Original Article

Evaluation of different mechanical cleaning protocols associated with 2.5% sodium hypochlorite in the removal of residues from the post space

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Abstract

Aims: This study evaluated the effectiveness of different mechanical protocols using rotary brush (RB), ultrasonic tip, and oscillatory system (OS) associated with 2.5% sodium hypochlorite (NaOCl) in the removal of residues and dentin permeability in the cervical and apical segments of the post space.

Settings and Design: Experimental *in vitro* study.

Methods: Forty roots from human first molars were prepared and divided into four groups according to the cleaning protocols: Control (CO), NaOCl 2.5% conventional irrigation with a syringe; RB associated with NaOCl 2.5%; ultrasonic tip (US) associated with NaOCl 2.5%; OS associated with NaOCl 2.5%.

Statistical Analysis Used: The persistence of residues was evaluated by scanning electron microscopy and data submitted to Kruskal–Wallis and Dunn tests, and dentin permeability evaluated by confocal microscopy and date submitted to ANOVA one-way and Tukey's tests ($P = 0.05$).

Results: There were no differences in residue cleaning among the CO, RB, US, and OS groups, regardless of the analyzed root segment ($P > 0.05$). When comparing groups, dentin permeability in the CO group was significantly lower in the cervical segment ($P < 0.05$).

Conclusions: The OS group promoted the highest permeability value in the apical segment. RB, US, and OS are similar in removing residues from the post space. However, OS results in higher dentin permeability in the apical segment.

Keywords: Cleaning; dentin permeability; post space; protocols; ultrasound

INTRODUCTION

Failures in the cementation of fiber posts are the result of improperly conducted techniques by the professional.[1] Prior clinical care is essential to ensure the success and longevity of the final restoration. Effective cleaning of root canals after obturation is one of the crucial steps during treatment. This is because the root dentin of the post

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space is composed of remnants of endodontic cement, gutta-percha remnants, or dentin residues. When not removed, these remnants occlude dentinal tubules and hinder the diffusion of resin monomers into the substrate, leading to adhesive failure during fiber post cementation.[2-4]

It is well known that residue removal within the post space is critical due to limited access, especially in deep areas of the apical segment.[5] Although new devices and techniques to enhance the cleaning effectiveness of root canals after biomechanical procedures are recommended in endodontics, such as passive ultrasonic irrigation, endodontic brush, and easy clean,[6-8] there is still no consensus in the literature regarding a gold standard protocol for effectively removing residues from the dentin within the post space.

It is mentioned that the differences between mechanical cleaning devices are primarily based on the source and amount of energy released, as well as the configuration of the device tip.[5] Rotary brush (RB) and Ultrasonic (US) are already commonly used and investigated as aids in cleaning the post space.[9,10] On the other hand, the use of the black NiTi oscillatory system (OS) for this purpose still lacks evidence, which prompted the authors to assess its effectiveness.

In addition, an irrigating chemical solution is of utmost importance, as mechanical forces generate friction and increase dentin dehydration, making it even more friable and less conducive to adhesion.[11] The use of sodium hypochlorite (NaOCl), commonly employed in clinical practice, for instance, could potentially induce deeper demineralization of the dentin substrate, assuming that the superficial smear layer has already been removed by the mechanical cleaning protocol.[12]

Given the importance and necessity of investigating an effective protocol for cleaning residues within the post space, this *in vitro* assay aimed to assess the effectiveness of different mechanical protocols for post space cleaning (RB, US, and OS) in conjunction with an irrigating chemical solution (2.5% NaOCl) in the removal of residues and dentin permeability within the post space in the cervical and apical segments. The null hypothesis (H0) tested was that there would be no statistically significant difference between the different mechanical protocols associated with the 2.5% NaOCl irrigating solution in the removal of residues and dentin permeability within the post space in the cervical and apical segments.

METHODS

This study was submitted to and approved by the Research Ethics Committee of the School of Dentistry in Araraquara, São Paulo State University (CAEE 70166317.9.0000.5416). Eighty human upper first molars with similar root anatomy and devoid of structural morphological alterations were selected and kept in a 0.2% thymol solution at 4°C until the time of use.

