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ORIGINAL ARTICLE

Comparing ProFile Vortex to ProTaper Next for the efficacy of removal of root filling material: An *ex vivo* micro-computed tomography study

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KEYWORDS

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Rotary file

Abstract *Aim:* This study compared the efficacy of ProFile Vortex (PV) with that of ProTaper Next (PTN) for the removal of root canal filling material.

Materials and methods: Twenty-six mesial canals of extracted mandibular first molars were instrumented, obturated with gutta-percha and sealant, and randomly allocated to a PTN (X3, X2, or X1) or PV group. The percentage of remaining material, amount of dentin removed, and extent of transportation were assessed using micro-computed tomography. The total time required for removal of material was calculated.

Results: Both systems were effective for material removal ($p \leq 0.001$). Less time was required to remove material using PV (256.43 ± 108.95 s) than using PTN (333.31 ± 81.63 s; $p \leq 0.05$). PV and PTN files removed approximately 84% and 78% of the filling material, respectively ($p >$ .05). There was no significant canal transportation in either group. PV and PTN files removed 1.32 ± 0.48 mm^3 and 1.63 ± 0.67 mm^3 of the dentin, respectively (p = .18).

Conclusion: Our findings suggest that PV is as effective as PTN for removal of root canal filling material. Therefore, PV can be considered for use in endodontic retreatment, although more effective files or techniques are still required.

1. Introduction

Nonsurgical endodontic retreatment is considered to be the first choice of treatment after failed root canal therapy (Stabholz and Friedman, 1988). However, it is a challenging procedure, particularly in cases of curved canals (Schirrmeister et al., 2006). After gaining access to the canal, the crucial step in retreatment is removal of the old filling material and measurement of the correct working length (WL) (Stabholz and Friedman, 1988; Haapasalo and Ricucci, 2008).

Complete removal of the previous filling material is required to eliminate bacteria that may be harbored within the material, which cannot be reached by antimicrobial solutions and compromise the seal of the new filling material

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(Ricucci et al., 2009; Siqueir, 2011). Remnant bacteria within the apical sites of the canal contribute significantly to persistent inflammation in the periradicular areas (Ricucci et al., 2009). Several methods for removal of gutta-percha from root canals, including chemical, thermal, and/or mechanical instrumentation, have been tested (Friedman et al., 1990). However, none of these methods have been proven to be successful for complete removal of gutta-percha and sealer from the canal (Zmener et al., 2006; Duncan, 2008, de Mello Junior et al., 2009; Rios Mde et al., 2014; Keles et al., 2015). Nickel-titanium rotary instruments are used to prepare and shape root canals (Walia et al., 1988), and different designs of these instruments have been developed specifically for removal of gutta-percha during retreatment (Gu et al., 2008).

Recently, the ProFile Vortex (PV) system (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) was introduced and is characterized by a triangular cross-section and manufactured using innovative M-wire technology (Alapati et al., 2009; Gao et al., 2010).

Subsequently, the ProTaper Next (PTN) system (Dentsply Tulsa Dental Specialties) was manufactured using the same M-wire technology used for PV files. This file is characterized by a rectangular cross-section and produces a unique asymmetric rotary motion (Ruddle et al., 2013).

Several reports have investigated the efficiency of PTN systems for removal of root canal filling materials and compared the results with those for different rotary and reciprocating files (Nevares et al., 2016; Ozyurek and Demiryurek, 2016). However, although the physical properties and material performance of PV systems have been investigated, there is limited information on their effectiveness in endodontic retreatment (Yamamura et al., 2012; Zhao et al., 2014).

The aim of the present study was to compare the efficacy of the ProTaper Next system with that of the ProFile Vortex system for removal of root canal filling material in terms of the amount of dentin removed, percentage of remaining material, extent of transportation, and time required to remove the material completely.

The null hypothesis was that there would be no significant difference in the efficacy of the ProFile Vortex and ProTaper Next systems for removal of root canal filling, time needed to complete the procedure, or in apical transportation during endodontic retreatment.

2. Materials and methods

2.1. Sample selection

Fifty-two extracted human mandibular first molars were screened for inclusion in the study; the reasons for extraction were not considered to be relevant to the study. The primary screening procedures used to evaluate morphology and apply inclusion criteria included surgical microscopy, periapical radiography in the mesiodistal and buccolingual directions (Vertucci's class IV) (Vertucci, 1984), and micro-computed tomography (μCT).

