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Original Article

Residual smear layer after root canal instrumentation by using Niti, M-Wire and CM-Wire instruments: A scanning electron microscopy analysis

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ABSTRACT

Objective: The purpose of this study was to compare the amount of residual smear layer after root canal instrumentation by using Ni-Ti, M-Wire, and CM-Wire instruments. **Materials and Methods:** Seventy-two mandibular incisors were randomly divided into six groups according to the system used: WaveOne (WO), Reciproc (RP), Unicone (UC), ProTaper Next (PN), Mtwo (MT), and HyFlex (HF). Afterward, the specimens were cleaved in the mesiodistal and buccolingual direction for analysis by scanning electron microscopy. **Results:** Considering both directions and root canal thirds, there was no difference between HF, MT, and PN. RP, UC, and WO presented a significant difference between the directions, and the cervical third showed a significantly smaller quantity of residual smear layer compared with the apical third. When the systems were compared among them, there was a significant difference only between RP and WO. **Conclusions:** Residual smear layer observed after instrumentation with the different systems was similar, except for quantities between the reciprocating systems.

Key words: Nickel-titanium, scanning electron microscopy, smear layer

INTRODUCTION

The thermomechanical treatment of nickel-titanium (NiTi) alloys, resulting in changes in the microstructure of instruments, has accentuated some of their properties such as flexibility and elasticity to an even greater extent. Within this class of instruments, those manufactured with

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M-Wire, and more recently, CM-Wire technology are outstanding.[1,2]

The instruments made of M-wire, are manufactured by transformation of the martensitic phase of the alloy into the austenitic phase, when they are submitted to a certain stress.[3] When this stress is removed, there is a spontaneous reversion of the alloy microstructure to the martensitic phase.[3] This process guarantees the greater flexibility of the instrument, and consequently, greater resistance to cyclic and torsional fatigue than that of the instruments made of conventional NiTi.[2,3] From then on, systems appeared, which use movements that differ from those of the conventional rotary type, such as the reciprocating type, and these are capable of performing root canal preparation with a reduced number of instruments.[4,5]

Whereas, instruments made of CM-Wire alloy are among the latest innovations. In this case, thermal treatment has led to the transformation of the austenitic phase of the alloy into an intermediate phase between this phase and the martensitic phase, denominated the R-phase. This treatment promotes a controlled memory effect on the alloy, allowing instruments to curve significantly under a determined stress, and recovering their original form when the stress is removed.[2,6]

These characteristics give the different instrumentation systems different cutting capacities, and therefore, distinct potentials in relation to smear layer production.[1,2,7-10] Nevertheless, in the same way that they are produced, instruments should be capable of mechanically removing a significant part of this smear layer because its removal is necessary before the use of intracanal medications or performing root canal filling, to ensure the success of endodontic treatment.[11]

Thus, the purpose of this study was use scanning electron microscopy analysis, to compare the amount of residual smear layer after root canal preparation with NiTi, M-Wire, and CM-wire instruments. The null hypothesis tested was that there would be no difference relative to the quantity of residual smear layer after the use of the different systems tested.

MATERIALS AND METHODS

Selection and preparation of teeth

To conduct this study, 72 mandibular incisors, without curvatures, resorptive processes, previous endodontic treatment, and anatomic complexities were selected The external root surfaces of the teeth were cleaned with ultrasound (Profi II Ceramic, Dabi Atlante Ltda., Ribeirão Preto, SP, Brazil). Then, the samples were stored in receptacles containing a 0.2% thymol solution, followed by washing in running water for disinfection for 24 h.

Afterward, the crowns of the teeth were sectioned close to the amelocemental junction, by using a double-faced disc (KG Sorensen, Barueri, SP, Brazil), to standardize the root segments to a length of 13 mm.

