A Comparative Evaluation of the Centering Ability and Canal Transportation of Simulated S-Shaped Canals Instrumented with Different Nickel –Titanium Rotary Systems

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ABSTRACT

Background: The purpose of this study was to evaluate and compare centering ability and canal transportation of simulated S-shaped canals instrumented with four different types of rotary nickel-titanium systems.

Materials and Methods: Forty simulated S-shaped canals in resin blocks were divided into four groups of ten each and were instrumented to an apical size 25 by different instrumentation technique using ProTaper Universal files (group A), ProTaperNext (group B), Reciproc (group C) and WaveOne (group D).Centering ability and canal transportation was measured at (11) measuring points from D0 to D10 bysuperimposion of the pre- and post-operative images obtained by using digital camera in standardized manner. An assessment of the canals shape was determined using Photoshop CS2 and AutoCAD software. The data were analyzed statistically using ANOVA and LSD test.

Results: In terms of centering ratio values, there was no statistically significant difference among the four groups at the coronal portion of the canals, with ProTaper system showing the least centering ability at all levels except at apical foramen. At the apical curvature, the Reciproc and WaveOne groups showed better centering ability than ProTaperNext and the difference was statistically highly significant among them at these points, while at the coronal curvature the ProTaperNext showed better centering ability than Reciproc and WaveOne. Canal transportation was seen in all groups but the ProTaper systems showed more transportation values at almost levels when compared with the other groups with the least values by ProTaperNext at the coronal curvature and the least values by Reciproc and WaveOne at the apical curvature.

Conclusions: Under the conditions of this study, ProtaperNext ,WaveOne and Reciproc instruments maintained the original curvature significantly better than ProTaperUniversal at almost levels. ProtaperNext showed a better shaping ability than Reciproc and WaveOne at the coronal curved section while at apical curved section Reciproc and WaveOne showed a better shaping ability than ProtaperNext.

Key words: centering ability, canal transportation, ProTaperNext, Reciproc, WaveOne. (J Bagh Coll Dentistry 2016; 28(1):48-56).

INTRODUCTION

Schilder in 1974 described five design objectives for canals to be filled with gutta-percha. These are: 1) the shape should be a continuously tapered funnel from apex to access cavity, 2) cross-sectional diameters should be narrower as we move apically, 3) the shape of the original canal should be maintained, 4) the original position of the apical foramen should be maintained, and 5) the apical opening should be kept as small as practical. Four important biological objectives were also described: 1) confinement of the preparation to the roots themselves, 2) avoidance of further irritation or infection of the peri radicular tissues from necrotic debris forced beyond the foramina, 3) removal of all tissue, vital and necrotic, from the main root canal, and 4) creating sufficient space for intracanal medicaments and irrigation. [1] These objectives are still considered in today's mechanical preparation of root canals.

The aims of root canal treatment are to eliminate microorganisms, to remove infected and necrotic pulpal remnants and to shape the root canal system in order to facilitate irrigation and the placement of a medicament and /or filling material **[2].** At the same time, the procedure should avoid any iatrogenic events, such as fracture of the instruments, transportation of the root canal, formation of a ledge or perforation of the tooth**.** Maintaining the original canal shape and avoiding canal aberrations like canal transportation is challenging, especially when preparing severely curved root canals [3].

Previous research on root canal morphology has reported that root canals not only have mesiodistal direction but also bucco-lingual curvature [4]. The preparation of this type of canal is difficult with stainless steel instruments. Similarly Ni-Ti rotary instruments, owing to their shape memory properties and super elastic behavior protected the original canal curvature in extremely curved or S- shaped canals but this still remains a challenge[5]. Numerous root canal shaping techniques with all of the NiTi systems have been advanced to maintain the original canal shape and thus remain better centered **[6].** New

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concept for NiTi files has been introduced with different working motions that finish root canal shaping with only a single file [7].

Up to now, there have been two sorts of file system composition, that is, single-file system and multi-file system. Single-file system with reciprocating motions (WaveOne and Reciproc), while multi-file system with continuous rotation (ProTaperUniversal and ProTaperNext). It is demonstrated reciprocation has better performance than continuous movements [8].

The aim of the current study was to evaluate and compare centering ability and canal transportation of simulated S-shaped canals instrumented with four different types of rotary nickel-titanium systems.