Teeth with caries, abnormal, dilacerated, cracked, or resorbed roots, and/or a history of root canal treatment were excluded. Thirteen teeth with two completely separate mesial canals, two separate apical foramina, and curvatures of less than 25° as determined by the Schneider method (Barletta et al., 2007) were included. The mean (± standard deviation) angle of curvature was 15.69° ± 3.46°. All teeth were stored in 0.1% thymol solution at room temperature. A single operator performed and conducted the study.

2.2. Sample and root canal preparation

The sample preparation protocol followed that used in a previous study (Gambill et al., 1996). In brief, standardized access cavities were prepared and the patency of the mesial canals was assessed using a #10 K-file (Dentsply Maillefer, Baillaigues, Switzerland). Using a dental operating microscope (OPMI Pico; Carl Zeiss, Oberkochen, Germany), the WL was determined by insertion of a #10 K-file into the canal until its tip could be visualized through the apical foramen. The WL was measured up to 1 mm from the apical foramen. To standardize the samples, all teeth were decoronized to achieve a unified WL of 18 mm. Customized silicone mounts were prepared to accurately position and standardize each specimen for μCT. Once a glide path was achieved, all canals were instrumented by continuous rotation using a ProTaper Universal system (Dentsply Maillefer) as recommended by the manufacturer to size an F3 file to the full WL. All canals were copiously irrigated with 5.25% sodium hypochlorite solution after each filing cycle. The smear layer was removed by irrigation with 17% ethylene diamine tetraacetic acid followed by 5.25% sodium hypochlorite as the final rinse.

2.3. Root canal filling

All canals were dried with paper points and filled using F3 gutta-percha cones with tips that were coated with AH-Plus sealer (Dentsply Detrey, Konstanz, Germany). A heated plugger (Alpha; B&L Biotech Inc., CA, USA) was introduced into the canal for 5 mm of WL, following which the entire canal was back-filled with gutta-percha in a continuous wave using the Beta obturation system (B&L Biotech Inc.). The quality of obturation was assessed on periapical radiographs obtained in the mesiodistal and buccolingual directions. The sample was replaced if voids were detected. All specimens were stored at 37 °C and 100% humidity for 15 days to allow the root canal sealer to set.

2.4. Preoperative micro-CT

Following obturation, all specimens were scanned preoperatively using a Skyscan 1172 micro-CT device (Bruker microCT, Kontich, Belgium) under the following conditions: source voltage, 100 kV; source current, 100 μA; 360° rotations around the vertical axis; isotropic resolution, 13.73 μm; camera exposure time, 1700 ms; and rotation step, 0.4°. X-rays were filtered with a 0.5-mm-thick aluminum and 0.5-mm-thick copper filter for changes in sensitivity of the polychromatic radiations. The raw images were then reconstructed using NRecon version 1.6.4 software (Bruker microCT), under the following conditions: smoothing, 5; smoothing kernel, 2 (Gaussian); ring artifact correction, 15; and beam hardening correction, 40%. CTan v1.11.10.0 software (Skyscan, Bruker microCT) was used for three-dimensional image reconstruction and measurement of the material volume in each canal.

2.5. Removal of the filling material

For retreatment, the specimens were randomized into a PV group (n = 16) and a PTN group (n = 16) by alternating the files between canals. If one rotary file was selected for one canal, the other system was used for the other. A new set of files were used for each canal. Considering the lack of retreatment protocols for both systems, the manufacturers' instructions for instrumentation were followed in this study.

PTN X1 (17/04) was used first to full WL, followed by PTN X2 (25/06) and X3 (30/06) up to WL. The files were used with a brushing motion against the side walls and the crown-down technique. The Crown-down technique was also used for the PV files, beginning with the 40/0.04 file, followed by the 35/0.04, 30/0.04, 25/0.04, and 30/04 files up to WL.

Both systems were used via an electric endodontic motor in continuous rotations at a speed of 500 rpm and torque of 2 N cm (X smart, Dentsply Maillefer). When no material could be visualized in the canal or file flutes under a dental operating microscope, the procedure was considered to be complete. The same irrigation protocol used during instrumentation was used during removal of the filling material.

