Comparison of the Shaping Ability of Reciprocating Single-File and Full-Sequence Rotary Instrumentation Systems in Simulated Canals

Nancy Ayyad[1], Abdul Rahman Mohammed Saleh[1]*

1. Department of Restorative Dentistry, Ajman University, Ajman, United Arab Emirates.

Abstract

To compare the shaping ability of two reciprocating single-file systems; WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc (VDW, Munich, Germany) with two full-sequence systems; ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) and Mtwo (VDW, Munich, Germany) in simulated L-shaped and S-shaped canals.

A total of 128 resin blocks were included. These were divided into 64 L-shaped and 64 S-shaped simulated canals in which each was subdivided into four subgroups of 16 samples each (n=16/ canal shape/group). All canals were prepared to apical size of 25 using WaveOne (primary file), Reciproc (R25), Mtwo (10, 15, 20 & 25) and ProTaper Next (X1 & X2). A series of preoperative and postoperative images were taken by a digital camera and superimposed in two different layers to make composite images. The amount of resin removed by each system was measured using a digital template and image analysis software. The amount of resin removed from both the inner and outer sides of the canal was measured to the level of 10 mm from the apical tip, at 1 mm increment. The data were statistically analysed by using analysis of variance and Tukey's post hoc test.

In L-shaped simulated canals, WaveOne and Reciproc significantly removed more resin from the outer wall of the apical end (P<0.05). At the middle part of the canal, ProTaper Next significantly removed the least amount of resin from the inner wall (P<0.05). In S-shaped samples, ProTaper Next significantly removed the least amount of resin from the inner side of both curvatures (P<0.05). No instrument fractured during canal preparation of all groups.

Under the conditions of this study, all rotary file instruments were safe to use and were able to prepare the canals efficiently. However, single-file systems seem to result in more straightening in the apical part of the canals of the L-shaped samples, and seem to be less favorable when preparing S-shaped canals because of their increased taper. ProTaper Next removed the least amount of resin and maintained centricity best.

Experimental article (J Int Dent Med Res 2019; 12(1): 22-30)

Keywords: Asymmetric rotation, Reciprocation, Shaping ability, Simulated canals, Single-file.

Received date: 27 May 2018 **Accept date:** 24 August 2018

Introduction

Chemo-mechanical root canal preparation is a predictive factor for the success of root canal treatment. It aims to remove infected and non-infected tissue from the root canal space to facilitate delivery of the antimicrobial agents. Furthermore, it aims to achieve a continuously tapered canal form while preserving the integrity and location of the canal and apical anatomy in preparation for an adequate filling.[1,2] Since it can be difficult to achieve these objectives by using stainless steel hand instrumentation,[3] the introduction of rotary nickel titanium (NiTi) instrumentation was an important step in achieving optimal root canal shaping.[4]

The unique property of super elasticity of NiTi files may allow them to be placed in curved canals with the exertion of less lateral forces against the canal walls. This better maintains the canal shape and reduces the risk of canal aberrations.[5,6] Despite these advantages, there is a risk of NiTi instruments fracture due to torsional and flexural stresses.[7,8]

To improve fracture resistance, manufacturers developed a new NiTi alloy (M-

*Corresponding author:
Abdul Rahman Mohammed Saleh, BDS, MSc, PhD,
Department of Restorative Dentistry,
Ajman University,
Ajman, United Arab Emirates.
E-mail: rm.saleh@ajman.ac.ae

wire; Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) that is said to have improved resistance to cyclic fatigue.[9] However, torsional resistance does not show significant improvement. To further improve the fracture resistance, Yared in 2008 suggested the use of one single NiTi file in reciprocating movement.[10] The concept of the reciprocating movement was based on the balanced force technique, which has shown better maintenance of the original canal shape in curved root canal during preparation.[11] In 2010, two new single-file systems manufactured from M-wire alloy; WaveOne (Dentsply Tulsa Dental Specialties and Reciproc (VDW Munich, Germany), were introduced into the market. These files shape root canals using a reciprocating motion in which the file continuously changes its rotating direction during the shaping procedure with a larger rotating angle in the cutting direction and a smaller angle in the reverse direction.