MATERIALS AND METHODS

A total of 40 S-shaped simulated plastic canals (Endo Training Bloc-S; Dentsply-Maillefer) made of clear polyester resin were used in this study, these blocks were divided into four groups of ten each. All the simulated canals were standardized as follows: they were 16.5mm long, the apical foramen diameter was 0.15 mm, and the initial taper was 0.02. The radius and angle of curvature, respectively, were 5mm and 35◦ for the coronal curvature and 4.5mm and 30◦ for the apical curvature as shown in figure (1).

Figure 1: S-Shaped Simulated Canal.

Prior to experimental instrumentation of the resin blocks, all canals were stained with blue ink to obtain a clear image of the canal. Three landmarks were made with a round bur in the resin blocks from sidewall to near the inner and outer curve of the canal without penetrating into the canal. These landmarks ensured a precise alignment during superimposition of pre- and post- instrumentation images. The resin blocks were then numbered for identification.

A specific platform with white background was built to take pictures of the canals before and after shaping (Figure 2). This set-up allowed precise camera and plastic block repositioning. For calibration, a ruler was fixed adjacent to the plastic block (its units in the images were used for converting measurement to real dimension in mm) and holes were used as a size reference with 600% magnification [9].

Figure 2: Specific Platform with White Background

In order to facilitate the preparation of the canals, a custom made mold was used to hold each resin block during instrumentation, which covered almost the entire canal to ensure that the preparation was made in a purely tactile sensation. The forty simulated canals were randomly divided into four groups according to the instrumentation system used with ten blocks each.

Instrumentation of Simulated Canals

A total of the simulated canals were prepared by using a pre-programmed setting of Electric speed- and torque-controlled endodontic micromotor XSmart plus ProTaperNext (DentsplyMaillefer). All of the canals were enlarged by the researcher. The canals were prepared to a working length (WL) of 16.5 mm. All canals were enlarged to apical size 25.

The canals were first checked with #10 K-file (FlexoFile; Dentsply-Maillefer,) to confirm patency and precisely determine the working length. Before shaping, each instrument was coated with a lubricant (Glyde File Prep; Dentsply-Maillefer), and copious irrigation with distilled water was performed repeatedly before and after the use of each instrument by irrigating syringe with 27- gauge needle; approximately 5 ml of water for each canal **[10].** For standardization; the position and angle of the hand piece was fixed at each time during preparation perpendicular to a line drawn on the mold. Each instrument was used to enlarge two canals and then discarded.

Group (A): Ten simulated canals were prepared by rotary ProTaper universal systems. The instruments were used in a crown-down manner by X-Smart, Dentsply with recommended torque of (2.0 Ncm) and rotation speed of (300 rpm) in a continuous in-and-out movement with a suitable force; they were never forced apically [11]**,** the preparation sequence was as follows:

1- An ISO No.10 K-File was used to establish a glide path.
2- S1 and S2 files were used to 2/3 of the WL (11 mm).
3- Instrumentation was completed with the S1, S2, F1 and F2 to the full estimated working length (16.5) [12]. To optimize safety and efficiency, the Shaping files (S1, S2) are used, like a brush, to laterally and selectively cut dentin on the outstroke**.** Once the file had reached to the end of the canal and had rotated freely, it was withdrawn from the canal. The ProTaper files flutes were frequently cleaned using gauze with 70% ethyl alcohol **[13].**
4-The canals were irrigated with distilled water after each file was withdrawn from the canals, recapitulated and established patency, then re-irrigated to remove the debris from the canal.

Group (B): Ten blocks were prepared by rotary ProTaperNext system. The instruments that used in the preparation were (X1 , X2) at a rotational speed of 300 rpm and 2 Ncm torque in outward brushing motion in all direction east ,west, north, south. Importantly, this method of use would enable any given PTN file to passively move inward, follow the glide path, and progress toward the working length. The sequence of preparation was as follows:
1- An ISO No. 10 K-File was used to establish a glide path.
2- X1 file was advanced in the canal until resistance. The file was then removed, the flutes were cleaned were frequently cleaned and inspected using gause soacked with 70% ethyl alcohol and the canal was irrigated using distill water. This sequence was repeated until the X1 file reached the full working length.
3- X2 file was used in the same sequence as X1 until it reached full working length.