For each canal, the time interval between insertion of the file and completion of the procedure was measured in seconds using a digital stopwatch.

2.6. Postoperative micro-CT and analysis

Following removal of the material, postoperative μCT scans were obtained using the same machine and parameters utilized for preoperative scanning. The volume of remnant material in the canal was calculated. Data Viewer v.1.5.1 software (Bruker microCT) was used to align the three-dimensional images from both scans and precisely superimpose them for evaluation of preoperative and postoperative differences (Fig. 1). The volume of interest was marked from the canal orifice to the root apex and unified in all sections. Further, each canal was divided into coronal, middle, and apical thirds and the volume within each section was measured. The amount of dentin removed from the mesiobuccal and mesiolingual canals was also measured for the entire canal by comparing the canal volume before and after retreatment.

2.7. Apical canal transportation

Axial images of the preoperative and postoperative scans were used to determine the extent and direction of canal transportation at 2, 4, and 6 mm from the root apex (Fig. 2). The extent of transportation was measured using the formula (A1−A2) − (B1–B2) (Gambill et al., 1996), where A1 represents the shortest distance from the edge of the mesial surface of the root to the periphery of the filled canal, A2 represents the shortest distance from the edge of the mesial surface of the root to the periphery of the retreated canal, B1 represents the shortest distance from the edge of the distal surface of the root to the periphery of the filled canal, and B2 represents the shortest distance from the edge of the distal surface of the root to the periphery of the retreated canal (Fig. 3). An investigator who was blinded to group allocation calculated the extent of transportation by comparing the preoperative and postoperative sections.

2.8. Statistical analysis

The statistical analysis was performed using SPSS version 20.0 software (IBM Corp., Armonk, NY). The volumes of filling and remnant material, amount of dentin removed, extent of apical transportation, and time required to remove the material were compared between the PV and PTN groups using unpaired *t*-tests and are reported as the mean ± standard deviation. The amount of filling material removed is presented as a percentage with the median and was compared between the groups using the Kolmogorov-Smirnov nonparametric test. A p-value ≤ 0.05 was considered to be statistically significant.

3. Results

Table 1 shows the mean volume of remnant filling material, the mean percentage of filling material removed, the mean extent

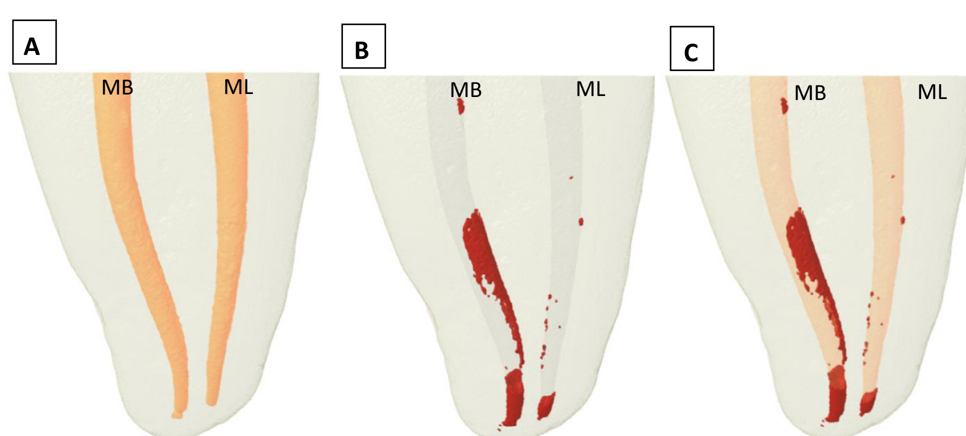

Fig. 1 Representative three-dimensional reconstructed images of mandibular first molar canals: (A) Initial root canal filling material in the mesiobuccal (MB) & mesiolingual (ML) canals (*orange*); (B) Remaining root canal material after retreatment (red) with ProTaper Next (MB) and ProFile Vortex (ML); (C) Superimposed images.