Specimen preparation

After storage in an aqueous solution buffered with 0.2% thymol, the teeth were rinsed with running water and subjected to prophylaxis using pumice and distilled water. Subsequently, the upper first molars were sectioned parallel to the cementoenamel junction level using a cutting machine (Isomet; Buehler Ltd, Lake Buff, Illinois, USA) to separate the crown from the root, standardizing the roots to a length of 16 mm. Only palatal roots were used in the present study.

Root canal preparation

The root canals were initially accessed using a K#10 file (Dentsply Maillefer, Ballaigues, Switzerland) at a length of 16 mm, followed by a glide path created with a K#15 file (Dentsply Maillefer, Ballaigues, Switzerland) and mechanically prepared to F2 instrument (Protaper, Dentsply Maillefer, Ballaigues, Switzerland), in clinical sequence as recommend by the manufacturer. The actual instrumentation length was set at 15 mm from the root apex. After each instrument change, the root canals were irrigated with 5 ml of 2.5% NaOCl. The final irrigation was carried out with 17% ethylenediaminetetraacetic acid (EDTA) (Biodinâmica, Ibiporã, Paraná, Brazil), which was left in the root canal for 3 min, followed by 5 mL of 2.5% NaOCl.[13]

Subsequently, the root canals were dried with an absorbent paper point (Tanari, Petrópolis, Rio de Janeiro, Brazil) and filled with an epoxy-based endodontic sealer (AH Plus; Dentsply DeTrey, Konstanz, Germany) and F2 gutta-percha cone (ProTaper; Dentsply Maillefer, Ballaigues, Switzerland) using the single-cone technique. After placing the gutta-percha cone with endodontic sealer, the cervical access of the roots was sealed with temporary cement (Coltosol; Coltene, Rio de Janeiro, Brazil), and the roots were kept in an incubator at 100% relative humidity at 37°C for 7 days.[13]

Evaluated protocols

After 7 days, root canals were desobturated to a length of 10 mm using #1 and #2 Peeso drills (MK Life, Porto Alegre, Rio Grande do Sul, Brazil) and standardized with a specific drill (Whitepost System DC1, FGM, Joinvile, Santa Catarina, Brazil). Subsequently, the specimens were randomly divided into four groups ($n = 20$) according to the cleaning method.

Control group

Irrigation with 5 ml of 2.5% NaOCl. Irrigation was performed using a syringe with the aid of an irrigation cannula (Safetip

30 mm, Angelus, Londrina, Paraná Brazil) at a speed of 5 ml/min.

Rotary brush group

Mechanical cleaning with a RB (MK Life, Porto Alegre, Rio Grande do Sul, Brazil), attached to an electric motor (NSK, Joinville, Santa Catarina, Brazil), in 3.4 N. cm and 500 rpm for 15 s, touching the canal walls, followed by chemical cleaning with 5 ml of 2.5% NaOCl.

Ultrasonic group (US)

Mechanical cleaning with an ultrasonic tip (E1F tip; Helse, Santa Rosa de Viterbo, SP, Brazil), attached to ultrasonic device (Jet Sonic; Gnatus, São Paulo, Brazil), in 30.000 Hz, touching the canal walls, for 15 s, followed by chemical cleaning with 5 ml of 2.5% NaOCl.

Oscillatory system group

Mechanical cleaning with a #40 reciprocating NiTi instrument (Prodesign R; Easy System, Belo Horizonte, Brazil), attached to a oscillatory contra-angle (FXM700 70:1; Dentiflex, Ribeirão Preto, São Paulo), for 15 s, touching the canal walls, followed by chemical cleaning with 5 ml of 2.5% NaOCl.

Subsequently, the canals were dried using an absorbent paper point. Ten specimens from each group were submitted to residue persistence evaluation using scanning electron microscopy (SEM), and ten other teeth from each group were submitted to dentin permeability using confocal microscopy.

