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Different biomechanical preparation protocols on the penetration and bond strength of the filling material to dentin

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The aim of this study was to evaluate the influence of different instruments and mechanisms of agitation of the irrigating solution on the penetration by confocal laser scanning microscopy (CLSM), and the bond strength (BS) of the filling material to the dentin by push-out test. Human premolars were distributed in two experimental groups (n=30), according to the instrumentation system: ProTaper Next (PN) or XP-endo Shaper (XS) and three irrigation protocol (n=10): NaviTip (Nv), XP-endo Finisher (XF), passive ultrasonic irrigation/ XP-endo Finisher (PUIXF). The 2.5% NaOCl and 17% EDTA were the irrigating solutions used. The filling was performed using a lateral condensation technique, with AH Plus added to 0.1% rodhamine B. The roots were sectioned, obtaining 2 slices for each third of the root. The first slice was submitted to the sealer penetration analysis and the push-out test. The second slice was submitted to qualitative analysis (SEM) of the union interface. For the penetration (%) Tukey showed that PNXF (82.38±13.48), PNPUIXF (82.48± 12.02), XSXF (82.24±11.28) and XSPUIXP (86.23±10.45) presented the highest values, different ($p<0.05$) from PNNv (68.29±15.12) and XSNv (71.41±16.50). The BS (MPa) test evidenced that in the cervical third, PNPF (4.92±1.04) and XPSPF (5.03±0.70) obtained the highest values differing from the others groups ($p<0.05$). CSLM and SEM showed greater penetration of the sealer on the entire length of the root canal when the irrigation solution was stirred. In conclusion that the association PUI and XP-endo Finisher favored the penetration and bond strength of the filling material to the root dentin.

Key Words: Endodontics, bond strength, penetration, irrigation solution

Introduction

The internal morphology of the root canal system can hinder the action of the endodontic instruments on the canal walls (1). The root canal system can have different cross sections (circular, oval, long or flattened), according to its buccolingual and mesiodistal dimensions. In flattened root canals, the action of the instruments on the wall causes a rounded shape, revealing untouched areas, mainly in the buccolingual direction, which favors the fixedness of the smear layer (2, 3).

Biomechanical preparation in root canals with distal mesial flattening are not efficient in the total removal of the smear layer and debris due to the difficulty of the instruments and irrigation solutions to reach this region of the root canals system (1, 4). Thus, different irrigation protocols during biomechanical preparation in flattened root canals (5) have been recommended in order to favor the removal of the smear layer (6) as well as the penetration and bond strength of the filling material to dentin (7, 13).

In order to optimize the cleaning of the root canal system, several agitation protocols of the solution have been recommended during biomechanical preparation, such as: passive ultrasonic irrigation, sonic irrigation, complementary rotating instruments, such as XP-endo Finisher and EndoActivation, as well as the association of these protocols (8-11).

The irrigation energized with ultrasound, commonly called passive ultrasonic irrigation (PUI), allows the renewal of the irrigating solution through micro flow during biomechanical preparation, which favors the removal of debris kept in suspension inside the root canal (8, 12, 13). On the other hand, there might occur a wear of the root dentin due to touching of the insert on the canal wall or, otherwise, due to the ultrasonic waves produced by the agitation of the solution inside the root canal

(13). In addition, passive ultrasonic irrigation has not shown effectiveness in fully removing the smear and debri layer on the apical third of flattened teeth (5).

The XP-endo Finisher instrument (Martensite-Austenite Electropolish-FleX, FKG) was developed with the purpose of touching the walls and favoring the cleaning of the root canal (13) without dentin wear. This special NiTi Max Wire alloy instrument is made in the marten site phase of the metallic alloy, taking on a straight shape below 30° C and, when activated and heated, it assumes the austenite phase, taking the semi-circle shape in the last 10 mm of its active tip (13), favoring the swirling of the irrigating solution inside the root canal and, consequently, providing efficient cleaning in the middle and apical thirds, leaving the remaining smear layer and debris in the cervical third (5).

Foreseeing the need to remove debris from inside the root canal, during and after biomechanical preparation, Alakshar et al. (11) evaluated the association of rotary instruments developed to agitate irrigating solutions: XP-endo Finisher and EndoActivation. However these combined instruments did not promote greater removal of the smear layer when compared to the XP-endo Finisher instrument alone. In an in vitro study by Leoni et al. (5) it was reported that passive ultrasonic irrigation was not effective to clean the apical third, while the XP-endo Finisher instrument provided a lower percentage of smear layer and debris in the middle and apical thirds.

Thus, taking into account that biomechanical preparation is a primordial factor for effective cleaning and modeling of the root canal system, and that both agitation of irrigation solutions with the XP-endo Finisher and passive ultrasonic irrigation system do not promote complete removal of the smear layer and debris in the cervical and apical third respectively, the purpose of this study was to evaluate the influence of different instruments and the associated mechanisms of agitation of the irrigating solution, passive ultrasonic irrigation and XP-endo Finisher, on the penetration and bond strength of the filling material on the root dentin.

Material and Methods

This study was submitted to and approved by the Research Ethics Committee (CAAE: 80318417.9.0000.5498).