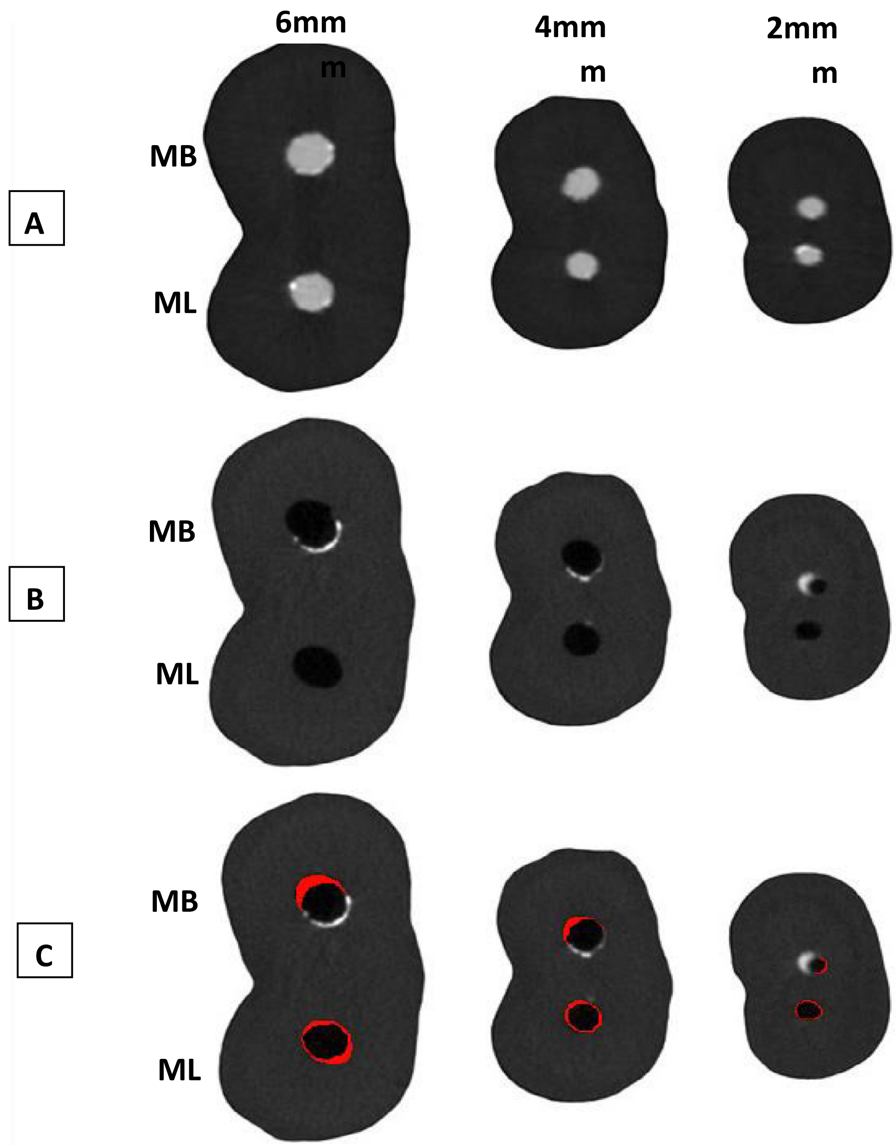

Fig. 2 Representative cross sectional micro-CT images: (A) After placing the root canal filling material at 2 mm, 4 mm, and 6 mm level from the apical foreamen. (B) After retreatment at respective cross sections. (C) transported area (*red*) at different cross sections.

of apical transportation, and the time required to remove the material.

Significantly less time was required to remove the material using PV (256.43 ± 108.95 s) than using PTN (333.31 ± 81.63 s; $p \leq 0.05$; Table 1). Moreover, a significant difference was found between the volume of filling material before retreatment and that after retreatment ($p \leq 0.001$). However, there was no significant difference ($p > .05$) in the initial mean volume of filling material in the coronal, middle, and apical thirds between the two groups (Table 1). The PV system removed 84% of the filling material and the PTN removed 78% ($p > .05$; Table 1). There were no significant differences in the percentages of filling material removed from the coronal, middle, and apical thirds between the two groups ($p > .05$; Table 1). The extent of canal transportation in the PV group and PTN group, respectively, was 0.0909 ± 0.0894 and 0.0983 ± 0.0885 mm at 2 mm, 0.0779 ± 0.1035 and 0.1035 ± 0.0827 mm at 4 mm, and 0.0939 ± 0.0753 and 0.1612 ± 0.1285 mm at 6 mm ($p >$ .05); there was no significant difference at any level (Table 1 and Fig. 3). The amount of dentin removed was not significant between the two groups (PV, 1.32 ± 0.48 mm^3; PTN, 1.63 ± 0.67 mm^3; $p = .1882$).