The WaveOne system consists of three files with tip sizes of 21, 25, and 40. Primary WaveOne file has a tip size of 25 with a constant taper of 0.08 over the first 3mm from the tip. It has a modified triangular convex cross-section at the tip region that changes to a convex triangular cross-section near the shank. Reciproc system also consists of 3 files: R25, R40, and R50. The R25 file has a taper of 0.08 over its first 3mm and is characterised by an S-shaped cross-section throughout the instrument. Recently, ProTaper Next (PTN) (Dentsply Tulsa Dental) was introduced; this instrument is also made from M-Wire alloy. However, its design features include variable tapers and a newly introduced concept of an off-centered rectangular cross section. Therefore, although many studies have evaluated and tested the efficacy of the single-file technique;[12-14] the aim of this study was to compare the shaping ability of the two single-file systems WaveOne (Dentsply) and Reciproc (VDW) with the two full-sequence rotary file systems produced by the same companies ProTaper Next (Dentsply) and Mtwo (VDW) in simulated canals. The study evaluated the efficacy of the instruments in terms of the amount of resin removed.

Materials and methods

128 ISO 15, 0.02 taper simulated canals in plastic blocks (64 Endo Training Blocks-L and 64 S; Dentsply-Maillefer, Ballaigues, Switzerland) were included in this study. Each simulated L-shaped canal had a radius and angle of curvature of 4.5mm and 60°, respectively. For S-shaped canals, the respective angles and radii of the curvature were 35° and 5 mm for the coronal curvature and 30° and 4.5 mm for the apical curvature. Shaping of all of the simulated canals was done by a single operator. The canals were first scouted with #10 K-file (Dentsply-Maillefer, Ballaigues, Switzerland) to check patency and precisely determine the working length. The working length was obtained by measuring the length of the canal using size 10 at the apical foramen. Each root canal was irrigated with a total of 10 ml normal saline. The amount of Glyde-Prep was enough to cover all the flute area of each file. Canal recapitulation was performed after the use of each file. Files were regularly being wiped using wet gauze to remove resin debris, and the instruments were checked for signs of distortion. Prior to instrumentation, landmarks were placed on the resin blocks to be used later as reference points for accurate superimposition of the images. The randomly distributed blocks were then numbered and labelled according to the system under investigation using a waterproof pen. Canals were then injected with black ink (Parker Quink, Parker, France) to obtain a clear pre-operative image and a series of photographs were taken using a digital camera (Sony Alpha DSLR-A 100 with DSLR-A 100 macro lens, Sony, Japan) that had a constant setting during all the study.

The 64 L-shaped and 64 S-shaped simulated canals were subdivided into four subgroups of 16 samples each (n=16/ canal shape/group) according to the rotary file system used. Canal preparation for the different rotary systems was done according to the manufacturer's instructions. All canals were prepared to apical size of 25 using WaveOne (primary file), Reciproc (R25), Mtwo (10, 15, 20, and 25) and ProTaper Next (X1 & X2). After instrumentation, the simulated canals were further irrigated with 2ml of normal saline to remove any debris and then they were injected with red ink (Parker Quink, Parker, France) to improve the outlines. The canals were then photographed again under identical conditions. The pre- and post-instrumentation images were then superimposed on a composite image, by using a computer software program (Adobe

Photoshop Elements 7.0, Adobe Systems Incorporated, San Jose, CA, USA) and by taking the landmarks as reference points. Images were then cropped and a measuring template was superimposed on the composite images. Shaping ability of the different rotary systems was compared in terms of amount of resin removed from both the inner and outer sides of the canal to the level of 10 mm from the apical tip, at 1 mm increment. Data were analysed using SPSS 22.0 (IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.). Mean and standard deviation were calculated for each group. Results for the amount of resin removed were compared using One-way ANOVA and Tukey post hoc tests. The level of statistical significance was set at $P<0.05$.