Uniradicular human mandibular premolars have been scanned to standardize the samples regarding internal anatomy using SkyScan 1176 microtomograph (Bruker-microCT, Kontich, Belgium) with 18 µm, 70 KV and 278 µA resolution. The inclusion criteria were: root canals with buccolingual and mesiodistal (equal ratio) dimensions between 1-2 (flattened root canals), absence of calcifications, pulp nodules and internal resorption. The exclusion criteria were: root fracture, previous endodontic treatment and the presence of dentinal defects in the external and internal root morphology. The selected 60 teeth had their roots sectioned in order to standardize their length by 15 mm.

Root canal preparation

The root apex of all roots has been sealed with hot glue (Hot Melt, Rhamos and Brito, São Paulo, SP, Brazil) to avoid leakage of the irrigating solution, and the working length has been established at 1mm from the apical foramen.

The roots have been distributed in two experimental groups (n=30), according to the instrumentation system: ProTaper Next (PN) or XP-endo Shaper (XS) and three irrigation protocol (n=10): NaviTip (Nv), XP-endo Finisher (XF), passive ultrasonic irrigation/ XP-endo Finisher (PUIXF).

For all groups, an acrylic device has been used with a hole for fixing the roots, positioned 1 mm below the mouth of the root canal. Once roots have been fixed, the complete assembly was submerged in a stainless steel container (36 X 27 X 6 cm) filled with water at 37°C and controlled with a thermocouple (Vigoar, GPD LTDA, Hong Kong, China).

ProTaper Next

The biomechanical preparation was carried out with the ProTaper Next system (PTN; Dentsply-Sirona, Ballaigues, Switzerland) with X1, X2, X3 instruments, driven by the 6:1 Sirona reducing angle (SN 25185; VDW GmbH, Munich, Germany), which is coupled to a SMR 114058 micro motor (VDW GmbH, Munich, Germany) and a VDW Silver electric motor (VDW GmbH, Munich, Germany) with 300 rpm and 2 Ncm torque. At each instrument change, the root canal was irrigated with 2.33 mL 2.5% NaOCl. A white NaviTip needle (Ultradent Products Inc., Indaiatuba, SP, Brazil) was used, adapted to a disposable plastic syringe (Ultradent Products Inc., Indaiatuba, SP, Brazil) and aspirated with a cannula. The instruments were used with insertion and removal movement of the root canal, performed with amplitude of approximately 3 mm and light pressure against the walls. The final irrigation was carried out with 2 mL of 17% EDTA for 5 min. The root canals were irrigated with 2 mL 2.5% NaOCl and dried with absorbent paper cones # 30 after aspiration (Dentsply, Petrópolis, Rio de Janeiro, Brazil).

XP-endo Shaper

The biomechanical preparation was performed with XP-endo Shaper (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland). The root canal has been flooded with 2 mL 2.5% NaOCl by a NaviTip needle, adapted to a disposable plastic syringe. Afterwards, the root canal was instrumented with XP-endo Shaper (800 rpm and torque of 1 Ncm), driven by the VDW electric motor. This instrument has been introduced into the canal and slightly moved back to activate the rotation, progressing slowly to the working length with smooth insertion/ removal movements. For the root canal shapping, 5 additional insertion/ removal movements have been performed with the instrument, leading to the achievement of the final apical enlargement of 30.04. With each movement, the root canal was irrigated with 1mL of 2.5% NaOCl. The final irrigation was carried out with 2 mL of 17% EDTA for 5 min, using a syringe and a NaviTip needle. The root canals were irrigated with 2 mL 2.5% NaOCl and, after aspiration, dried with # 30 absorbent paper cones.

Irrigation protocols

NaviTip irrigation

Root canals have been irrigated with the aid of a white NaviTip needle for the experimental groups in which conventional irrigation was performed. The used needle was adapted to a disposable plastic syringe and inserted at 1 mm from the working length through longitudinal movements with amplitude of 3 mm of insertion/ removal during 60s. This protocol was repeated with each instrument change in the ProTaper Next system or each insertion/ removal of the XP-endo Shaper instrument.

XP-endo Finisher

The XP-endo Finisher instrument (FKG Dentaire SA, La Chaux-de-Fonds, Switzerland), while still inside its plastic tube, was connected to the Sirona 6:1 contra-angle reducer and cooled with butane-based refrigerant spray (Endo Ice Spray Maquira, Maringá, PR, Brazil) for 5 s. Afterwards, it was removed from the rotating tube (800 rpm and torque of 1 Ncm) and inserted without rotation into the root canal flooded with 2.5% NaOCl. The instrument was activated (800 rpm and torque of 1 Ncm) for 60s with longitudinal insertion/ removal movements with amplitude between 7 and 8 mm, against the side walls up to the working length, followed by irrigation with 2 mL of NaOCl 2,5%.

Passive ultrasonic irrigation/ XP-endo Finisher

For this groups in which passive ultrasonic irrigation (PUI) was associated with irrigation by XP-endo Finisher, the root canal has been flooded with 2.5% NaOCl. Afterwards, irrigation solution was agitated for 20s with a non-cutting insert (# 20, taper 0.01) 18 mm stainless steel (E1-Irrisonic, Helse Dental Technology, Santa Rosa de Viterbo, SP, Brazil), powered by a piezoelectric ultrasonic unit (P100, EMS - Electro Medical System, Switzerland) with a power of 10%, at 1 mm from the working length, in longitudinal insertion/ removal movements with an amplitude of 3 mm. The irrigation solution has been aspirated and the root canal flooded again. Stirring was performed with XP-endo Finisher, as described in the previous experimental group. This protocol has been repeated for each instrument change in the ProTaper Next system or insertion/ removal of the XP-endo Shaper instrument.