Biomechanical preparation

Root canal entrances were prepared with largo burs No. 2 (Dentsply/Maillefer, Ballaigues, Switzerland) and 3082 burs (KG Sorensen). The cervical and middle thirds were prepared with Gates Glidden drills No. 4, 3, and 2 (Dentsply/Maillefer), according to the crown-down technique. After this, the working lengths were determined by inserting a K-type #10 instrument (Dentsply/Maillefer) until it could be visualized at the apical foramen and subtracting 1 mm from this measurement. For performing instrumentation of the root canals, the teeth were randomly divided into 6 groups (n = 12) according to the different systems used [Table 1].

All the root canals were instrumented by the same operator, using an X-Smart Plus motor (Denstply/Maillefer), in accordance with the recommendations of the manufacturers of each system as regards the torque applied. The canals were irrigated with 2.5% sodium hypochlorite solution (Fórmula and Ação, São Paulo, SP, Brazil)

Table 1: Disposition of experimental groups according to systems used for root canal preparations

Group	System/alloy (manufacturer)	Instruments used for preparation
WO	WaveOne/M-Wire (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA)	21/0.06 (small) + 25/0.08 (primary) + 40/0.08 (large)
RP	Reciproc/M-Wire (VDW GmbH, Munich, Germany)	25/0.08 (R25) + 40/0.06 (R40)
UC	Unicone/NiTi - refined alloy (Medin, Lachovická, Czech Republic)	20/0.06 (yellow) + 25/0.06 (red) + 40/0.06 (black)
PN	ProTaper Next/M-Wire (Dentsply Tulsa Dental Specialties)	17/0.04 (X1) + 25/0.06 (X2) + 30/0.07 (X3) + 40/0.06 (X4)
MT	Mtwo/NiTi (VDW)	10/0.04 + 15/0.05 + 20/0.06 + 25/0.06 + 30/0.05 + 35/0.04 + 40/0.04
HF	HyFlex CM/CM-Wire (Coltène/Whaledent AG, Altstätten, Switzerland)	25/0.08 + 20/0.04 + 25/0.04 + 20/0.06 + 30/0.04 + 40/0.04

at every change of instrument, and on conclusion of instrumentation, totaling 20 mL of irrigant solution. Subsequently, 5 mL de 17% ethylenediaminetetraacetic acid (EDTA) (Maquira Dental Products, Maringá, PR, Brazil) was applied for 5 min inside the root canal to remove the smear layer, then abundant irrigation was performed with 0.9% saline solution. The root canals were irrigated using a 30G needle (Navitip, Ultradent Products Inc., South Jordan, UT, USA) calibrated to reach 2 mm short of the working length. In two teeth of each group, the EDTA was not used, with the aim of obtaining control specimens.

Analysis by scanning electron microscopy

In each group, 6 teeth were randomly selected to have longitudinal grooves made in the mesiodistal and buccolingual directions, using a flexible double-faced diamond disc (KG Sorensen). Final cleavage was performed with cutting pliers with the aim of exposing the root canal in both directions (mesiodistal and buccolingual). The hemisections were then fixed on circular metal stubs for sputter-coating the surface with a 30 nm thickness of gold (Quorum Q150R ES, Ashford Kent, UK). For each hemisection, images were captured at ×1000 magnification, corresponding to each root third, using a scanning electron microscope (SEM) (Tescan VEGA 3, Tescan, Brno, Czech Republic).

Three previously calibrated, blinded examiners (Kappa test - 96% agreement) classified the residual smear layer residual, according to the criteria of Torabinejad *et al*.:[12] (1) absence or small quantity of smear layer; (2) moderate presence of smear layer; and (3) dense smear layer covering practically all the dentinal tubule entrances.

Statistical analysis

The data were analyzed relative to normality using the Lilliefors test. Due to their nonparametric distribution, the Mann–Whitney and Kruskal–Wallis tests for the analysis of variance were used ($P < 0.05$). For multiple comparisons, the Student–Newman–Keuls test was used with a level of significance of 5%. Data were analyzed using Minitab 17.0 software (Minitab Inc., State College Philadelphia, PA, USA).

