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Comparative Evaluation of Shaping Ability of Different Rotary Nickel Titanium Single File Systems in Root Canals of Mandibular Molars: An In-Vitro Study.

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ABSTRACT

Background: Cleaning and shaping is a critical aspect of endodontic treatment as it influences the outcome of the subsequent phases of canal irrigation and filling and the success of the treatment itself. The goal of instrumentation is to produce a continuously tapered preparation that maintains the canal anatomy, without any deviation from the original canal curvature, facilitating optimal irrigation, debridement, and placement of local medicaments and permanent root filling, at the same time retaining the integrity of the radicular structures. AIM: The aim of the study was to compare the shaping ability of four different Nickel-Titanium single file systems in mesial roots of mandibular first molars. **Methods**: Eighty freshly extracted mandibular molars, extracted for periodontal reasons were used for the study A muffle-block was constructed as given by Aviad et al.[59] After sealing the apices with wax, the canals were mounted in the muffle-block using self-cure acrylic resin. After complete polymerization of the resin, the block was removed from the model. The blocks were sectioned horizontally at three sites (coronal, middle and apical) by a thin cutting disk (0.3-mm thick) at two levels: one 3 mm from the apex and the other 6 mm from the apex. The disk was mounted on an electric saw (CIR-SAW, Confident Dental Equipments Ltd, India) for cutting the blocks. Photographs were taken of all three cross-sections of each tooth using a DSLR Camera (Nikon Digital, Tokyo, Japan) at a fixed position. The sections were reassembled in the muffle. The specimens were randomly divided into the following four groups: Group I: Prepared using Reciproc rotary files. Group 2: Prepared using WaveOne rotary files. Group 3: Prepared using OneShape rotary files. Group 4: Prepared using F6 SkyTaper rotary files. **Results**: The results of the present study revealed that the use of Reciproc and WaveOne instruments resulted in significantly better canal centering ability than the use of OneShape instruments and F6 SkyTaper ($P < 0.05$) Reciproc and WaveOne exhibited less canal transportation than OneShape and F6 SkyTape There were no significant differences in the canal transportation between Reciproc and WaveOne. And also no significant difference between OneShape and F6 SkyTaper. One Shape instruments required significantly less time to prepare the root canals followed by Reciproc, WaveOne and F6 SkyTaper ($P < 0.05$). **Conclusion**: Reciproc and WaveOne instruments respected the original canal curvature better than OneShape and F6 SkyTaper files.

Keywords: Centering Ability; F6 SkyTaper; OneShape; Reciproc; WaveOne.

INTRODUCTION

Canal preparation is one of the major steps in root canal treatment and directly related to subsequent disinfection and filling.[1] The aim of root canal shaping is to form a continuously tapered shape with smallest diameter at apical foramen and largest at the orifice so as to allow effective irrigation and filling and not change the original canal curvature. However, traditional stainless steel hand instruments are time consuming and often fail to achieve the desired root canal shape, especially in narrow and curved canals, which in turn hinders filling. These instruments are stiff, thus increase the incidence of canal aberrations, such as zips, elbows, ledges and perforations, particularly with increasing instrument size. In order to overcome the short-comings of these traditional instruments, nickel- titanium (Ni-Ti) instruments have been developed.

It has been demonstrated that rotary Ni-Ti instruments are able to maintain canal shape even in severely curved canals. However despite these positive results, manufactures continue to introduce

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Ni-Ti systems with new blade designs and tapers, claiming safety and ease of use.[2]
Initially most of the Nickel Titanium file systems used multiple files to achieve the goal of successful endodontic treatment.[3]
Recent advances for endodontic canal preparation have focused on the concept "Less is more". Thus a single-file technique has been developed for shaping the vast majority of canals, regardless of their length, diameter, or curvature.[4]
Number of manufacturers have adopted single-file technique and introduced different files with a unique flute design, cross-sectional shape, alloy, and working motion to the market. Canal preparations have become faster with the single file technique.[5] In addition, the single use of files reduces the risk of file separation and prevents possible cross-contamination among patients.[6]
There are two different motions in which single file systems can be used, reciprocation and continuous rotation.

1. **Reciprocal motion:** The reciprocating working motion consists of a counter clockwise (cutting direction) and a clockwise motion (release of the instrument), while the angle of the counter clockwise cutting direction is greater than the angle of the reverse direction. Due to the fact that the counter clockwise angle is greater than the clockwise one, it is claimed that the instrument continuously progresses towards the terminus of the root canal. Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) belong to this group of single file system.
2. **Continuous rotation:** Another concept of instrumentation is that a single instrument is to be used in a full clockwise rotation. OneShape (Micro Mega, Besancon, France) and F6 SkyTaper (Komet Brasseler, Lemgo, Germany) belong to this group of single file systems.