Obturation technique

The sealer has been handled according to the manufacturer recommendation, added with the 0.1% rodhamine, and taken into the root canal by a # 25 lentulo drill. The main cone of gutta-percha 30.04 (Dentsply-Sirona, Petrópolis, RJ, Brazil) has been inserted up to the working length. In addition, a digital spacer #25 (Dentsply-Sirona, Ballaigues, Switzerland), has been inserted adjacent to the main cone, opening space for insertion of accessory F cones (Dentsply-Sirona, Petrópolis, RJ, Brazil) of gutta-percha. The gutta-percha cones have been cut at the mouth of the root canal and compacted with a heated no. 3 Paiva condenser (Duflex, S. S. White dental articles Ltd., Rio de Janeiro, RJ, Brazil).

After three times of the setting time (480 min) of the AH Plus, the specimens were fixed on acrylic plates using hot glue (Hot Melt, Rhamos e Brito; São Paulo, SP, Brazil) and transversally sectioned in 2mm slices by a cutting machine (Isomet 1000; Buehler; Hong Kong, China) at 325 rpm under refrigeration.

Confocal Laser Scanning Microscopy (CLSM)

The first slice of each third of a sample has been analyzed in a Leica SEM inverted confocal microscope (Leica; Mannheim, Germany) in the epifluorescence mode. The images of the filled areas have been acquired at absorption wavelengths and rodhamine B emission wavelengths of 540 nm and 590 nm, respectively. The samples have been analyzed 10 µm below the surface at a 500× magnification. Images have been acquired using Leica Application Suite-Advanced Fluorescence software (Leica) and imported into Image Tool version 3 (University of Texas Health Sciences Center, San Antonio, TX, USA) to calculate the circumference of the root canal wall. The root dentin, where sealer penetration occurred, has been circumvented and measured to determine the percentage of sealer penetration, calculated by simple proportion.

Bond strength

The same slices used in the analysis by CLSM were subjected to the push-out test in a universal testing machine (Instron 3345; Instron Corporation; Canton, MA, USA) at a crosshead speed of 0.5 mm min^{-1}. A stainless steel support was used to hold the specimens in such a way that the side with the smaller diameter of the root canal faced upwards and was aligned to the shaft that would exert pressure on the sealer (apical-coronally). Four-millimetre-long points with tip diameter of 1.0, 0.6 and 0.4 mm for the coronal, middle and apical third, respectively, were used. However, in order to be used without touching the dentin, the filling mass of each specimen was measured using a caliper (Digimess, Shiko, China) in the buccal and distal mesial directions. From these measurements, the tip was selected for each third of the root.

This method assured the alignment of the specimen in an accurate and reproducible manner and also maintained the shaft in a centralized position and avoided its contact with dentin during testing, when the material was pushed and dislodged from the canal wall. The force needed to dislodge the filling material (F; in kN) was transformed into tension (T; in MPa) by dividing the force by the adhesive area of the filling material (SL; in mm^2), using the equation: $T = F/SL$. SL was calculated using the equation: $SL = P (R + r) g$, where SL = sealer bonding area; P = 3.14; R = mean radius of the coronal canal, in mm; r = mean radius of the apical canal, in mm; and g = height relative to the tapered inverted cone, in mm.

Failure type analysis

After the push-out test, the samples were analyzed under a stereoscopic magnifying glass (Leica Microsystem LTD; Wetzlar, Germany) with 40× magnification and classified according to the type of failure as follows: adhesive (root canal walls were completely free from the filling material), cohesive (root canal walls were completely covered by the filling material) and mixed (root canal walls were partially covered by the filling material).

Scanning Electron Microscopy (SEM)

The second slice of each third has been used in the analysis of the dentin/ filling material interface by a scanning electron microscopy JSM 5410 (JEOL Ltd, Tokyo, Japan). The samples have been prepared by the following protocol: polishing with water paper of decreasing granulation (400, 600 and 1200), dehydration in increasing degree of ethanol 25%, 50%, 75%, 95% (for 20 min immersion in each solution) and 100% for 1 h, washing in an ultrasonic well with distilled water for 20 min., demineralization with HCl 6 mol/ L for 2 min, deproteinization in 2.5% NaOCl for 10 min and washing in an ultrasonic well with distilled water for 10 min. After 24 hours, metallization was performed in a vacuum chamber with a gold layer of approximately 300 Å (Bal-Tec SCD 005, Bal-tec Co., USA). The specimens have been analyzed in a panoramic view (15×) to locate the representative areas and then in 500× magnifications.

Statistical analysis

Percentage data concerning the penetration (%) of AH Plus around the root canal wall and the bond strength (MPa) have been subjected to preliminary statistical tests to verify the normality of the sample distribution. The Kolmogorov-Smirnov test showed that the results of penetration and bond strength have been consistent with a normal distribution curve. The parametric statistical analysis has been performed (two-way analysis of variance [ANOVA] and post hoc Tukey-Kramer test), and the significance level has been set at 5% (GraphPad InStat; GraphPad Software Inc, San Diego, CA).

