switzerland). The canals were explored with a #10 K-type file (FKG, Chaux-de-Fonds, Switzerland), and the working length (WL) was set at 1 mm from the apical foramen.

Root canal preparation

Initial root canal preparation was performed with the ProTaper Next until X2 file (25/0.06; Dentsply Sirona, Ballaigues, Switzerland) driven by a low-torque endodontic motor (X-Smart Plus; Dentsply Sirona) at a rotational speed of 300 rpm and a torque of 3 N.cm. Irrigation was performed with 5 mL of 2.5% sodium hypochlorite (NaOCl) followed by 5 mL of 17% ethylenediamine tetra-acetic acid (EDTA) for 3 minutes and then another 5 mL of 2.5% NaOCl.

The canals were dried with paper points (Dentsply Sirona). Each canal was then filled with gutta-percha and AH Plus sealer (Dentsply Sirona). Radiographs in the mesiodistal and buccolingual directions were used to confirm the final quality of the fillings. The teeth were sealed with the temporary filling material Coltosol (Vigodente, Rio de Janeiro, Brazil), and stored at 37 ºC and 100% humidity for 30 days to allow complete curing of the sealer. The specimens were placed in silicone molds (Vigodente) to ensure that radiographs were taken in the same position, and scanned in a Brunker micro-CT device (Skyscan 1176, Bruker-micro-CT, Kontich, Belgium) with the following parameters: 70 kv, 114 mA, 14.9 mm pixel size, and rotation step of 0.3º. Images were reconstructed using NRecon V.1.6.9.4 software (Bruker micro-CT). The root canal and filling material volumes were analyzed using CTAn V.1.17.7.2 software (Bruker micro-CT). After initial scanning, the specimens were randomly divided into 2 groups of 10 mesial canals each.

Endodontic retreatment

Filling materials were removed with PDR (25/0.06) and RECB (25/0.08) files. The same tooth was subjected to instrumentation with both systems by alternately working the two mesial canals of each tooth, resulting in 10 root canals per group. Both instruments were used in reciprocating motion and driven by a VDW motor set to "Reciproc ALL" mode. A dental operating microscope (Alliance, São Paulo, Brazil) with 8x magnification was used to support the procedure. The files of both systems were designed for single use, so they were discarded after each use. Filling removal was considered complete when no evidence of filling material was visible on the files or on the teeth under the microscope. The re-treated specimens were then subjected to a new micro-CT scan using the same procedure as previously described.

Supplementary root canal filling removal

The XP-Endo Finisher R file was used in both groups to remove any residual material detected during the micro-CT assessment. First, the root canals were irrigated with 5.0 mL of 2.5% NaOCl using a syringe and a 30 G needle for 30 s. After irrigation, the XP-Endo Finisher R file was operated in the root canal for 1 min at a speed of 800 rpm and a torque of 1 N.cm, performing 7 to 8 mm vertical movements along the WL. Finally, the teeth were washed with 5 mL of 17% EDTA for 15 s to remove debris, and then dried with paper points. After this supplementary step, the teeth were subjected to a third micro-CT scan.

Statistical analysis

The quantitative data of the remaining volume (mm^3) and the percentage reduction of filling material (%) obtained from the micro-CT analysis were processed using BioEstat 4.0 software. The Wilcoxon-Mann-Whitney U test was used to compare the residual volumes of filling material between the study groups, and the Wilcoxon's signed-rank test was used for pairwise comparisons within groups. The significance level was set at 5% ($p< 0.05$).

RESULTS

Descriptive statistics were performed for the remaining volume (mm^3) and percent reduction of filling material. The mean values and standard deviations for each experimental group are shown in Table 1.

Both systems removed a significant amount of root canal filling material ($p < 0.05$). Although the mean percentage of filling material removed was higher for A than with B PDR (91.2%) than with RECB (82.7%), no significant difference was found between the two systems after filling removal (Table 1). Similarly, the mean volumes of residual filling

Table 1. Means and standard deviations of the quantity of remaining filling material in mm³ and mean percentage of remaining filling material (%) by postoperative root instrumentations and after supplementary cleaning protocol.

Group	N	Preoperative	Postoperative	%	XP-Endo Finisher R	%
ProDesign R	10	4.19 ± 1.38^{a}	0.33 ± 0.20^{bB}	91.2	0.19 ± 0.12^{cC}	42.7
Reciproc Blue	10	4.15 ± 1.83^{a}	0.64 ± 0.54^{bB}	82.7	0.53 ± 0.50^{cC}	27.7
			p = 0.075		p = 0.095	p = 0.012

The values are expressed as mean ± SD.
*Different lower-case letters in the mean column denote significant differences between the ProDesign R and Reciproc Blue instruments.
Different uppercase letters in the mean line denote significant differences between Postoperative and XP-Endo Finisher R. (Mann-Whitney U test, p>0.05).

material were significantly reduced in both groups after supplementary protocol with XP-endo Finisher R ($p < 0.05$), but no statistical difference was found between groups (Table 1). All samples were found to have residual filling material in the root canals after the filling removal. Representative micro-CT reconstructions of specimens from each group are shown in Fig. 1.