4. Discussion

The complete removal of old root canal filling material is important for effective elimination of microorganisms possibly harbored by the failing material (Ricucci et al., 2009). In the current study, μCT was used to compare the efficacy of the ProTaper Next with that of the ProFile Vortex in removing root filling material from mesial roots of extracted mandibular molars.

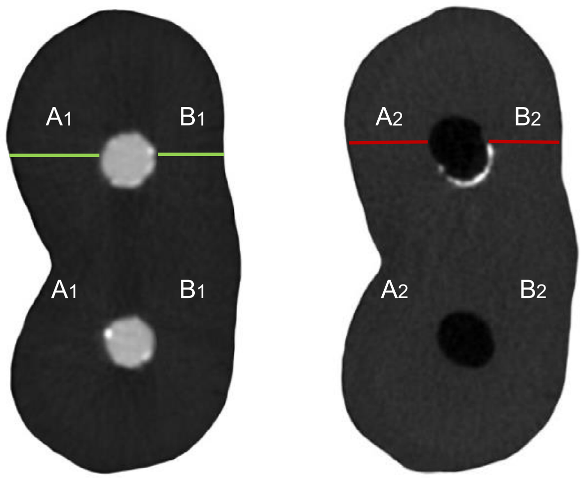

Fig. 3 Representative micro-CT cross-sectional images showing points of measurement for calculating apical canal transportation; *green:* after obturation and *red*: after removal of obturation material.)

Several techniques have been used to evaluate the remnant filling material in treated root canals, including split-tooth, clearing, and two-dimensional radiographic techniques (de Carvalho Maciel and Zaccaro Scelza (2006); Saad et al., 2007; de Mello Junior et al., 2009). However, these techniques have some limitations in that they are destructive, can result in removal of filling material during processing, and do not provide three-dimensional data. Since its advent in dentistry in the late 1990s, μCT technology has been used in several areas of dental research because it is a nondestructive technique that provides three-dimensional information on the root canal filling material (Peters et al., 2000; Rödig et al., 2012). By comparison of postoperative and preoperative images, this technology enables quantitative evaluation of several associated parameters, including the amount of filling material and dentin removed and the extent of transportation (Rödig et al., 2012).

As in the previously published studies, we used the mesial roots of mandibular molars with canals that were completely separate from the orifice to the apical foramen (Junaid et al., 2014; Alves et al., 2016; Nevares et al., 2016). Further, no solvents were used, which allowed more accurate evaluation of the effects of each rotary file system. We used both file systems alternately in the canals of each root to minimize the effect of morphologic variations between the teeth or among canals within the same tooth.

The initial mean volume of the filling material in the mesiobuccal and mesiolingual canals was not significantly different ($p > .05$), indicating the feasibility of comparison between the two groups.

Considering there is no current evidence regarding the superiority of any particular instrument for removal of root canal filling material (Alves et al., 2014; Ozyurek and Demiryurek, 2016; Rossi-Fedele and Ahmed, 2017; Fariniuk et al., 2017), we compared two rotary file systems that are manufactured and marketed for root canal shaping. Of the two, to our knowledge, PV has never been tested for retreatment. Our

Table 1 Initial mean volume of the root canal filling material (mm^3), mean volume of remnant material after retreatment (mm^3), mean percentage of the removed filling material, mean extent of apical transportation at different sections (mm), and the total time required for retreatment (seconds) with ProTaper Next (PTN) and ProFile Vortex (PV).