Extensive review of literature has shown paucity of studies that have been done which compares the shaping ability of these single continuous and reciprocating file systems. Therefore the aim of this study was to compare the shaping ability of these four different single file systems in mesial root of mandibular molars.

MATERIALS AND METHODS

Eighty freshly extracted mandibular molars, extracted for periodontal reasons collected from the Department of Oral and Maxillofacial Surgery, GDC Srinagar were used for the study.

Criteria for samples

Teeth with completely formed apices and mesio-buccal canal curvature between 20º and 35º assessed according to Schneider's technique.57

Exclusion criteria for sample selection:
Teeth with canal curvature greater than 35°.
Teeth with open apices.
Teeth with calcified canals.
Teeth with anatomical variations.
Teeth with caries and restorations invading the pulp.

Equipments used in the study

1. X-Smart plus endomotor (Dentsply, Maillefer, Ballaigues, Switzerland).
2. DSLR Camera (Nikon digital, Tokyo, Japan).
3. Diamond discs (0.3mm diameter).
4. Radiographic jig.
5. Modified Bermante muffle system.
6. Digital Vernier calliper.

Materials used in the study

RECIPROC rotary files (VDW, Munich, Germany).
WAVEONE rotary files (Dentsply, Maillefer, Ballaigues, Switzerland).
ONESHAPE rotary files (MicroMega, Besancon, France).
F6 SKYTAPER rotary files (Komet, Brasseler, Lemgo, Germany).
17% EDTA solution (Prevest Denpro, India).
5% NaOCl (Prevest Dentpro, India).
0.9 Physiologic saline (Punjab formultions Ltd, India).

Selection of root canals

The teeth were disinfected in 5% sodium hypochlorite solution for 30 min. The Teeth were then cleaned of calculus, soft tissue tags, debris and attached bone by a periodontal curette and washed with distilled water. The teeth were kept in normal saline until used. Radiographs were taken to evaluate the mesial roots. In each tooth specimen, any one canal of the mesial root was standardized to 9mm length by removing the crown using diamond discs. The canals were controlled for apical patency with ISO no #10 k –files (Dentsply Maillefer, Ballaigues, Switzerland). Only teeth whose canal width near the apex was approximately size 15 were included; this was evaluated with size 15 K-file. Working length was established at 9 mm, and was determined by subtracting 0.5 mm from the length at which the tip of a size #15 K-file could be visualized.
A radiographic platform, as described by previous researchers was used to take standardized radiographs prior to instrumentation with the k-file size #10 has been inserted into the buccal or lingual canal in order to determine the degree and radius of the curvature using periapical Kodak Insight films (Eastman Kodak Company, Rochester, NY).[58] The X-ray tube (Siemens, Heliodent, Germany) was aligned perpendicular to the root canal. The

exposure time (0.125; 70Kv, 7mA) was the same for all radiographs. The degree and radius of canal curvature were obtained from these preoperative radiographs with a computer program Corel draw X6 software tools using Schneider technique.

Preparation of model

A muffle-block was constructed as given by Aviad et al.[59] After sealing the apices with wax, the canals were mounted in the muffle-block using self-cure acrylic resin (Orthoplast; Vertex, Zeist, the Netherlands). After complete polymerization of the resin, the block was removed from the model, the wax removed and the apical foramen exposed. The blocks were sectioned horizontally at three sites (coronal, middle and apical) by a thin cutting disk (0.3-mm thick) at two levels: one 3 mm from the apex and the other 6 mm from the apex. The disk was mounted on an electric saw (CIR-SAW, Confident Dental Equipments Ltd, India) for cutting the blocks. Photographs were taken of all three cross-sections of each tooth using a DSLR Camera (Nikon Digital, Tokyo, Japan) at a fixed position. The sections were reassembled in the muffle. The specimens were randomly divided into the following four groups:

Root canal instrumentation

Group 1: In this group, one canal of mesial root of twenty madibular first molars was prepared using Reciproc rotary files. The R25 Reciproc file (tip size = 25, apical taper = 0.08) was used in a programmed reciprocating motion generated by the X-Smart plus motor (Dentsply Maillefer) in the ‘‘RECIPROC ALL’’ mode. The files were used in a pecking motion (amplitude less than 3 mm, 3 pecks) according to the manufacturer’s instructions.