DISCUSSION

Many studies have shown that reciprocating systems are effective in endodontic retreatment procedures, successfully removing most of the filling material from straight and curved canals, with performances comparable to those of continuous rotation techniques or hand files[21,22]. In this study, the PDR and RECB files were found to be equally effective (91.2% and 82.7%, respectively). Therefore, the first null hypothesis tested (a) was accepted; both reciprocating instruments effectively removed most of the filling material from moderately curved canals ($p>0.05$).

The present study used de microcomputed tomography to assess the volume of filling material after the retreatment, which is the gold-standard method for root canal assessment due to its non-invasive nature, and the fact that it allows 3D analysis of several root canal anatomical parameters, both before and after treatment and retreatment[4,19,23]. Some similar studies assessing different reciprocating instruments used microcomputed tomography to evaluate retreatment[9,21], but there are few studies on

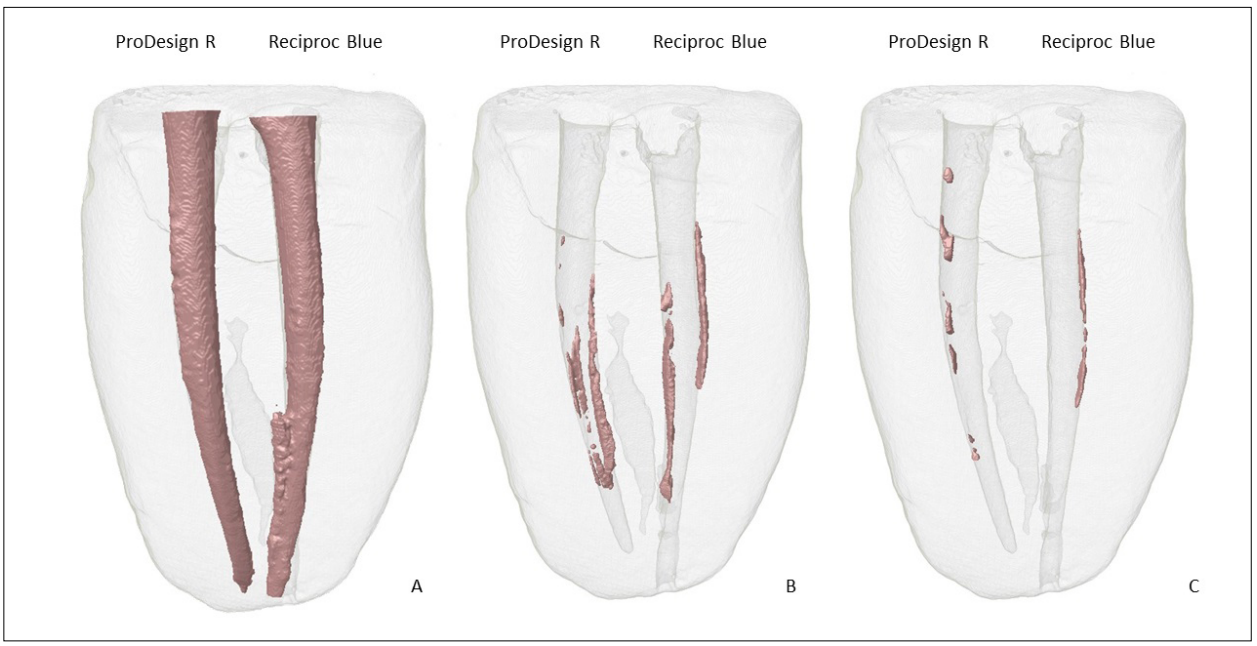

Fig. 1: A): Representative three-dimensional images showing an obturated specimen. B) After preparation with Prodesign R (PR) and Reciproc Blue (RECB) instruments. C) After supplementary cleaning protocol with XP-Endo Finisher R.

the removal of filling material by PDR and RECB files after retreatment procedures. Rodrigues et al.[24] tested different instruments and movements, concluding that the effectiveness of filling material removal with PDR CM files was similar to that with Reciproc R25 files with M-wire, suggesting that the type of alloy was not a relevant factor under the conditions of their study. Studies testing of RECB files have shown that their effectiveness for filling removal is comparable to that of Reciproc R25 and WaveOne Gold instruments and superior to that of manual instruments[25,26]. The results of the present study are consistent the literature that reports that the reciprocating instruments of the PDR and RECB systems were equally effective in removing filling material from moderately curved canals, although their thermal treatment and taper size characteristics differed from those of systems previously tested elsewhere[19].