The canal was irrigated after each instrument was withdrawn from the root canal, recapitulate and confirm patency, then re-irrigate to liberate debris from the canal [14].

Group (C): Ten blocks were prepared by Reciproc syste. This was accomplished by establishing a smooth glide path with ISO No. 10 stainless steel hand file. Then commence the preparation with R25 Reciproc file having a size 25 at the tip and a taper of 0.08 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion according to the manufacturer's instructions and XSmart program was set at "Recproc All" mode when Reciproc was used. A light pecking motion was used to advance the file tip followed by a 2.5-3mm passive penetration cycle into the canal, then repeated these cycles until working length was reached. The flutes of the instrument were cleaned after three in and-out-movements (pecks), using gauze soacked with 70% ethyl alcohol then the canal was irrigated, recapitulated and re-irrigated [15].

Group (D): Ten canals were prepared by wave one reciprocatin. This was accomplished by establishing a smooth glide path with ISO No. 10 stainless steel hand file. Then starting with primary reciprocating Wave One file having a size 25 and a taper of 0.08 was used in a reciprocating, slow in-and-out pecking motion according to the manufacturer's instructions and XSmart program was set at "WaveOne" mode when WO was used. A light pecking motion was used to advance the file tip followed by a 2.5-3 mm passive penetration cycle into the canal, and then these cycles were repeated until working length was reached. The flutes of the instrument were cleaned after three pecks using gause soacked with 70% ethyl alcohol. Then the canal was irrigated, recapitulated and re-irrigated [15].

Once the preparation of samples was completed, red ink was injected into the canal space within each resin block with a syringe. Each block was then re-mounted on the platform then the post-instrumentation images were acquired by the mentioned camera. The images were saved in .jpg format at a resolution of 5760 x 3084.

Photoshop (CS2 extended Adobe systems) was used to superimpose and standardize pre- and post-instrumentation images for each sample.

Measurement of Canal Centering Ability and Canal Transportation

The image calibration was performed by a digital image processing system (AutoCAD 2014; Autodesk Inc. San Rafael, CA, USA). Once the superimposition image was created, the images were opened in the AutoCAD program before starting, used the units of the ruler in the image to convert the measurement to real dimension.

Measurements were done at the foramen level instead of 1mm from the foramen; measurements were made every one millimeter from D0 to D10 Levels D0 to D10 corresponded to the distance (in millimeters) from the apical foramen. Level D0 represented the apical foramen; D1to D4 represented the apical curvature, whereas levels D4 to D8 represented the coronal curvature. Three measurements were recorded with 0.001mm precision and 600% magnification at each level for a total of 33 measurements per canal.

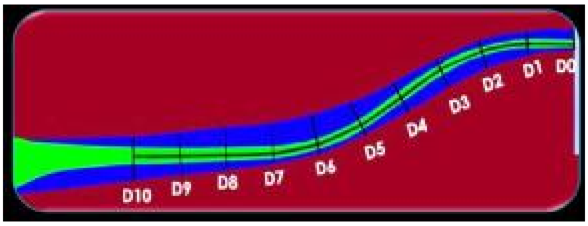

Figure 3: Measurement Levels on Image in AutoCAD Program

We measured:

(1) The distance between the upper limit of the initial canal and the upper limit of the instrumented canal (*X*sup),

(2) The distance between the inferior limit of the initial canal and the inferior limit of the instrumented canal (*X*inf),

(3) The width of the shaped canal (*Y*) (Figure 4).

- The centering ratio was calculated by the equation:

$(X\text{sup} - X\text{inf})/Y$

- And the amount and direction of transportation using the formula:

$(X\text{sup} - X\text{inf})$

According to the formula, the centering ratio approaches zero as Xsup and Xinf become closer to the center. The lower the scores, the better are the instruments centered in the canal and less are the canal transportation [16].

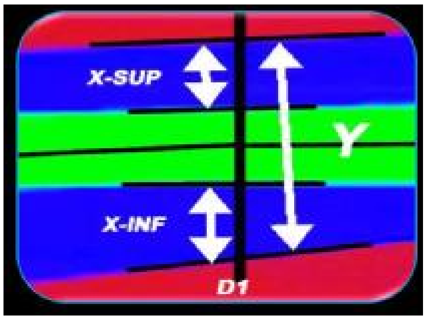

Figure 4: Measurement of Canals.