RESULTS

Representative SEM images of the cleaning capacity of the different systems tested may be visualized in Figures 1-3. Irrespective of the system used for preparing the canals, a significantly larger quantity of smear layer was observed in the buccolingual in comparison with the mesiodistal direction ($P < 0.05$) [Table 2]. Similarly, when comparing the root canal thirds, the quantity of smear

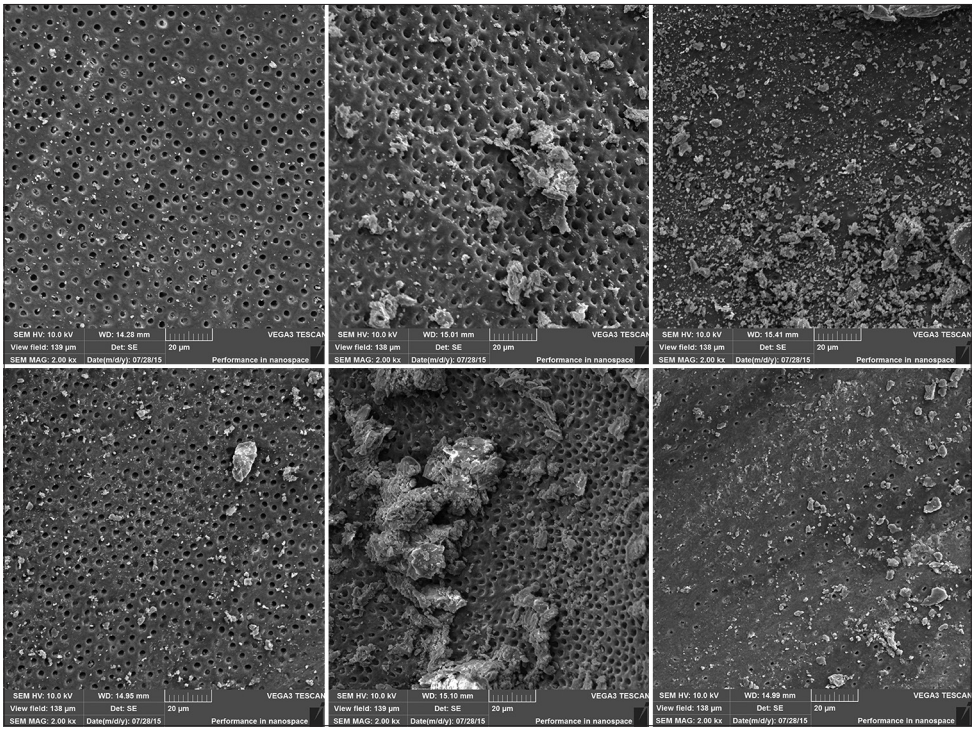

Figure 1: Scanning electron microscope images representative of the root canal walls in the mesiodistal (above) and buccolingual (below) directions after instrumentation with the HyFlex system. Please observe the similar quantity of smear layer adhered in both directions of analysis, and in the root canal thirds (cervical-left; middle-center; and apical-right) (×1000)