Results

Confocal Laser Scanning Microscopy (CLSM) - qualitative analysis

In general, the qualitative analysis of the histotomographs (Figure 1) evidenced the presence of AH Plus tags (in red) inside the dentinal tubules. Regions were observed around the root canal with sealer penetration when conventional irrigation was used; however, some other regions did not present this characteristic. In contrast, when irrigation solution agitation protocols were used, it was observed, in general, that sealer penetration occurred in all extension of the root canal wall, including in the polar regions.

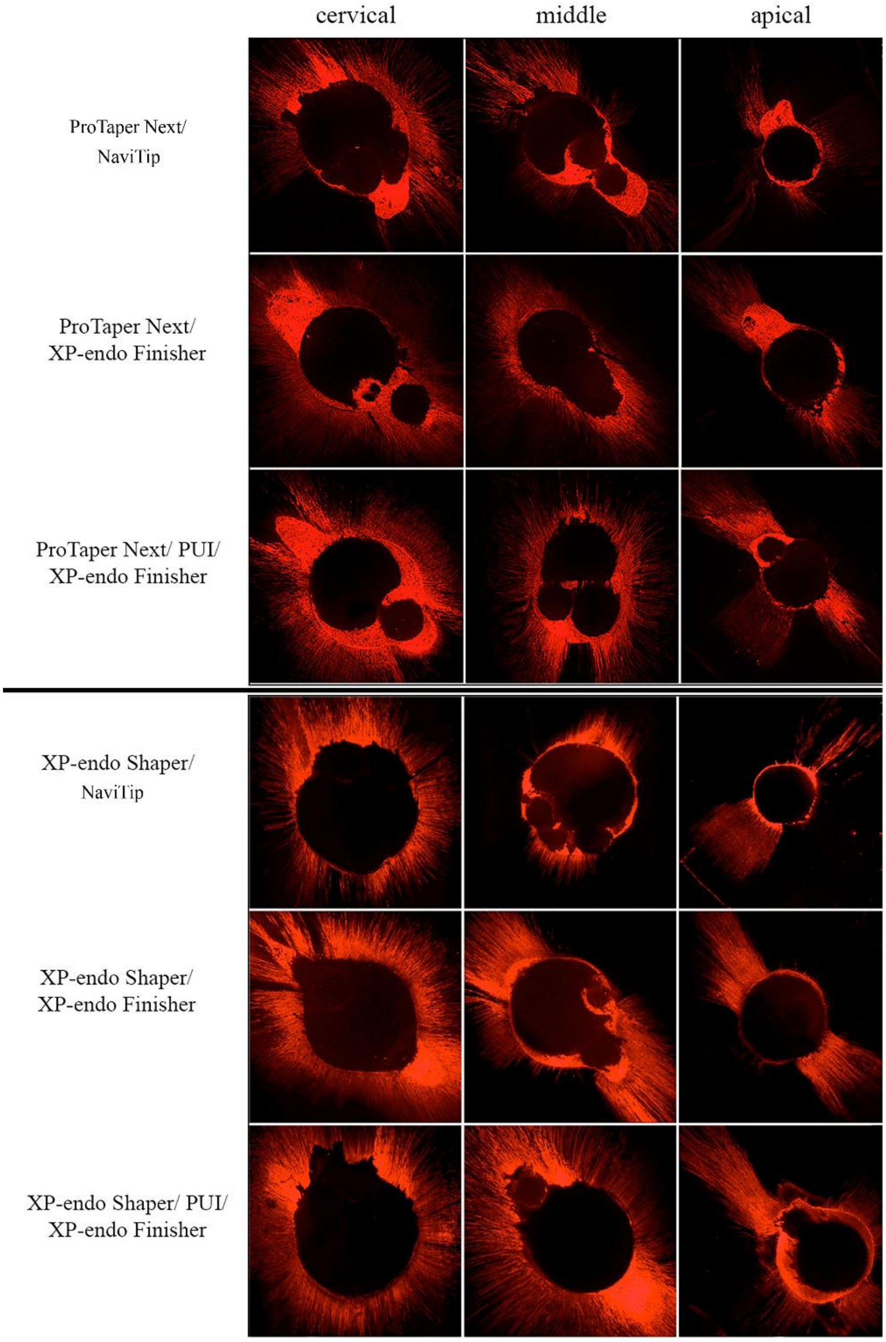

Figure 1. Histotomographs representative of sealer penetration (in red), in root thirds on the different experimental groups. ProTaper Next/ NaviTip: areas without sealer penetration were observed in the root thirds. ProTaper Next/ XP-endo Finisher: in the cervical and middle thirds, penetration was observed along the entire length of the wall and in the apical third, in the polar areas. ProTaper Next/ PUI/ XP-endo Finisher: in the cervical and middle thirds there was penetration along the entire length of the wall and in the apical third few areas without penetration. XP-endo Shaper/ NaviTip: in the cervical and middle thirds some regions without penetration were observed and in the apical third penetration in the polar areas were observed. XP-endo Shaper/ XP-endo Finisher in the cervical and middle thirds penetration occurred with greater intensity and in the apical third it occurred in the polar regions with greater intensity. XP-endo Shaper/ PUI/ XP-endo Finisher: penetration occurred with greater intensity in the entire length of the wall in the root thirds.