Residue persistence evaluation

For this evaluation, two longitudinal grooves were made, one on the vestibular face and another on the palatal face of the root of four specimens from each group using a double-sided diamond disc (#7020, KG Sorensen, São Paulo, Brazil), at low speed. Subsequently, the root was separated with a chisel, and the distal section was used for microscopic analysis. The specimens were mounted on metal stubs, coated with gold (single cycle 120 s) under vacuum, and placed in a metallization chamber (MED 010, Balzers Union, Balzers, Liechtenstein) for evaluation through SEM (DSM 940; Carl Zeiss, Oberkochen, BW, Germany) operating at 20 kV.[2]

Four different images of the root surface from the cervical and apical segments of the post space were obtained, with a magnification of ×500, captured by the same operator. Subsequently, two blinded and calibrated examiners ($\kappa = 0.93$) classified the persistence of residue on the dentin surface.[14]

- Score 1: Absence or slight presence of residues with visible dentinal tubule openings
- Score 2: Slight presence of residues, with more than 50% of the dentin surface free from residues
- Score 3: Moderate presence of residues, with <50% of the dentin surface free from residues
- Score 4: Intense presence of residues, with dentinal tubule openings practically or completely obstructed.

Dentin permeability assessment

After cleaning the post space according to the different evaluation protocols described above (CO, RB, US, and OS), specimens had their root canals dried using absorbent paper points and filled with 0.01% Rhodamine B solution (Synth, São Paulo, Brazil), for 1 min, aspirated and dried using paper point.

Subsequently, two slices (2 mm, thickness), one in the cervical segment and another in the apical segment post space, were made using a double-face diamond disk (Buehler Ltd, Lake Bluff, IL, USA) attached to a cutting machine (Isomet, Buehler Ltd, Lake Bluff, IL, USA), under constant cooling, for dentin permeability assessment using laser confocal microscopy (LSM 800, Carl Zeiss, Oberkochen, Germany) at a magnification of ×1024.

One image was obtained from each quadrant of the root segment of each specimen, and the 10 longest extensions (in μm) of 0.01% Rhodamine B solution penetration into the dentin were measured using ImageJ software (ZEN BLUE 2.3 System), resulting in a total of 40 measurements and the arithmetic mean was obtained to each specimen and cleaning protocol.

Statistical analysis

The data obtained from the evaluation of residue persistence (in scores) were subjected to the nonparametric Kruskal–Wallis and Dunn tests ($\alpha = 0.05$). On the other hand, the dentin permeability values showed a normal data distribution, as observed after previous analysis by Shapiro–Wilk test, and subjected to one-way ANOVA and Tukey's tests ($\alpha = 0.05$).

RESULTS

Residue persistence

The results of this study demonstrated that there were no differences in residue cleaning evaluations between the CO, RB, US, and OS groups, regardless of the analyzed post space segment ($P > 0.05$). Table 1 shows the median, maximum, and minimum values, first quartile (1Q), and third quartile (3Q) of dentinal tubule count after different cleaning protocols in the cervical and apical segments of the post space.

The root dentin surface after the use of different cleaning protocols in the cervical and apical post space segments is illustrated in Figure 1.

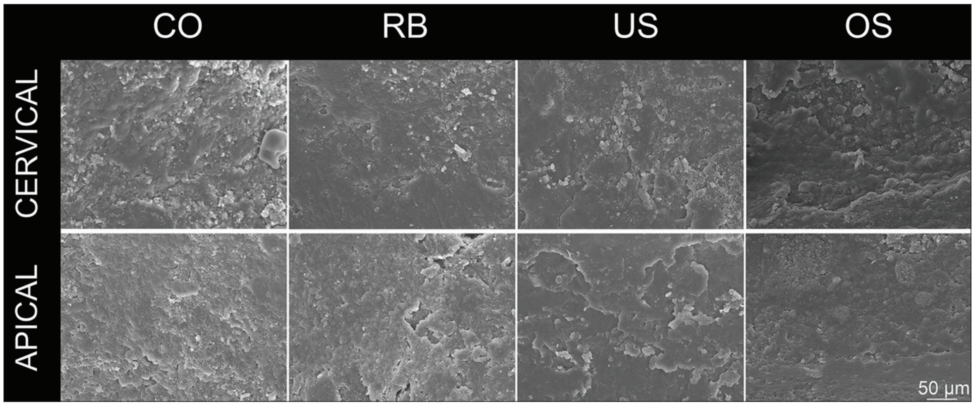

Figure 1: Images scanning electron microscope in the cervical and apical segments of residue cleaning on the dentin surface, according to the evaluation protocol. CO: Control, RB: Rotary brush, US: Ultrasonic tip, OS: Oscillatory system (×500)