Results

During preparation of the resin blocks, none of the instruments separated, and deformation was not noticed. Therefore, the following results are based on the total number of 128 canals included in the study.

Amount of resin removed from L-shaped resin blocks

Inner wall: Using One-way ANOVA and Post-hoc Tukey tests, statistical analysis of the mean amount of resin removed from the inner wall showed that there was no significant difference between WaveOne, Reciproc and Mtwo in the amount of resin removed from the inner wall of the L-shaped samples ($P>0.05$). At points 2 and 3, ProTaper Next removed significantly less amount of resin compared to Reciproc and Mtwo ($P<0.05$). At points 4, 5 and 6 ProTaper Next removed significantly less amount of resin compared to the other three groups ($P<0.05$) (Table 1).

Outer wall: WaveOne and Reciproc removed more resin than Mtwo and ProTaper Next at points 1, 2 and 3 ($P<0.05$). There was no significant difference between WaveOne and Reciproc in the amount of resin removed at all measured points ($P>0.05$). There was no significant difference between ProTaper Next and Mtwo at all points ($P>0.05$) (Table 2).

Total amount of resin removed: A steady and increasing amount of resin was removed among the four groups; therefore, a continuous tapered preparation was achieved. ProTaper Next removed less total amount of resin when compared to WaveOne and Reciproc at points 1, 2, 3, 4, 5, and 6 ($P<0.05$). When compared to Mtwo, ProTaper Next removed significantly less total amount of resin at points 2, 3, 4, 5, and 6 ($P<0.05$). Mtwo showed a significant difference in comparison with WaveOne and Reciproc at points 1, 2, and 3 ($P<0.05$). There was no statistically significant difference between WaveOne and Reciproc at any measured point ($P>0.05$) (Table 3).

Amount of resin removed from S-shaped resin blocks

In S-shaped sample, points 0-4 represent the apical curvature, while points 5-9 represent the coronal curvature.

Apical curvature (Points 0-4)

Inner wall: At points 0 and 4, there was no difference between the four groups in the amount of resin removed from the inner wall ($P>0.05$). Points 1, 2, and 3 showed that ProTaper Next removed the least amount of resin ($P<0.05$)(Table 4).

Outer wall: At points 0 and 1, ProTaper Next and Mtwo removed less amount of resin compared to WaveOne and Reciproc ($P<0.05$). At points 2 and 3, there was no difference between all investigated groups ($P>0.05$). Point 4 shows that there is a statistically significant difference between Reciproc and ProTaper Next ($P<0.05$)(Table 5).

Coronal curvature (Points 5-9)

Inner wall: At points 5 and 6, ProTaper Next removed the least amount of resin ($P<0.05$). At points 7, 8 and 9 there was no significant difference between all groups ($P>0.05$) (Table 4).

Outer wall: At points 5 and 9, ProTaper Next and Mtwo removed significantly less amount of resin ($P<0.05$). Point 6 shows that Mtwo significantly removed the least amount of resin compared to the three investigated groups ($P<0.05$). Point 7 shows that ProTaper Next removed the least amount of resin ($P<0.05$). There was no significant difference between the four groups at points 8 ($P>0.05$) (Table 5).

Total amount of resin removed: There is a significant difference between ProTaper Next

and the other three systems at most points measured (0-7 when compared to WaveOne and Reciproc, and 2-7 when compared to Mtwo) (P<0.05). Mtwo showed a significant difference when compared to WaveOne and Reciproc at points 0, 1, 5, and 6 (P<0.05) (Table 6).