Group	N	Initial mean volume of the filling material (mm^3 ± SD)				Mean volume of the remaining filling material (mm^3 ± SD)				Mean% of removed filling (Median)				Mean apical transportation (mm ± SD)			Total time (sec ± SD)	*P* value ≤
		Coronal	Middle	Apical	Total	Coronal	Middle	Apical	Total	Coronal	Middle	Apical	Total	2 mm	4 mm	6 mm		
PV	13	1.89 ± 0.54	1.14 ± 0.29	0.42 ± 0.09	3.46 ± 0.89*	0.18 ± 0.37	0.26 ± 0.37	0.15 ± 0.13	0.60 ± 0.84*	91.41 (99.78)	79.48 (97.20)	66.96 (68.24)	84.42 (94.93)	0.09 ± 0.08	0.07 ± 0.10	0.09 ± 0.07	256.43 ± 108.95**	0.001*
PTN	13	1.74 ± 0.48	1.02 ± 0.23	0.35 ± 0.09	3.12 ± 0.73*	0.30 ± 0.33	0.21 ± 0.29	0.14 ± 0.13	0.66 ± 0.69*	81.38 (83.21)	78.73 (90.77)	60.05 (56.31)	77.79 (78.90)	0.09 ± 0.08	0.10 ± 0.08	0.16 ± 0.12	333.31 ± 81.63**	0.001*
P value ≤		0.08	0.23	0.46	0.29	0.83	0.73	0.42	0.85	0.29	0.87	0.87	0.57	0.83	0.27	0.38	0.05**	–

* $P \le 0.05$.
** P value ≤ 0.001.

results indicate that neither of the two systems was successful in achieving complete removal of the filling material, which is consistent with previous reports documenting that PTN could not eliminate the filling material completely (Nevares et al., 2016; Ozyurek and Demiryurek, 2016). Similar findings have been reported for other tested rotary file systems, which were unable to eliminate material completely (Zuolo et al., 2013; Keles et al., 2015; Rossi-Fedele and Ahmed, 2017). Another recent report compared PTN with the Reciproc system (VDW, Munich, Germany) with and without use of sonic and ultrasonic irrigation and concluded that there was no significant difference in ability to remove root filling material between the two files. We found no significant difference in the efficacy of PV and PTN for removal of root canal filling material; thus, the null hypothesis of the study was accepted. We may attribute the non-significant difference in removing the filling material between the two files to the continuous rotation motion and crown down technique being used in both systems. Also, both systems used in the present study were manufactured using the same M-wire technology. In the current study, PTN used at full WL had more taper (7%) than PV (4%) used at a similar length. However, this difference in taper did not have a significant effect on the efficacy of removal of filling material. Moreover, the "swaggering" effect or snake like movement of PTN in the canal did not add any effect in the efficiency of removing filling material over PV. In fact, PV was more efficient for removal of filling material from the coronal third, although the difference was not significant ($p > .05$). We think this might be caused by the unique triangular cross section of PV file, so the file would touch the canal in three points all the time compared to only touching the canal in two points in the PTN file (asymmetrical rectangular cross section) which may influenced the effectiveness in removing the filling material ($p > .05$). When the volume of filling material removed was compared with the initial volume before retreatment, both file systems were able to reduce the amount of filling material significantly ($p \leq .001$).

To the best of our knowledge, no study has evaluated the efficacy of PV for removal of root canal filling material; therefore, direct comparisons with the findings of previous studies were not possible. In the present study, PV took significantly less time to remove filling material from root canals than PTN ($p \leq .05$), but the clinical significance of this statistical finding is presently unclear.

It should be noted that previous studies of the efficacy of PTN for retreatment did not include the X1 file (Nevares et al., 2016; Ozyurek and Demiryurek, 2016), which was attributed to the high risk of separation. However, in the present study, PTN was used in a brushing motion against the wall, which may have contributed to better preservation of the instrument.

Some amount of dentin may be removed during removal of root canal filling material, which can alter the canal morphology and result in transportation. Although we could not find any reports comparing PV and PTN with regard to their shaping abilities and the extent of transportation, we found studies showing that PTN preserved the tooth structure and did not cause significant transportation during shaping when compared with other file systems (Saber et al., 2015; Zhao et al., 2014). A similar report is available for PV (Yamamura et al., 2012). In our study, we evaluated the extent of apical transportation at 2, 4, and 6 mm from the apical foramen and found that neither PV nor PTN caused significant transportation. Both systems safely preserved the apical dentin and remained centered, as reported in a previous study on PTN (Nevares et al., 2016).

5. Conclusions

Within the limitations of this study, we can conclude that the PV and PTN rotary file systems are equally effective for removal of root canal filling material, although neither can eliminate the filling material completely. PV takes less time to perform and can be used for endodontic retreatment; however, further studies are necessary to identify the most effective system or technique for complete removal of filling material.

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Conflicts of interest

None.

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