Table 1: Median, maximum, and minimum values, first quartile, and third quartile of dentinal tubule count after the different cleaning protocols in the cervical and apical segments of the post space

Values	CO	RB	US	OS
Median				
Cervical	4[a]	4[a]	3[a]	3[a]
Apical	4[a]	3[a]	3[a]	4[a]
Vmin–Vmax				
Cervical	4–4	2–4	3–4	2–4
Apical	4–4	2–4	2–4	3–4
1Q–3Q				
Cervical	4–4	3–4	3–4	3–3
Apical	4–4	2–4	3–4	3–4

[a]Equal letters indicate no statistically significant difference ($P<0.05$). CO: Control, RB: Rotary brush, US: Ultrasonic tip, OS: Oscillatory system, Vmin: Minimum value, Vmax: Maximum value, 1Q: First quartile, 3Q: Third quartile

Dentin permeability

In the comparison between groups, dentin permeability in the control (CO) group was significantly lower in the cervical segment [$P < 0.05$, Table 2]. Furthermore, there was no difference between RB, ultrasonic (US), and OS, which had the highest values [$P > 0.05$, Table 2]. In the apical segment, the OS provided the highest permeability value among the evaluated groups [$P < 0.05$, Table 2], while RB and ultrasonic (US) presented similar values [$P > 0.05$, Table 2] and were higher than the CO.

Figure 2 demonstrates dentin permeability marked with Rhodamine B after the different cleaning protocols.

DISCUSSION

The results of the present study demonstrated that all evaluation groups exhibited similar effects in the analysis of residue persistence in the cervical and apical segments of the post space. However, the OS group (OS associated with NaOCl) showed higher dentin permeability in the apical post space segment with statistically significant differences compared to the other groups, partially rejecting the null hypothesis.

In this study, the authors chose to conduct a specific analysis of the cervical and apical segments, which are critical areas for the evaluations in question. The apical region is challenging to visualize within the root canal, making it more likely to retain residues on the dentin walls.[5] In addition, the cervical portion assumes particular importance because the preparation of the canal for post cementation follows a conical design, exposing this region more to contact with chemical substances. Furthermore, it involves a more significant removal of dentin from the walls, which can become impregnated with materials used in endodontics.[15]

The evolution of endodontic sealer and their remarkable resistance to solubility, along with improved adhesion to dentin walls, is widely acknowledged.[16] Consequently, the dentin preparation for post space becomes even more critical, demanding greater care from the professional during residue cleaning. This study demonstrated that the protocols combining mechanical and chemical residue cleaning have the same effect, contrary to findings from previous studies.[17-20] However, it is worth mentioning that discrepancies may arise from the different experimental designs used, such as the activation of the irrigant, suggesting that this protocol enables a more effective flow of the solution, enhancing its action.[18] In addition, it is important to note that, despite NaOCl being a preferred chemical cleaning agent for root canal disinfection, its effectiveness in removing the smear layer is reported to be limited when applied alone.[21]

Regarding the assessment of dentin permeability, it was found that the CO group exhibited lower permeability in the cervical segment, while no differences were observed among the RB, US, and OS groups. It is well documented that the smear layer can reduce dentin permeability by up to 86%.[22] However, it alone cannot form a completely impenetrable barrier to products from materials applied over it. Instead, it reduces this diffusion by approximately 25%–30%.[22] It is presumed that isolated cleaning with 2.5%