Discussion

In the present study, simulated canals in resin blocks in both L and S-shaped curvatures were used to make a direct comparison of the shapes obtained after preparation with different movements and instruments. Resin blocks were chosen instead of extracted teeth in this study to rule out the variations in canal anatomy that could influence the preparation outcome. Simulated root canals provide standardization of root canal diameter, length and curvature in terms of angle and radius in three-dimensions.[15] It also allows direct comparison of the shaping ability of different instruments.[16] However, there are two major limitations associated with the use of resin blocks. First, there is a difference in hardness between dentine and resin. Therefore, care should be taken in extrapolating the results to the clinical situation. Second, the heat generated by the rotary instruments in the resin blocks might soften the resin material and lead to binding of the cutting blade and separation of the instrument. Nevertheless, provided that the conditions are the same for either of the instruments or techniques tested a comparison of the resultant shape of the canal using simulated canals in resin blocks may be a valid substitute for natural teeth.[17]

The methodology used in this study was described by Schäfer et al.[16] In this method, the amount of resin removed from the inner and outer sides of the canal are measured at 1 mm steps after superimposition of the pre and post-operative images. Ten points were described that maintain a fixed distance from each other and from the apical foramen and hence remove any subjective factors that might influence in deciding the measuring point. Superimposition of canal outlines using digital photography is an accurate method to assess reproducibility and measurement of transportation and is widely used in the literature.[18,19] To compare the shaping ability of the different rotary systems used in the study, it was important that the experimented instruments have similar apical preparation diameters (#25). This eliminates the possibility that the different apical size becomes a variable between the groups.

Schäfer and Oitzinger[20] showed that the cross-sectional design seems to be a decisive parameter concerning the cutting efficiency of rotary NiTi instruments. Results in this study showed that Reciproc removed the largest amount of resin in both the L and S-shaped samples. This comes in agreement with a report published by Capar et al[21] in which Reciproc removed the greatest amount of dentin compared to the other five systems investigated including WaveOne and ProTaper Next. However, statistical analysis using One-way ANOVA revealed no significant difference in the mean amount of resin removed between WaveOne and Reciproc at the 10 measuring points in L and S-shaped simulated canals. These results come in contrary to the results published by Yoo and Cho[22] which reported that there was a statistically significant difference in the mean resin removal between WaveOne and Reciproc at all levels except at the apical third. This study was conducted on L-shaped resin blocks only, and the difference in the results could be attributed to the smaller sample size used in their study (n=5). (Figure 1).Moreover, our observation is in agreement with previous studies that compared the shaping effects of WaveOne and Reciproc instruments in S-shaped canals and found no significant difference in the amount of resin removed between the two groups.[23] The similar behavior of WaveOne and Reciproc noticed in the current investigation can be attributed to their common features such as the reciprocating working motion, the taper of 0.08 at their tip region, and the fact that both files are manufactured from M-Wire alloy.

Results have also revealed that Reciproc and WaveOne removed greater amounts of resin material from the outer and inner walls of the L and S-shaped canals compared to Mtwo and ProTaper Next at most of the 10 measuring points (Figure 2). The increased amount of resin removed that is noticed with WaveOne and Reciproc as compared to the other two groups can be explained by their increased taper. These files appear to be less flexible compared to other files of the same tip-size because of their greater taper over the first 3mm.[24] This observation is in agreement with previous studies that compared the shaping effects of different instruments in S-

shaped canals.[25,26] It should also be noted that although these two files have different cross-sectional designs, this did not seem to have influenced the amount of resin removed by the two groups significantly. This comes in agreement with Hyo-Jin et al[27] who concluded that the different cross-sectional designs between WaveOne and Reciproc did not result in a significant difference in the cutting efficiency between the two groups. In S-shaped canals, the greatest material removal was noticed on the inner sides of both the coronal and apical curvatures, resulting in more straightening of the canals, which is in accordance with research published by Saleh et al.[23] In this study the shaping ability of four single-file systems (WaveOne, Reciproc, F360 and Oneshape) were assessed in S-shaped simulated canals and the results have shown that Reciproc and WaveOne files removed significantly greater amounts of resin from the inner side of both curvatures and that there was no significant difference between these two groups in the amount of resin removed.