The data were collected and analyzed by using SPSS (Version 18) for statistical analysis. One Way Analysis of Variance Test (ANOVA) was performed to identify the presence of any statistically significant difference among the means of canal centering ability and canal transportation of all groups, at each level at a significance level of 0.05. Least significant difference test (LSD) was performed for multiple comparison between groups at different levels.

RESULTS

Centering ability: The mean of canal centering ability in (mm) at the different levels of all groups are shown in table (1) and figure (5).

Table 1: Centering Ability Means and Standard Deviation at Different Levels of All Groups. (D0 to D10) Measure Points (in mm From the Foramen).

	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
ProTaper											
Mean	0.430	-0.396	-0.627	-0.567	0.275	0.511	0.582	0.427	0.196	-0.109	-0.153
± SD	0.064	0.057	0.067	0.033	0.029	.078	0.041	0.060	0.028	0.009	0.025
ProTaper Next											
Mean	0.637	-0.181	-0.559	-0.550	0.265	0.478	0.538	0.367	0.168	-0.107	-0.150
± SD	0.056	0.036	0.068	0.036	0.035	0.052	0.027	0.022	0.018	0.011	0.019
Reciproc											
Mean	0.667	-0.175	-0.476	-0.380	0.184	0.489	0.551	0.385	0.181	-0.101	-0.138
± SD	0.071	0.038	0.053	0.043	0.018	0.075	0.049	0.060	0.020	0.012	0.011
WaveOne											
Mean	0.658	-0.178	-0.483	-0.394	0.204	0.478	0.564	0.418	0.190	-0.098	-0.137
± SD	0.115	0.029	0.040	0.051	0.025	0.064	0.042	0.067	0.040	0.005	0.014

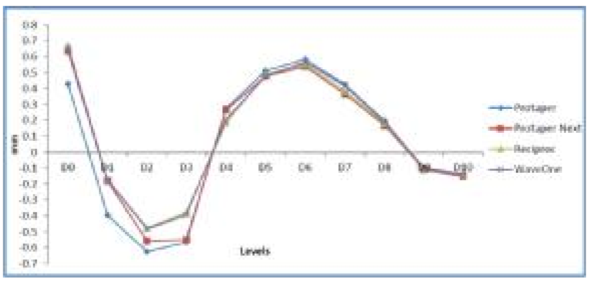

Figure 5: Line Chart of Centering Ability

Note that a negative value indicates that preparation deviated toward the inner aspect of the curve. It can be shown from figure (5) that ProTaper group has the highest mean values of canal centering ability at almost all levels except at D0. While there were a comparable values of canal centering ability among ProTaperNext, Reciproc and WaveOne group at almost all levels with the better values shown with Reciproc and waveone at apical (first) curvature.

Analysis of variance (ANOVA) test was performed to identify the presence of any statistically significant difference among the means of canal centering ability of all groups, at each level. ANOVA test showed that there was a high significant difference ($p < 0.001$) among the groups at D0, D1, D2, D3 and D4 and a non significant difference ($P > 0.05$) among the groups at the other levels. Further analysis of all data was needed to examine the difference between each two groups so least significant difference test (LSD) was performed for multiple comparison between groups.

By using (LSD) test;

- At D0 the PT group showed the best centering ability and the difference was a high significant ($p < 0.001$) with the other groups.

-At the other levels the PT showed the least centering ability with a high significant difference with both of the R and WO groups at D0, D1, D2, D3 and D4.

-The difference was a high significant between PT and PTN at D0, D1 and a significant difference at D2 and no significant difference at D3 and D4.

-AT D0, D1 the difference was none significant between PTN and both of the R and WO but a high significant difference was found among them at D2, D3 and D4.

- At apical curve the R and WO groups showed better centering ability than PTN while at coronal curve the PTN showed better centering ability.

-At all levels the difference was non significant between the R and WO groups.