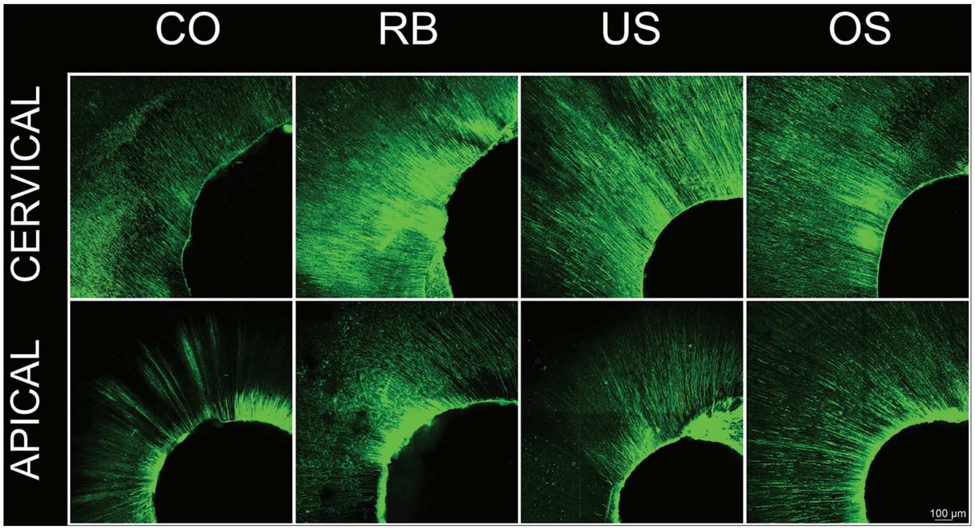

Figure 2: Representative images in laser confocal microscopy of dentin permeability stained with Rhodamine B after the different cleaning protocols in the cervical and apical segments of the post space. CO: Control, RB: Rotary brush, US: Ultrasonic tip, OS: Oscillatory system (×1024)

Table 2: Mean and standard deviation (µm) values of dentinal penetrability according to the cervical and apical segments of the post space

	CO	RB	US	OS
Cervical	230.25[a] (32.39)	361.03[b] (34.02)	377.48[b] (20.5)	402.87[b] (13.72)
Apical	233.02[a] (21.32)	364.09[b] (14.8)	370.78[b] (28.71)	414.17[c] (22.73)

[a,b,c]Different letters on the same line indicate significant differences in dentinal penetrability. ($P<0.05$). CO: Control, RB: Rotary brush, US: Ultrasonic tip, OS: Oscillatory system

NaOCl in the CO group generated residues on the smear layer, further reducing its permeability in this segment.

Mallmann *et al*.[23] mentioned the heterogeneity of intraradicular dentin along the canal's length, especially regarding the density and diameter of dentinal tubules, toward the apical direction. It is known that during post space preparation, the drills create a new smear layer rich in debris, including residual sealing materials – cement and gutta-percha, the latter being softened by the heat generated from the drill's friction.[24] In addition, the thickness and texture of the smear layer vary depending on the substrate type and cutting instrument used.[25]

The assessments of dentin permeability in the apical segment revealed that the OS achieved superior results. This leads the authors to speculate that the tip of the OS, during its working motion, may have generated a less dense smear layer, and thus, more permeable.

This *in vitro* assay has certain limitations that deserve consideration. First, it is important to acknowledge the need for future investigations comparing the studied protocols with other methods, particularly those involving irrigant agitation, as different approaches may influence the outcomes. Furthermore, an important aspect not addressed in this study, but deserving investigation, is evaluating the impact of these cleaning protocols on the bond strength of the fiber post cementation system, as this may have significant implications in dental clinical practice. Another relevant aspect is the measurement of smear layer density, which, although not assessed in this study, is essential to provide a more thorough and precise understanding of the results obtained.

CONCLUSIONS

The use of different mechanical cleaning protocols (RB, ultrasonic tip, and OS) associated with chemical irrigation using 2.5% NaOCl showed similar results in the removal of residues from the post space. However, the OS associated with NaOCl provides greater dentin permeability in the apical post space segment.

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Conflicts of interest

There are no conflicts of interest.

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