ProTaper Next removed the least amount of resin when compared to the other three groups in L and S-shaped samples. This could be attributed to the unique file design. ProTaper Next has an off-centered cross section and is non-radial landed, such a modification in the cross-section should involve a reduction of the contact area with the canal and therefore in the cutting efficiency.[28] This is again in accordance with Capar et al,[21] where ProTaper Next showed the least amount of dentine removal compared to WaveOne and Reciproc.

Mtwo showed a statistically significant difference with WaveOne and Reciproc in the total amount of resin removed at points 1, 2, and 3 for the L-shaped samples and points 0, 1, 5 and 6 for the S-shaped samples. This also could be attributed to the difference in taper between the instruments. Mtwo have a smaller taper (6%) at the apical tip; this makes it more flexible at the tip region and hence removes lesser amounts of resin compared to the more tapered single-files.[26] When comparing Mtwo with ProTaper Next, results showed that Mtwo removed more total amount of resin that was statistically significant at points 2- 6 for the L-shaped group and points 2-7 for the S-shaped group. A possible explanation for the increased amount of resin removed seen in Mtwo is the shaping technique used in this system. Mtwo uses a single-length technique to a full length as opposed to crown-down technique.[29] In comparison with the crown-down procedure, Mtwo instruments allow more blades to be in contact with the canal at the same time, and therefore increase the cutting of dentin.[30] Moreover, the increased contact with the canal walls increases the friction in the canal which increases the incidence of apical transportation as the file does not go into the canal freely.[31]

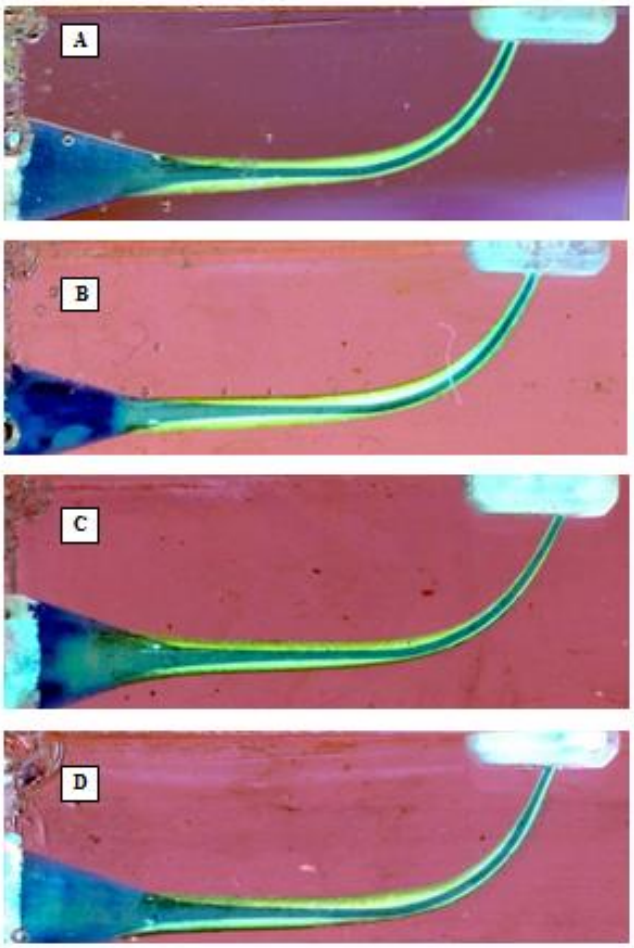

Figure 1. Representative Composite Images of L-shaped Simulated Canals Instrumented using (A) WaveOne (B) Reciproc(C) ProTaper Next (D) Mtwo

During the present study, no instrument fractured. All instruments were used to enlarge four simulated canals.[30,32] This is justified by the fact that these files could be used to enlarge at least four canals in a natural tooth. This means that a molar tooth having four root canals may be prepared with one single-file instrument