Canal Transportation

The results of the descriptive statistics which include the mean and Standard Deviation (±SD) of canal transportation in (mm) at different levels for all groups are shown in the Table (2) and Figure (6). ProTaper group has the highest mean values of canal transportation at almost levels except at D0, while the ProTaperNext exhibited the least mean values at the second (coronal) curvature. Reciproc and WaveOne showed least values at the apical (first) curvature and straight coronal portion.

Table 2: Canal Transportation and Standard Deviation at Different Levels of All Groups. (D0 to D10) Measure Points (in mm from the Foramen).

	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
ProTaper											
Mean	0.233	-0.224	-0.464	-0.394	0.174	0.404	0.503	0.382	0.176	-0.088	-0.133
± SD	0.033	0.022	0.072	0.064	0.036	0.057	0.049	0.042	0.036	0.0014	0.019
ProTaper Next											
Mean	0.247	-0.086	-0.332	-0.303	0.161	0.314	0.407	0.262	0.96	-0.082	-0.130
± SD	0.033	0.016	0.043	0.047	0.033	0.026	0.062	0.034	0.013	0.011	0.021
Reciproc											
Mean	0.267	-0.082	-0.291	-0.230	0.136	0.399	0.462	0.357	0.157	-0.072	-0.113
± SD	0.046	0.037	0.051	0.043	0.017	0.065	0.064	0.044	0.032	0.008	0.015
WaveOne											
Mean	0.267	-0.084	-0.300	-0.235	0.143	0.402	0.501	0.372	0.172	-0.069	-0.114
± SD	0.023	0.015	0.040	0.042	0.033	0.045	0.035	0.058	0.035	0.011	0.016

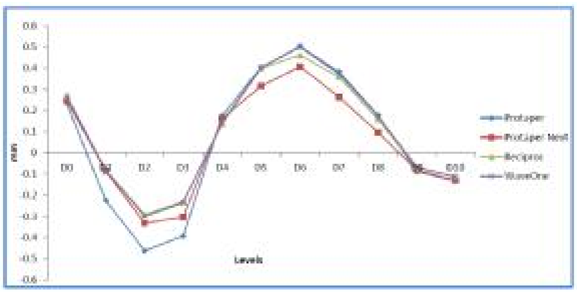

Figure 6: Line Chart of Canal Transportation

The lowest canal transportation scores were found at points D1, D4 and D9 which corresponded to the straight portion of the canal. The highest ratios were found at points D0, D2, D5 and D6 which corresponded to the foramen and initiating zones of the apical and coronal curvatures.

To identify the presence of statistically significant difference among the means of canal transportation of all groups, at each level, analysis of variance (ANOVA) test was performed. There was a high significant difference ($p < 0.001$) at D1, D2, D3, D5, D6, D7 and D8 and a none significant difference ($p > 0.05$) at other levels. The least significant difference test (LSD) was performed for multiple comparison between groups.

By using (LSD) test,

-At D1, D2, and D3 ProTaper showed the highest canal transportation than the other groups with a high significant difference ($p < 0.001$) was found among them.

-At D2, D3 the PTN showed more canal transportation than both of R and WO with a high significant difference at D3.

- While at D5, D6, d7 and D8 the PTN showed the best values of canal transportation than the the others with a high significant difference was found among them except at D7 the difference was significant between the PTN and R.

-The R and WO showed comparable values of canal transportation at all levels and the difference was none significant between them.

DISCUSSION

One of the chief determinants of quality canal shaping ability of an endodontic instrument is its ability to remain well centered within the root canal space and not make iatrogenic errors such as canal transportation **[17].**

The present study compared the effects of four file systems that have different designs, manufacturing methods, number of files, and kinematics when used to prepare simulated s-shaped canal on centering ability and canal transportation. Two file systems that were designed for use in rotary instrumentation, and two file systems that have been designed for use in reciprocation instrumentation were used for comparisons.

In the present study, the final apical preparation size was 25 for all groups. For single-file systems, the Reciproc R25 file and the WaveOne primary reciprocating file were selected. These instruments had the same tip size of 25. This was performed in accordance with the recommendation of their manufacturers as these sizes are designated for narrow and curved canals when hand instruments do not passively reach the full working length. Whereas ProTaper and ProTaperNext instruments have various apical sizes with gradual increase, Reciproc and WaveOne have omitted the conventional increments and offer apical widths of apical size 25 and 40, and the risk of transportation always increases in curved canals and with the increase of file size. Wider apical preparation might result in some canal straightening and undesirable weakening of the tooth structure, whereas minimal enlargement may leave tissue remnants and infected dentin behind. [18] Thus, the Reciproc R25 file, the WaveOne primary reciprocating file, ProTaper F2, ProTaperNext X2 file were selected for the current study.