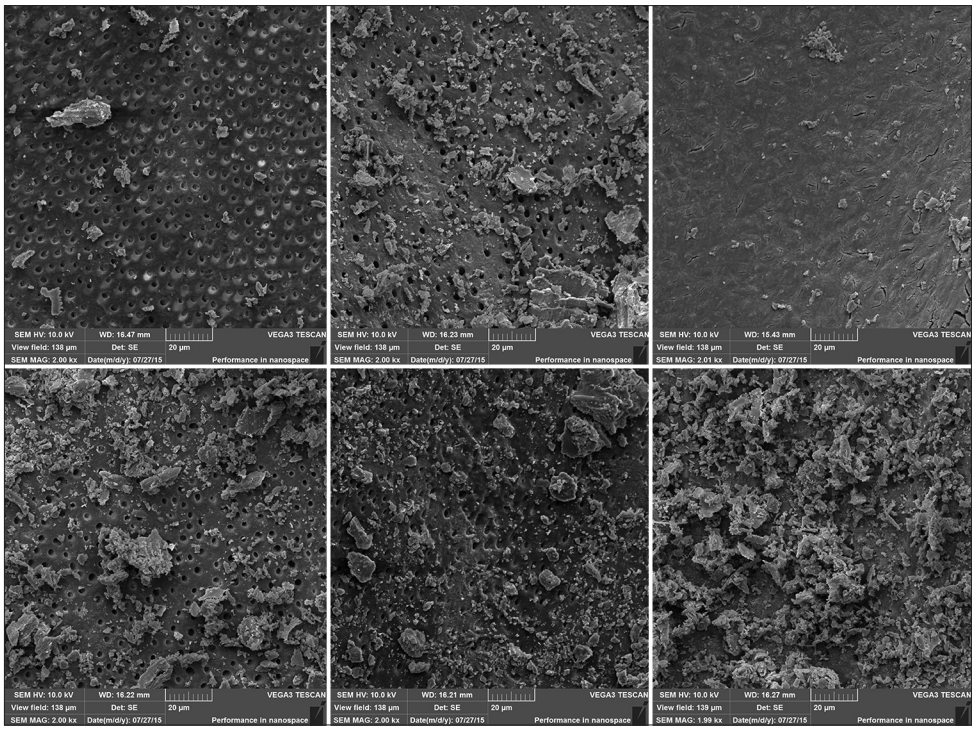

Figure 2: Scanning electron microscope images representative of the root canal walls in the mesiodistal (above) and buccolingual (below) directions after instrumentation with the Unicone system. Please note the significant difference in the quantity of smear layer adhered to the dentin substrate in the two directions of analysis. A significantly larger quantity of smear layer could be observed from the cervical (left) to the apical (right) region, in both directions of analysis (×1000)

layer increased significantly from the cervical to the apical region [Table 3].

When the systems were considered in the comparison between the two directions of analysis and root canal thirds [Table 4], there was no statistical difference between Groups HyFlex, Mtwo (MT) and ProTaper Next ($P > 0.05$). The specimens in Groups Reciproc (RP), Unicone, and WaveOne (WO) presented a significant difference between the directions of analysis ($P < 0.05$), and the cervical third showed a significantly smaller quantity of residual smear layer compared with the apical third ($P < 0.05$).

When the same systems were compared among each other, considering both directions of analysis and the three root canal thirds, there was statistically significant difference only between Groups RP and WO ($P < 0.05$) [Table 5].

Table 2: Values referring to smear layer removal in the mesiodistal and buccolingual directions

Direction	*n*	Median	Quartile deviation	*P*
MD	90	1.00[a]	0.50	0.0007
BL	90	2.00[b]	2.20	

Different lowercase letters indicate statistically significant difference ($P<0.05$). MD: Mesiodistal, BL: Buccolingual

Table 3: Values referring to smear layer removal in the different root canal thirds

Root canal third	*n*	Median	Quartile deviation	*P*
Cervical	60	1.00[a]	1.50	0.000
Middle	60	2.00[b]	2.50	
Apical	60	3.00[c]	2.00	

Different lowercase letters indicate statistically significant difference ($P<0.05$)

DISCUSSION

The aim of this study was to make a quantitative evaluation of the residual smear layer after root canal instrumentation with systems made of different NiTi alloys. Based on the results obtained, the null hypothesis tested was partially rejected, since the different systems presented a similar performance, with the exception of the comparison between the WO and RP systems. In spite of the superior performance of the WO system in comparison with RP, it is worth pointing out that the two systems are manufactured of the same alloy (M-Wire), demonstrating that this factor of itself does not play a fundamental role in the production and removal of smear layer by these instruments.