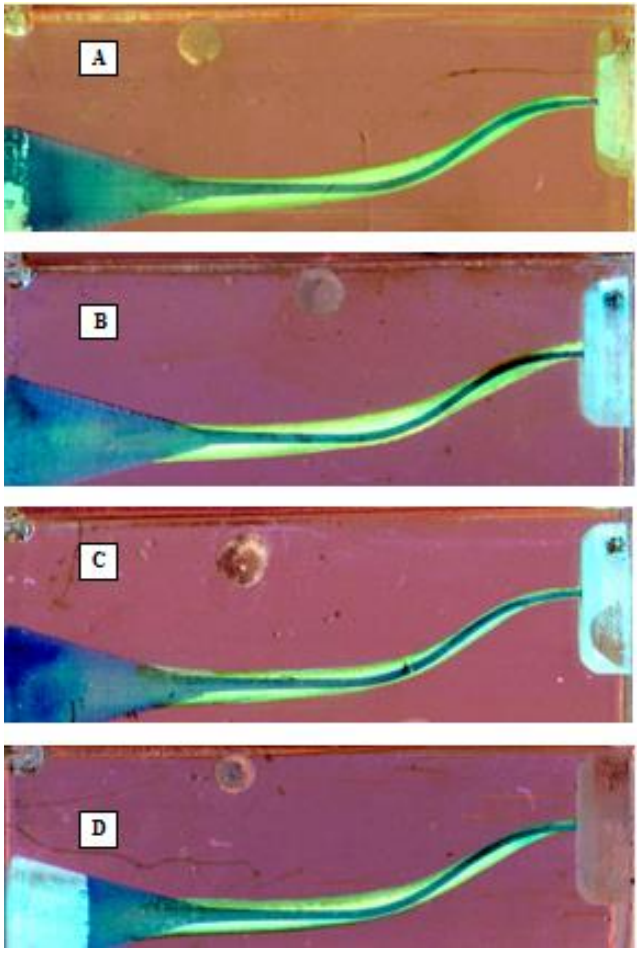

Figure 2. Representative Composite Images of S-shaped Simulated Canals Instrumented using (A) WaveOne (B) Reciproc(C) ProTaper Next (D) Mtwo.

(WaveOne and Reciproc) or with one sequence of rotary files (ProTaper Next and Mtwo). However, WaveOne and Reciproc will no longer be suited for sterilization processes, as they do not fit into the hand piece again. The single-use of endodontic instruments was recently recommended to decrease instrument fatigue and possible cross-contamination.[33] Reciproc, WaveOne and ProTaper Next are made of M-wire alloy. Some studies have shown that instruments made of M-wire alloy have an increased torsional resistance of up to 400% compared with conventional NiTi.[34] Thus, this might explain why none of these files fractured during preparation. However, it is remarkable that although Mtwo is made of a conventional 55-NiTi alloy none of the files fractured during preparation as well.

Conclusions

Within the limitations of this study, it was concluded that all the investigated systems performed well and were safe to use. The two investigated single-file systems (WaveOne and Reciproc) showed similar behavior in terms of the amount of resin removed in most parts of the simulated canals. In L-shaped canals, single-file systems showed removal of greater amounts of resin from the outer wall of the apical end, while in S-shaped simulated canals they removed greater amounts of resin from the inner sides of the apical and coronal curvatures. ProTaper Next removed the least amount of resin. The off-centered cross-section and asymmetric motion are the two main features that distinguish ProTaper Next from the other groups and these are probably the main contributing factors that led to better canal preparations. In terms of fracture resistance, there was no difference between instruments manufactured from NiTi and those from M-wire. Further investigations are needed to understand whether the better performance of ProTaper Next instrument is due to the asymmetric rotary motion, the unique rectangular cross-section design or a combination of these variables. The aspect that the investigated systems didn't have the same apical taper also requires further investigations. Some attempts should be made to standardize not only the apical preparation size but also the final taper. This approach is difficult because most of the full-sequence rotary and all rotary single-file systems do not match with the reciprocating systems in terms of regressive tapers or tip diameter.

Declaration of Interest

The authors report no conflict of interest and the article is not funded or supported by any research grant.