Confocal Laser Scanning Microscopy (CLSM) - quantitative analysis

Tukey's test (Table 1) for the penetration percentage (%) has shown that PNF, PNPF, XPSF and XPSPF provided the highest penetration percentage values, which were statistically similar to each other (p>0.05). In contrast, such values were different (p<0.05) from the ones obtained from PNNv and XPSNv, which were statistically similar to each other (p>0.05). The cervical third (90.15 ± 12.62) had presented the highest mean penetration values (%), being statistically different (p<0.05) from the others. The middle third (78.43 ± 10.01) had presented intermediate values, which were different (p<0.05) than the apical third (67.93 ± 11.50).

Table 1. Tukey test for percentage (%) penetration of AH Plus into the dentinal tubules after the different biomechanical preparation protocols.

Experimental groups	Mean ± S.D.
ProTaper Next/ NaviTip	68.29 ± 15.12 b
ProTaper Next/ Finisher	82.38 ± 13.48 a
ProTaper Next/ PUI/ Finisher	82.48 ± 12.02 a
XP-endo Shaper/ NaviTip	71.41 ± 16.50 b
XP-endo Shaper/ Finisher	82.24 ± 11.28 a
XP-endo Shaper/ PUI/ Finisher	86.23 ± 10.45 a

* Different letters indicate statistically significant difference (p<0,05). Critical value: 10.28

Push-Out Test

Tukey (Table 2) shows that in the cervical third, the XPSPF and PNPF achieved the highest values, being similar to each other (p>0.05), but different from the other interactions (p<0.05). In the middle third, PNPF, XPSNv and XPSPF showed the highest mean values, which were similar to each other (p>0.05), but different from the other interactions (p<0.05). In the apical third, PNPF and XPSPF provided the highest values of bond strength, similar to each other (p>0.05), but different from the other interactions (p<0.05).

Table 2. Tukey test for union resistance (MPa) of the filling material to dentin after different irrigation protocols. Interaction between factors.

Experimental groups	Root thirds		
	Cervical	Middle	Apical
ProTaper Next/ NaviTip	2.50 ± 0.81 c	1.91 ± 0.78 d	1.63 ± 0.24 d
ProTaper Next/ Finisher	2.77 ± 1.07 c	2.72 ± 0.61 c	1.86 ± 0.16 d
ProTaper Next/ PUI/ Finisher	4.92 ± 1.04 a	3.86 ± 1.18 b	3.41 ± 0.97 b
XP-endo Shaper/ NaviTip	3.23 ± 0.71 b	3.24 ± 1.36 b	1.68 ± 0.46 d
XP-endo Shaper/ Finisher	2.72 ± 0.33 c	2.66 ± 0.55 c	2.57 ± 0.36 c
XP-endo Shaper/ PUI/ Finisher	5,03 ± 0,70 a	3,52 ± 0,77 b	3,45 ± 0,48 b

* Different letters indicate statistically significant difference (p<0,05).

Failure type analysis

The analysis of the type of failure that occurred after the push-out test (Figure 2) demonstrated a predominance of cohesive type failures in the cervical third for all experimental groups. In the XPSPF group, there was a predominance of faults of the cohesive and mixed types; in the middle third there was a predominance of faults of the mixed type. In the apical third for PNNv, PNPF, XPSNv, XPSF and XPSPF, mixed and cohesive failures were observed, differently from what occurred in PNF that presented a predominance of mixed failures.

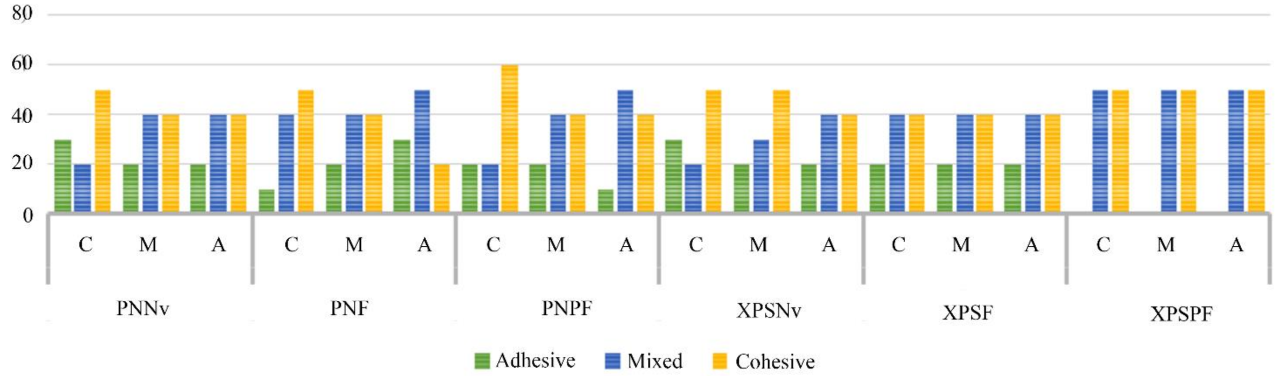

Figure 2. Failure types after push-out test, in each third, in the different experimental groups (percentage values). XPSPF group: there was a predominance of failure of the cohesive and mixed types; in the middle third there was a predominance of failure of the mixed type. In the apical third for PNNv, PNPF, XPSNv, XPSF and XPSPF, mixed and cohesive failures were observed. * C= cervical third; M= middle third; A= apical third.