The centering ratio can explain the ability of files to stay centered in prepared canals calculated by the formula $(X\text{sup} - X\text{inf})/Y$, which is more precise than measuring the amount of removed material. Actually, most previous studies did not include the final diameter (*y)* in the calculation, and instead considered only the amount of transportation, according to this formula, the centering ratio reach zero as *X*sup and *X*inf come to be closer to the center. The lesser the scores, the superior are the files centered in the root canal[19].

Regarding canal centering ability, when comparing the ratio at each point in all groups, the 4 NiTi instrument systems examined had comparable scores in the coronal and middle portion of the canals (D5 to D10) with no statistically significant difference was found at these points; this may be due to that all systems made from NiTi alloy and the final apical preparation sizes were 25 for all groups. Similar findings were found by a study of Burklein et al., of curved root canals in extracted teeth in which Reciproc, WaveOne, Mtwo, and ProTaper rotary instruments maintained the original curvature well with no significant differences between the different files[13].

Similarly Zhao et al., **[20]** found that PT, PTN and WO have comparable results regarding shaping ability in the coronal and middle portion of the canals in preparation of mandibular first molars. These results also agreed with Capar et al **[21]** whose compared the shaping effects of (OneShape, ProTaper Universal, ProTaper Next, Reciproc, Twisted File Adaptive and WaveOne primary on centering ability of curved mesial root canals of mandibular molar, and showed that the 6 different file systems produce similar canal centering ability in the preparation of curved mesial canals of mandibular molars.

The most previous finding showed that most instruments tended to straighten especially the apical curvature of S-shaped canals and is corroborated by several studies (Bonaccorso et al.[22]; Madureira et al., [23]. This might be due to that the influence of the coronal curve on the instruments may have declined while progressing coronally owing to the presence of another more apically located curve; this agreed with the present results obtained with PT and PTN but in contrast with results obtained with WO and R in which reciprocating single file showed good shaping effects in apical curve of S-shaped simulated canals. This agreed with (Burklein et al., [15]; Wu et al. [24] The obtained results may be due to the reciprocation motion or the single file used with WO and R.

At the level of D0 (apical foramen) the ProTaper files showed superior centering ability than the ProTaperNext which had comparable scorces with Reciproc and WaveOne. This may be due to use more successive files in ProTaper system. Similar finding was found in the research of Göktürk et al. [25], who studied the shaping ability of greater HeroShaper, Revo-S, ProTaper Universal, Mtwo, and RaCe. The HeroShaper and Revo-S showed lower centering ability than the other groups in simulated curved canals in the apical area. Similar results were reported by Yoo and Cho [26], who compared the shaping ability of Reciproc and WaveOne instruments compared with ProTaper and Profile NiTi instruments in simulated curved canals indicated that in the groups of Reciproc and WaveOne, the instrument had a tendency to maintain the centering ability better than ProTaper. This may be attributed to the sharp cutting edges and the multiple tapers along the cutting surface of the ProTaper files, especially the large increase in taper size from 0.04 to 0.07 (S2 to F1) this may increase the rigidity of the file consequently more resin will be removed from the one side of the canal than the other. Additionally the brushing action which is recommended with this system may cause uneven resin removal, these factors may explain relatively low centering ability of this system compared with other NiTi instruments at these measuring levels. ProTaperNext showed comparable values with both of the two reciprocating groups (WaveOne and Reciproc) and there was no significant difference among them except at D2, D3 and D4 (apical curve) at which the two reciprocating systems produced better centering ability.

Although at the apical curvature the Reciproc and WaveOne preserved the canal best and showed a better centering ability than PTN; the PTN preserved the coronal curvature best with no significant difference among the groups at this area. This might be due to the taper of PTN varies on a different part of this file or because of the asymmetric motion, which lead to only two edges are in contact with canal wall at time.