Although they are made of the same alloy, the reciprocal systems tested in this study had different

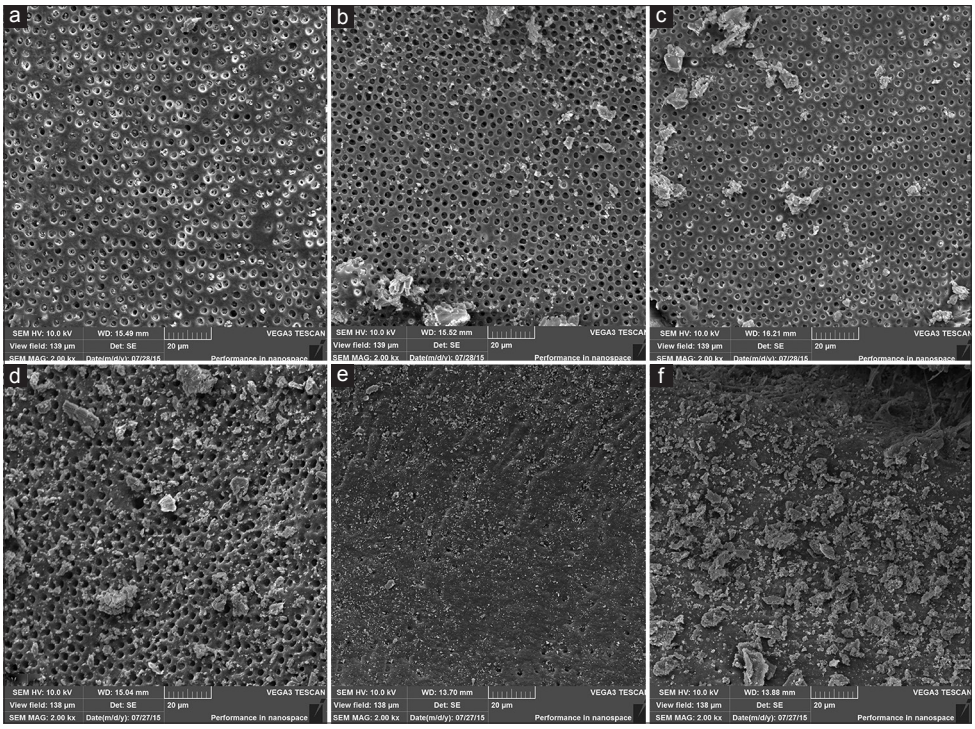

Figure 3: Scanning electron microscope images representative of the root canal walls (mesiodistal direction) after action of the tested systems. Cervical (a), middle (b), and apical (c) thirds of the group instrumented with the WaveOne System. Note signifi cant increase in the quantity of smear layer from the cervical to apical region; the same could be observed in the cervical (d), middle, (e) and apical (f) thirds of the samples of group Reciproc. Moreover, it was possible to observe a signifi cantly larger quantity of smear layer in Group Reciproc in comparison with Group WaveOne (×1000)

Table 4: Smear layer removal in each group, considering the direction of analysis and the root canal thirds

Group/direction of analysis	Root canal third			*P*
	Cervical	Middle	Apical	
WO/MD	1.0±0.5	1.0±0.5	2.0±1.5	*
WO/BL	1.0±0.5[a]	1.0±1.5[a,b]	3.0±2.0[b]	0.01
RP/MD	1.0±0.5[a]	3.0±2.0[b]	2.0±2.0[b]	0.028
RP/BL	2.0±1.5[a]	3.0±1.5[a,b]	3.0±1.5c	0.028
UC/MD	1.0±1.5	1.0±0.5	3.0±2.5	*
UC/BL	2.0±1.5[a]	3.0±2.0[b]	3.0±2.0[b]	0.04
PN/MD	1.0±1.5	1.0±1.5	2.0±2.5	*
PN/BL	1.0±1.5	2.0±1.5	2.0±2.5	*
MT/MD	1.0±1.5	1.0±1.5	2.0±1.5	*
MT/BL	2.0±1.0	2.0±2.0	3.0±1.5	*
HF/MD	1.0±1.5	2.0±1.5	3.0±2.5	*
HF/BL	1.0±0.5[b]	2.0±1.0[a,b]	3.0±1.5[a]	0.0063