Scanning Electron Microscopy (SEM)

In general, SEM analysis (Figure 3) showed the presence of tags in all experimental groups. In the cervical and apical thirds of the groups in which the PUI and XP-endo Finisher protocols have been performed, the presence of a larger amount of bulky tags have been observed, while short and sparse tags were observed for groups that used conventional irrigation. In the middle third, XPSNv and XPSF had fewer and shorter tags. In contrast, long, denser and larger tags were observed in XPSPF in the middle third.

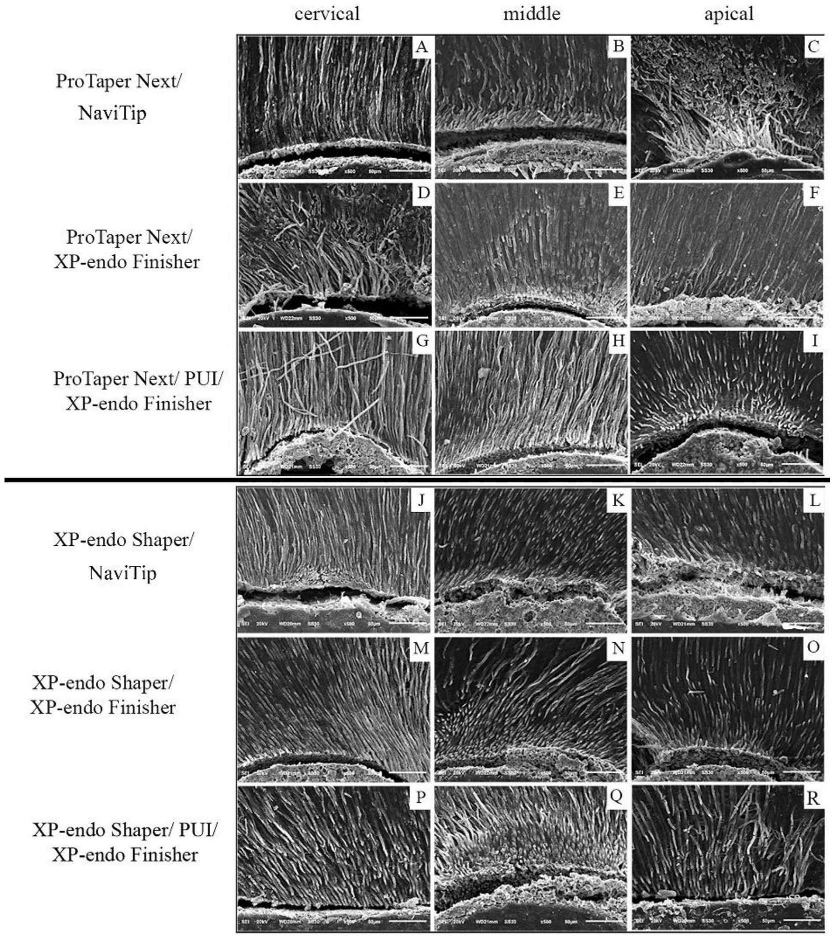

Figure 3. Electromicrographs representing the root thirds of the different protocols of biomechanical preparation. ProTaper Next/ NaviTip, in the cervical third, long, thin, numerous tags were observed, and in the middle and apical thirds, short and sparse tags were noted. ProTaper Next/ XP-endo Finisher, in the cervical third, numerous, long and thin tags were observed, while in the middle and apical thirds, longer, voluminous and in greater numbers were observed. ProTaper Next/ PUI/ XP-endo Finisher, in the cervical third were verified longer tags, more voluminous and in greater quantity, and in the apical third it was noticed long, thin tags and also in greater quantity.

Discussion

The qualitative analysis of histotomographs, obtained by CSLM, showed penetration of the sealer inside the dentinal tubules regardless the recommended biomechanical preparation protocol. This fact can be explained by the above-mentioned physical-chemical properties of the AH Plus. Another reason is the lateral condensation technique, which generates a combination of forces in the lateral and apical direction during the filling of the root canal. This occurs due to the application of gutta-percha cones and spacers, which provide greater interaction between sealer and dentin (14, 15).

At this point, it is worth noting that the analysis of sealer penetration inside the dentinal tubules, by means of confocal laser scanning microscopy, is only possible due to the addition of a fluorescent. In the present study, the AH Plus sealer was manipulated with the addition of 0.1% of the fluorescent rhodamine B, which according to Marciano et al. (16) does not interfere with the physicochemical properties of sealer. Furthermore, it allows a panoramic view of sealer penetration around the root canal wall, without the need for metallization of the specimens, which allowed the reuse of the same specimens in another analysis as performed in this study.

The ProTaper Next system followed by NaviTip irrigation promoted in the present study low penetration values and bond strength of AH Plus to the dentin. Elnaghy (17) speculated that the decentralization of the mass of the ProTaper Next system might reduce the contact area between the instrument and the root canal wall. In the present study, the decentralization of the mass resulted in a lower percentage of sealer penetration into the dentinal tubules when this system was associated with conventional irrigation, as evidenced in the qualitative and quantitative analyses carried out by CSLM and SEM. Similar phenomenon has been observed for XPSNv, which resulted in penetration values similar to the PNNv group. However, for bond strength, the XPSNv obtained higher values than the PNNv group.