The files in both systems have S-shaped cross-sections, which may have been responsible for their similar performance during the retreatment procedure. Instrument safety is a critical factor in endodontic retreatment procedures, and instrument fractures and deformities have been described, especially in curved root canals[27]. The root canal curvature of the specimens and the mechanical properties of the thermally treated reciprocating instruments used in the present study may have been responsible for the single instrument fracture observed during instrumentation of the mesiobuccal canal with the PDR file.

The PDR files have a similar taper size (0.06) to RECB files (0.08) in the first 3 mm from the tip of the file, decreasing towards the cervical, with the average taper varying from 0.06 to 0.05 along the instrument, so they are likely to be subjected to stress during instrumentation, possibly resulting in a higher fracture rate. Studies have reported that an additional cleaning procedure performed with XP-endo Finisher files effectively removes filling material debris from straight and curved oval-shaped canals[7,8,28]. Furthermore, additional cleaning by XP-endo Finisher is useful in removing biofilm[6,24], hard tissue debris[10], and calcium hydroxide[26].

This study also aimed to assess whether an additional finishing step could improve the cleaning process. To this end, any specimens with remaining filling, irrespective of their preparation group, underwent a finishing procedure using the XP-endo Finisher R instrument. Another study reported the effectiveness of the XP-endo Finisher in removing residual filling materials[5]. The XP-endo Finisher R, specifically designed for retreatment, was found to further improve the removal of filling materials when used as an additional step in this study. The instrument's greater reach, up to 6 mm in diameter or 100 times that of a standard instrument of the same size, is attributed to the shape-memory properties and flexibility of the MaxWire alloy. This feature potentially allows the instrument to contact more dentine walls and displace filling remnants, thereby improving cleaning. These results align with a previous study reporting that XP-endo Finisher and XP-endo Finisher R instruments are equally effective in removing filling remnants[27].

Although without differences between groups, in the present study, when compared the filling material removal and XP-endo Finisher R steps, it was found a significant difference, from 91.2 to 42.7% for PDR, and from 82.7 to 27.7% ($p = 0.012$), showing good results in filling material remnants removal, in accordance with previous studies[19,27].

Although the present study found no difference between groups, it found significant intragroup filling material removal by PDR and RECB (91.2% and 82.7%, respectively) and by XP-endo Finisher R (42.7% and 27.7% for canals treated with PDR and RECB, respectively) ($p = 0.012$), in agreement with previous studies[19,27].

Recently, Silva et al.[7] investigated the efficacy of XP-endo Finisher and XP-endo Finisher R in the removal of filling material, finding that both systems cleaned equally effectively under the conditions of their study. The results of the present study are consistent with reports that the amount of filling material observed after the use of XP-Endo Finisher R was significantly less than the amount observed before this additional cleaning. Thus, the second null hypothesis tested (b) was also rejected. This finding could be related to the austenitic memory effect of the XP-endo finisher files, which helps to extend their reach, thereby improving root canal cleanliness. Both instrumentation protocols failed to completely remove the filling material from the root canal samples in the present study, even after the additional cleaning procedure. Several studies have reported similar results, finding residual filling material in all canals, regardless of the retreatment technique used[13,14,24,29].

Nevertheless, the results of the current study confirm that removing as much gutta-percha and sealer as possible by combining different instruments and complementary approaches is still an essential strategy to address the problem of cleanliness in endodontic retreatment. Overall, all samples presented remnant filling material. However, after the use of the XP-endo Finisher R instrument, the remnants were reduced to 42.7 and 27.7% for canals treated with ProDesign R and Reciproc Blue, respectively. Residual filling materials can cover areas inhabited by remaining bacteria, such as recesses, isthmuses, dentinal tubules, and ramifications[30]. Bacteria can remain viable in these hard-to-reach areas protected by residual filling material, as they may not be affected by antimicrobial agents used during retreatment. The impact of these filling material remnants on root canal disinfection and, consequently, the outcome of the retreatment, is yet to be fully understood[19].

CONCLUSION

The tested systems ProDesign R and Reciproc Blue were equally effective for root canal filling removal in mesial canals of mandibular molars, but neither system completely removed the filling material. Using Xpendo finisher R as a supplementary step improved remnant removal.

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CONFLICT OF INTERESTS

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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