Different lowercase letters indicate statistically significant difference ($P<0.05$). *Without statistically significant difference ($P>0.05$). WO: WaveOne, RP: Reciproc, UC: Unicone, PN: ProTaper Next, MT: Mtwo, HF: HyFlex, MD: Mesiodistal, BL: Buccolingual

cross-sections. RP instruments have an S-shaped cross-section blade and WO instruments a triangular concave design.[13] According to Burklein *et al*.[14] the cross-sectional design of the RP system instruments favors the removal of the smear layer and debris, because it has deeper indentations than those of the WO instruments, thereby optimizing its cleaning capacity. However, other studies have demonstrated that there were no differences between the systems relative to the cleaning promoted in the root canal.[15,16] These results differ from those obtained in the present research because the WO system showed smear layer removal capacity superior to that of RP.

The RP system instruments have greater dentin cutting capacity than that of the WO system instruments.[17] The greater the cutting capacity of an instrument, the greater will be its smear layer production.[18-21] This may explain the results obtained by the RP Group in the present study. Moreover, the WO system instruments have a larger cross-sectional area than that of the RP system instruments.[13] This feature of the cross-section allows greater contact between the instrument and root canal wall, promoting greater drag on the smear layer adhered to it.[22]

Furthermore, it is valid to point out that the manufacturers of the different reciprocating systems normally recommend the use of a single instrument for root canal preparation.[14] However, in the present study, more than one instrument was used due to two factors; to obtain an automated glide path for the use of instruments with a larger tip and taper,[8,23] and to

Table 5: Comparison among the different groups relative to smear layer removal in the mesiodistal and buccolingual directions, considering the three root canal thirds

Groups	*n*	Median	Quartile deviation	*P*
WO	30	1.00[b]	1.50	0.0029
RP	30	2.50[a]	2.50	
UC	30	2.00[a,b]	2.50	
PN	30	1.50[a,b]	2.25	
MT	30	2.00[a,b]	2.50	
HF	30	2.00[a,b]	2.25	

Different lowercase letters indicate statistically significant difference ($P<0.05$). WO: WaveOne, RP: Reciproc, UC: Unicone, PN: ProTaper Next, MT: Mtwo, HF: HyFlex

maintain the identical frequencies and quantities of irrigant solution for all the systems tested.[24,25] Studies have demonstrated that for systems that use a reduced number of instruments, such as the reciprocating types, a glide path must previously be created to allow free access of the instrument to the entire working length of the root canal.[15,26] Furthermore, due to the reduced number of instruments used during preparation, the quantity of irrigant solution used would also be reduced, compromising the cleaning capacity of these systems.[14]

The instruments of the MT system are made of conventional NiTi alloy, and although they have a lower degree of flexibility than those made of M-Wire, the results presented were similar. These instruments presented characteristics very similar to those of the RP system instruments, with an S-shaped cross-section, positive cutting angle, and two cutting edges.[10,27] However, they also have an increasing pitch length that prevents the screwing effect of instruments and debris accumulation, thus achieving performance close to that of the WO system.[10,27] Furthermore, the reciprocating movement itself is considered more aggressive than that of the continuous rotary movement, predisposing to a larger quantity of dentin excised and greater accumulation of smear layer and debris in untouched areas, such as the buccolingual walls.[28]

Considering the direction of analysis, the results of this study demonstrated that the buccolingual walls presented a larger deposition of smear layer when compared with the mesiodistal walls. The previous studies have demonstrated that particularly in teeth with flattened canals, such as the mandibular incisors, the vestibular and lingual walls may act as veritable niches for accommodating the smear layer and debris,[29,30] a fact corroborated by our findings. The same could be said as regards the root canal thirds since the preparation of the apical third is more critical, making it difficult to clean this area.[29,30]

CONCLUSIONS

In spite of the limitations of this *ex vivo* study, the systems tested presented similar performance as regards their capacity to remove the smear layer, irrespective of the alloy of which they were made. However, considering only the systems with reciprocating movement, WO had a performance superior to that of RP, which proved that factor such as the cross-section and shape of the instrument active tip were more relevant for smear layer production and removal than the type of alloy of which they are manufactured.

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Conflicts of interest
There are no conflicts of interest.

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