A possible reason could be that the XP-endo Shaper instrument has been more effective in cleaning the root canal due to its cross-section with six cutting edges and core, contraction and expansion capacity promoted by its special NiTi Max Wire alloy. Furthermore, when in contact with body temperature, the internal walls of the root canal are adapted, favoring the preparation of the root canal, and thus, creating space for the hydraulic movement and swirling of the solution inside the root canal (6). It suggests that its distorted shape has been developed based on the characteristics of the hydraulic movement of the irrigating solution inside the root canal, promoted by PUI.

When compared to NaviTip irrigation, energized agitation of the irrigating solutions provided the highest values of penetration and bond strength of AH Plus to root dentin. In addition, according to Mozo et al. (8), the agitation of the irrigating solutions carried out by the ultrasound promotes reduction of the smear layer and debri inside the root canal. The swirling of solutions and a concomitant increase and reduction in hydrostatic pressure, promoted by ultrasonic agitation, is based on the transmission of acoustic energy from an insert to an irrigating solution in the root canal by ultrasonic waves. These waves promote formation of cavitation bubbles that implode and produce an increase in the temperature of the solutions (12, 18), enhancing the cleaning of the root canal wall (12, 21). Nevertheless, agitation of the solutions by passive ultrasonic irrigation (5, 12) or XP-endo Finisher instrument (5) does not completely remove the smear layer and debri inside the flattened root canals. Moreover, agitation promoted by each activation protocol generates greater effectiveness in different regions along the root canal, as observed by Pacheco-Yanes et al (19). Thus, in the present study, the association of two irrigation solution agitation protocols would provide greater efficiency in removing the smear layer and debri, in which one protocol would be complementary to the other, each acting differently along the root canal.

In the present study, association of passive ultrasonic irrigation and XP-endo Finisher promoted the highest percentage values of sealer penetration inside the dentinal tubules. This can be observed in histotomographs and electromicrographs, as well as in greater bond strength to root dentin, especially in the cervical thirds and apical. This fact can be explained by the action of the XP-endo Finisher, which reaches amplitude of 3 mm in the last 10 mm due to its flexibility, when activated in a rotary movement at 800 rpm. Furthermore, it reaches up to 6 mm when compressed, enhancing the agitation of the solution and dirt removal from the inner channel (20). In addition, the association provided an increase in volume, time of action and renewal of the irrigating solution within the root canal system, increasing the dissolution capacity and entrainment of organic tissue (21). In this way, it is speculated that this association may have enhanced the remaining deformation of the smear layer and debris left by XP-endo Finisher in the cervical third and by passive ultrasonic irrigation in the apical third, as observed by Leoni et al. (5), differing from the association between XP-endo Finisher/ EndoActivation proposed by Alakshar et al. (11). In the present study, it was demonstrated greater chemical and mechanical interaction of AH Plus with dentin, and consequently, greater bond strength when compared to other protocols. This can also be evidenced by the type of failures occurred after the push-out test, in the groups in which the association of the XP-endo finisher and PUI instrument was recommended, there was a predominance of cohesive failures.

The difference in penetration and bond strength between the root thirds found in the present study can also be justified by the decreasing quantity and diameter of the dentinal tubules in the cervical, middle and apical thirds, respectively (22). It reinforces the need and importance of the association of energized agitation protocols of the irrigating solutions to enhance the interaction of the filling material with the root dentin.

Resumo

O objetivo neste estudo foi avaliar a influência de diferentes instrumentos e mecanismos de agitação da solução irrigadora na penetração e resistência de união (RU) do AH Plus à dentina. Pré molares humanos foram distribuídos em dois grupos experimentais (n=30), de acordo com o sistema de instrumentação: ProTaper Next (PN) ou XP-endo Shaper (XS) e de acordo com três protocolos de irrigação (n=10): NaviTip (Nv), XP-endo Finisher (XF), passive ultrasonic irrigation/ XP-endo Finisher (PUIXF). A irrigação do canal radicular foi realizada com NaOCl 2,5% e EDTA 17%. A obturação foi realizada por meio da técnica da condensação lateral, com AH Plus acrescido de rodhamina B 0,1%. As raízes foram seccionadas, obtendo-se 2 *slices* de 2,0 mm para cada terço radicular. O primeiro *slice* foi submetido a análise da penetração do cimento e ao teste de push-out e o segundo *slice* submetido a MEV para análise da interface de união. Para penetração (%) Tukey evidenciou que PNXF (82,38±13,48), PNPUIXF (82,48±12,02), XSXF (82,24±11,28) e XSPUIXF (86,23±10,45) apresentaram os maiores valores, diferentes ($p<0,05$) de PNC (68,29±15,12) e XPSC (71,41±16,50). Na RU (MPa) foi evidenciado que PNPF (4,92±1,04) e XPSPF (5,03±0,70), no terço cervical, obtiveram os maiores valores diferentes dos demais ($p<0,05$). MCVL e MEV evidenciaram maior penetração do cimento em toda extensão da parede do canal radicular inclusive nas regiões polares, quando foi realizada a agitação da solução irrigadora. Concluiu-se que a associação PUI e XP-endo Finisher favoreceu a penetração e resistência de união do material obturador à dentina radicular.