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.09[a]	0.12[a]	0.15[a,b]	0.18[a,b]	0.22[a]	0.29[a]	0.31[a]	0.27[a]	0.23[a]	0.23[a]
	SD	0.01	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Reciproc											
	Mean	0.09[a]	0.12[a]	0.17[a]	0.20[a]	0.24[a]	0.30[a]	0.33[a]	0.28[a]	0.25[a]	0.24[a]
	SD	0.01	0.01	0.03	0.03	0.02	0.02	0.01	0.02	0.02	0.02
Mtwo											
	Mean	0.08[a]	0.11[a]	0.16[a]	0.19[a]	0.24[a]	0.29[a]	0.31[a]	0.27[a]	0.23[a]	0.22[a]
	SD	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02	0.02
ProTaper Next											
	Mean	0.09[a]	0.11[a]	0.13[b]	0.16[b]	0.20[b]	0.25[b]	0.28[b]	0.27[a]	0.24[a]	0.25[a,b]
	SD	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02	0.02

Table 1. Mean and Standard Deviation (SD) (in mm) of the Amount of Resin Removed from the Inner Wall of the L-Shaped Canals at the Different Measuring Points After Root Canal Preparation. Values with the same superscript letters were not statistically different at *P*<0.05 (analysis of variance and post-hoc Tukey test)

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.10[a]	0.13[a]	0.16[a]	0.19[a]	0.17[a]	0.15[a]	0.17[a]	0.24[a]	0.29[a]	0.32[a]
	SD	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.03	0.03	0.04
Reciproc											
	Mean	0.10[a]	0.13[a]	0.16[a]	0.17[a]	0.16[a]	0.13[a]	0.15[a]	0.23[a]	0.29[a]	0.33[a]
	SD	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02
Mtwo											
	Mean	0.09[a]	0.10[b]	0.13[b]	0.14[b]	0.15[a]	0.13[a]	0.16[a]	0.23[a]	0.28[a]	0.31[a]
	SD	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02
ProTaper Next											
	Mean	0.09[a]	0.10[b]	0.13[b]	0.14[b]	0.16[a]	0.13[a]	0.16[a]	0.23[a]	0.27[a]	0.30[a]
	SD	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02

Table 2. Mean and Standard Deviation (SD) (In Mm) of the Amount of Resin Removed from the Outer Wall of the L-Shaped Canals at the Different Measuring Points after Root Canal Preparation.

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.29[a]	0.36[a]	0.43[a,b]	0.50[a,b]	0.55[a]	0.61[a]	0.67[a]	0.68[a]	0.73[a]	0.79[a]
	SD	0.04	0.02	0.02	0.03	0.03	0.03	0.02	0.01	0.02	0.04
Reciproc											
	Mean	0.29[a]	0.37[a]	0.45[a]	0.52[a]	0.55[a]	0.62[a]	0.68[a]	0.70[a]	0.75[a]	0.78[a]
	SD	0.03	0.03	0.01	0.02	0.02	0.03	0.03	0.04	0.03	0.02
Mtwo											
	Mean	0.27[a]	0.33[b]	0.41[b]	0.47[b]	0.54[a]	0.60[a]	0.66[a]	0.69[a]	0.75[a]	0.80[a]
	SD	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02
ProTaper Next											
	Mean	0.27[a]	0.32[b]	0.37[c]	0.42[c]	0.50[b]	0.56[b]	0.60[b]	0.67[a]	0.74[a]	0.81[a]
	SD	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table 3. Mean and Standard Deviation (SD) (in mm) of the Total Amount of Resin Removed from the L-Shaped Canals at the Different Measuring Points after Root Canal Preparation.