Similar findings were obtained by Wu et al. [24] who compared the shaping ability of the ProTaper Universal, WaveOne and ProTaper Next in simulated L-shaped and S-shaped root canals respectively and showed that PTN could better preserve the coronal curvature than PTU and WO in simulated S-Shaped canals.

At all measuring levels, there was no significant difference between WaveOne and Reciproc. This agreed with Saber et al., [27] compared shaping ability of WaveOne, Reciproc and One Shape in severely curved root canals of extracted teeth showed the same finding these results also agreed with Burklein et al. [13, 28]; Capar et al. [29]

Canal transportation demonstrates the straightening tendency of the file as it prepares the canal. In this study, all tested rotary systems resulted in canal transportation at most examined levels, a finding that is consistent with other studies that showed canal transportation occurs mostly in curved canals at the outer wall of the apical portion of the canal and the inner aspect of the mid-root of the canal [21]. The lowest canal transportation was found at points D1, D4 and D9 which corresponded to the straight portion of the canal. The highest ratios were found at points D2, D5, D6 which corresponded to the foramen and initiating zones of the curvature.

At apical foramen point (D0) the four groups showed no statistically significant difference among them in canal transportation. This might be because of the noncutting tip design they all possess, which functions only as a guide to allow easy penetration with minimal apical pressure, and the standardized master apical file size, this agreed with Hashem et al. [29], whose compared the effect of Revo-S, Twisted file, ProFile GT Series X and ProTaper on volumetric changes and transportation of curved root canals, and found that all tested rotary systems produced canal transportation at the apical point in the same manner.

Similarly at D4, D9, D10 there was no statistically significant difference among the four groups. While there was a high statistically significant difference among the groups at D1, D2, D3, D5, D6 , D7 and D8 these points represent the apical and coronal curvature and probably these differences could be noticed because , at these points of the curvature there is a higher stress on the instrument owing to the critical changes on the relationship of diameter and flexibility this agreed with the study of Farah and Al-Gharrawi **[30],** in which they found a statistically significant difference among the Protaper , Biorace and SAF groups at level 6 mm. ProTaper instruments showed the greatest material removal on the inner sides of the apical curvatures and outer side of coronal curvatures, resulting in a marked straightening of the canals, which is in accordance with a recent study of Göktürk et al. **[25],** who restudied the shaping ability of five different systems in S-shaped canals in resin blocks and showed that the ProTaper instruments have a tendency to straighten both curved parts of the canal this may be due to the ProTaper Universal finishing files have a greater taper at the apical part of the instrument (F1, .07 and F2, .08), leading to increased stiffness or rigidity, similar findings obtained by

The ProTaperNext showed the lowest canal transportation scores at the coronal curvature compared with other groups .It may be partly explained by the smaller overall and apical taper of PTN X2 (size 25/.06) compared with PTU F2, reciproc R25 and WaveOne primary files (all tips are size 25/.08 or this might have been because of the offset asymmetric design. In general, besides the dimension of the instrument, other factors including the instrument design, and the way the instruments are used can influence canal transportation during instrumentation. This observation is in agreement with a previous study of Saleh et al. [31],

that compared the shaping effects of the F360 and OneShape instruments have a taper of 0.04 and 0.06, respectively, with the 2 reciprocating instruments (i.e., WaveOne and Reciproc) which characterized by a taper of 0.08 over the first 3 mm from the tip in S-shaped canals and found the Reciproc and WaveOne removed more resin compared with F360 and OneShape and that the resulting canal widths were wider after preparation with these reciprocating single files due to these files appear to be less flexible compared with other files.

The results of the present study are in agreement with several previous studies like Yoo and Cho [26] using simulated canals in resin blocks and found that WaveOne and Reciproc produced similar canal straightening and maintained the original canal curvature equally good and better than ProTaper and ProFile .

Also**,** Bürklein et al., **[13]** reported that WaveOne, Reciproc and OneShape maintained the original curvature of severely curved canals in extracted teeth equally well and produced similar canal transportation.

Although the difference between WO and R was not large enough to be statistically significant, the R instruments produced less canal transportation than WO at almost levels. Their different cross-sectional designs may explain these results. R has a double-cutting edge S-shaped geometry, whereas WO has a modified, convex, triangular cross-section with radial lands at the tip and a convex triangular cross-section in the middle and coronal portion of the instrument.

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