References

1. Lacerda MFLS, Marceliano-Alves MF, Pérez AR, Provenzano JC, Neves MAS, Pires FR, et al. Cleaning and Shaping Oval Canals with 3 Instrumentation Systems: A Correlative Micro-computed Tomographic and Histologic Study. J Endod 2017;43:1878-1884.

2. Ribeiro EM, Silva-Sousa YTC, Souza-Gabriel AE, Sousa-Neto MD, Lorencetti KT, Silva SRC. Debris and smear removal in flattened root canals after use of different irrigant agitation protocols. Microsc Res Tech 2012;75:781-790.

3. De-Deus G, Belladonna FG, Zuolo AS, Perez R, Carvalho MS, Souza EM, et al. Micro-CT comparison of XP-endo Finisher and passive ultrasonic irrigation as final irrigation protocols on the removal of accumulated hard-tissue debris from oval shaped-canals. Clin Oral Invest 2019; 23:3087-3093.

4. Plotino G, Ahmed HM, Grande NM, Cohen S, Bukiet F. Current Assessment of Reciprocation in Endodontic Preparation: A Comprehensive Review--Part II: Properties and Effectiveness. J Endod 2015;41:1939-50.

5. Leoni GB, Versiani MA, Silva-Sousa YT, Bruniera JFB, Pecora JD, Sousa-Neto MD. Ex vivo evaluation of four final irrigation protocols on the removal of hard-tissue debris from the mesial root canal system of mandibular first molars. Int Endod J 2017;50:398-406.

6. Azim AA, Piasecki L, Silva-Neto UX, Cruz ATG, Azim KA. XP Shaper, A novel adaptive core rotary instrument: Micro-computed tomographic analysis of its shaping abilities. Int Endod J 2017;43:1532-1538.

7. Yilmaz A, Turgut YY, Helvacioglu-Yigit, D. Effectiveness of Various Final Irrigation Techniques on Sealer Penetration in Curved Roots: A Confocal Laser Scanning Microscopy Study. Biomed Res Int 2020;13:1-7.

8. Mozo S, Llena C, Forner L. Review of ultrasonic irrigation in endodontics: increasing action of irrigating solutions. Med Oral Patol Oral Cir Bucal 2012;17:512-516.

9. Bao P, Shen Y, Lin J, Haapasalo M. In vitro efficacy of XP-endo finisher with 2 different protocols on biofilm removal from apical root canals. J Endod 2017;43:321-325.

10. Siqueira Junior JF, Perez AR, Marcelino-Alves MF, Provenzano JC, Silva SG, Pires FR, et al. What happens to unprepared root canal walls: a correlative analysis using micro-computed tomography and histology/scanning electron microscopy. Int Endod J 2018;51:501-508.

11. Alakshar A, Saleh ARM, Gorduysus MO. Debris and Smear Layer Removal from Oval Root Canals Comparing XP-Endo Finisher, EndoActivator, and Manual Irrigation: A SEM Evaluation. Eur J Dent. 2020;14:626-633.

12. Van Der Sluis LWM, Versluis M, Wu MK, Wesselink PR. Passive ultrasonic irrigation of the root canal: a review of the literature. Int Endod J 2007;40:415-426.

13. Trope, M.; Debelian, G. XP-3D Finisher file-the next step in restorative endodontics. Endod Pract 2015;8:22-24.

14. Hatton JF, Ferrillo PJ, Wagner G, Stewart P. The effect of condensation pressure on the apical seal. J Endod 1988;14:305-308.

15. Macedo LMD, Silva-Sousa Y, Silva SRC, Baratto SSP, Baratto-Filho F, Rached-Júnior FJA. Influence of root canal filling techniques on sealer penetration and bond strength to dentin. Braz Dent J 2017;28:380-384.

16. Marciano MA, Guimarães BM, Ordinola-Zapata R, Bramante CM, Cavenago BC, Garcia RB, Bernardineli N, et al. Physical properties and interfacial adaptation of three epoxy resin-based sealers. J Endod 2011;37:1417-21.

17. Elnaghy A, Elsaka S. Assessment of the Mechanical Properties of ProTaper Next Nickel-Titanium Rotary Files. J Endod 2014;40:1830-1834.

18. Van Der Sluis LW, Wu MK, Wesselink PR. A comparison between a smooth wire and a K-file in removing artificially placed dentine debris from root canals in resin blocks during ultrasonic irrigation. Int. Endod. J 2005;38:593-596.

19. Pacheco-Yanes J, Provenzano JC, Marceliano-Alves MF, Gazzaneo I, Pérez AR, Gonçalves LS, Siqueira Junior JF. Distribution of sodium hypochlorite throughout the mesial root canal system of mandibular molars after adjunctive irrigant activation procedures: a micro-computed tomographic study. Clin Oral Invest 2020;24:907–914.

20. Vaz-Garcia ES, Vieira VTL, Petitet NPDSF, Moreira EJL, Lopes HP, Elias CN, et al. Mechanical Properties of Anatomic Finishing Files: XP-Endo Finisher and XP-Clean. Braz Dent J 2018;29:208-213.

21. Stojicic S, Zivkovic S, Qian W, Zhang H, Haapasalo M. Tissue dissolution by sodium hypochlorite: effect of concentration, temperature, agitation, and surfactant. J Endod 2010;36:1558-1562.

22. Tao L, Pashley DH. Shear bond strengths to dentin: effects of surface treatments, depth and position. Dent Mater 1988;4:371-378.

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