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.06[a]	0.14[a]	0.25[a]	0.27[a]	0.20[a]	0.31[a]	0.38[a]	0.20[a]	0.24[a]	0.21[a]
	SD	0.01	0.05	0.08	0.07	0.04	0.07	0.06	0.03	0.05	0.03
Reciproc											
	Mean	0.05[a]	0.15[a]	0.27[a]	0.29[a]	0.19[a]	0.35[a]	0.39[a]	0.18[a]	0.26[a]	0.23[a]
	SD	0.01	0.03	0.06	0.04	0.02	0.05	0.046	0.02	0.02	0.02
Mtwo											
	Mean	0.05[a]	0.12[a]	0.26[a]	0.27[a]	0.18[a]	0.30[a,b]	0.38[a]	0.18[a]	0.28[a]	0.24[a]
	SD	0.02	0.03	0.07	0.05	0.05	0.04	0.05	0.02	0.05	0.04
ProTaper Next											
	Mean	0.05[a]	0.08[b]	0.14[b]	0.18[b]	0.16[a]	0.23[b]	0.29[b]	0.20[a]	0.24[a]	0.23[a]
	SD	0.01	0.01	0.03	0.04	0.03	0.04	0.04	0.02	0.04	0.03

Table 4. Mean and Standard Deviation (SD) (in mm) of the Amount of Resin Removed from the Inner Wall of S-Shaped Canals at the Different Measuring Points After Root Canal Preparation.

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.20[a]	0.16[a]	0.11[a]	0.09[a]	0.17[a]	0.15[a]	0.14[a]	0.32[a]	0.29[a]	0.36[a]
	SD	0.08	0.05	0.02	0.02	0.06	0.03	0.02	0.05	0.04	0.05
Reciproc											
	Mean	0.20[a]	0.16[a]	0.11[a]	0.11[a]	0.21[a]	0.14[a]	0.12[a]	0.33[a]	0.27[a]	0.35[a]
	SD	0.06	0.02	0.02	0.03	0.04	0.02	0.02	0.04	0.02	0.02
Mtwo											
	Mean	0.13[b]	0.11[b]	0.10[a]	0.11[a]	0.17[a]	0.11[b]	0.09[b]	0.34[a]	0.26[a]	0.31[b]
	SD	0.04	0.02	0.02	0.03	0.04	0.02	0.01	0.04	0.02	0.03
ProTaper Next											
	Mean	0.10[b]	0.11[b]	0.10[a]	0.09[a]	0.13[b]	0.13[b]	0.13[a]	0.26[b]	0.27[a]	0.30[b]
	SD	0.02	0.02	0.03	0.03	0.04	0.02	0.02	0.05	0.02	0.02

Table 5. Mean and Standard Deviation (SD) (in mm) of the Amount of Resin Removed from the Outer Wall of S-Shaped Canals at the Different Measuring Points after Root Canal Preparation.

		Measuring points (mm from the apex)									
		0	1	2	3	4	5	6	7	8	9
WaveOne											
	Mean	0.40[a]	0.45[a]	0.54[a]	0.56[a]	0.58[a]	0.69[a]	0.74[a]	0.74[a]	0.76[a]	0.82[a]
	SD	0.10	0.06	0.09	0.06	0.06	0.07	0.05	0.05	0.07	0.07
Reciproc											
	Mean	0.39[a]	0.46[a]	0.56[a]	0.56[a]	0.60[a]	0.72[a]	0.76[a]	0.75[a]	0.76[a]	0.82[a]
	SD	0.07	0.07	0.05	0.05	0.03	0.03	0.04	0.03	0.03	0.03
Mtwo											
	Mean	0.28[b]	0.34[b]	0.52[a]	0.54[a]	0.58[a]	0.59[b]	0.67[b]	0.72[a]	0.76[a]	0.80[a]
	SD	0.05	0.04	0.06	0.04	0.04	0.04	0.05	0.04	0.03	0.03
ProTaper Next											
	Mean	0.26[b]	0.31[b]	0.38[b]	0.43[b]	0.47[b]	0.54[c]	0.62[c]	0.67[b]	0.72[a]	0.79[a]
	SD	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Table 6. Mean and Standard Deviation (SD) (in mm) of the total amount of Resin Removed from the S-Shaped Canals at the Different Measuring Points After Root Canal Preparation.

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