Group 2: In this group, one canal of mesial root of twenty mandibular first molars was prepared using WaveOne rotary files. The WaveOne Primary file (tip size = 25, apical taper = 0.08) was used in a programmed reciprocating motion generated by the X-Smart plus motor (Dentsply Maillefer) in the ‘‘WAVE ONE ALL’’ mode. The files were used in a pecking motion (amplitude less than 3 mm, 3 pecks) according to manufacturer’s instructions.

Group 3: In this group, one canal of mesial root of twenty mandibular first molars was prepared using OneShape rotary files. The OneShape file (tip size=25, taper=0.06) was used in full clockwise rotation with a rotational speed of 400 rpm generated by the X-Smart plus motor (Dentsply Maillefer), and the torque was adjusted to 4 N cm. The files were used in a slight pecking motion according to the manufacturer’s instructions.

Group 4: In this group, one canal of mesial root of twenty mandibular first molars was prepared using F6 SkyTaper rotary files. The SkyTaper file (tip size = 25, taper = 0.06) was used in full clockwise rotation with a rotational speed of 300 rpm generated by the X-Smart plus motor (Dentsply Maillefer), and the torque was adjusted to 1.8 Ncm. The files were used in a slight pecking motion according to the manufacturer’s instructions.

All canals were prepared by a single experienced operator. Copious irrigation with 5.0 ml of 5% NaOCl solution using side-vented close ended needles. Finally, the canal were irrigated with 5.0 ml of a 17% EDTA for 3 minutes, followed by 5 ml of 5% NaOCL. All the canals were rinsed with 10 ml of 0.9% sterile saline. After instrumentation, all sectioned canals were separated, and then photographed in the same manner as pre-instrumentation photographs. The shaping ability of the rotary instruments was evaluated using the computer program Corel draw X6 software.

Assessment of the canal preparation

Centering ability: Centering ability of the instruments towards the original canal was evaluated by the ratio of (a1-a2) ÷ (b1-b2) or (b1-b2) ÷ (a1-a2) according to the method developed by Gambil et al, in this formula, a1 and b1 represent the thickness of the internal and external sides of the canal wall, respectively, mesiodistally, before instrumentation and a2 and b2 after instrumentation.[9] If these numbers were not equal, the lower number was considered as numerator of the ratio. A result with ratio 1 indicates that the canal has remained centered and a result less than 1 indicates deviation of the canal outward, and result of more than one show that the canal deviates inward.

Canal transportation: The amount of canal transportation was determined by measuring the shortest distance from the edge of uninstrumented canal to the periphery of the root (mesial and distal) and then comparing this with the same measurements obtained from the instrumented images. The following formula was used for the calculation of transportation at each level for both groups: (a1-a2)-(b1-b2).

Statistical Methods: Statistical software SPSS (version 20.0) and Microsoft Excel were used to carry out the statistical analysis of data. Descriptive statistics of data including mean, standard deviation, minimum and maximum values were reported. The normality test of Kolmogorov-Smirnov (K-S) and Levene’s variance homogeneity test were applied to the data. The data were normally distributed, and there was homogeneity of variance amongst the groups. Analysis of variance (ANOVA) and the post hoc Tukey-HSD test were used for analysis of data. Graphically the data was presented by bar diagrams. A P-value of less than 0.05 was considered statistically significant. All P-values were two tailed.

RESULTS

A total of 80 samples, 20 from each groups were taken. Distribution of samples in four groups has been shown in Table 1 below:

Table 1: GroupWise Distribution of Samples.

S.No.	Group	Description	No. of samples
1.	1	Canals were shaped using Reciproc system	20
2.	2	Canals were shaped using WaveOne system	20
3.	3	Canals were shaped using OneShape system	20
4	4	Canals were shaped using F6 SkyTaper	20

The mean centering ability of the canals is shown in [Table 2].

Table 2: Descriptive statistics of canal centering ability among various groups.

		Mean	SD	Min	Max	P-value
Coronal	Group 1	0.636	0.084	0.51	0.82	<0.001*
	Group 2	0.572	0.071	0.50	0.81	
	Group 3	0.446	0.066	0.32	0.60	
	Group 4	0.422	0.089	0.25	0.55	
Middle	Group 1	0.619	0.069	0.48	0.70	<0.001*
	Group 2	0.605	0.104	0.50	0.81	
	Group 3	0.471	0.056	0.38	0.55	
	Group 4	0.449	0.087	0.25	0.56	
Apical	Group 1	0.625	0.074	0.46	0.73	<0.001*
	Group 2	0.652	0.107	0.47	0.87	
	Group 3	0.483	0.086	0.25	0.57	
	Group 4	0.496	0.105	0.27	0.74	

*Statistically Significant Difference (P-value<0.05)

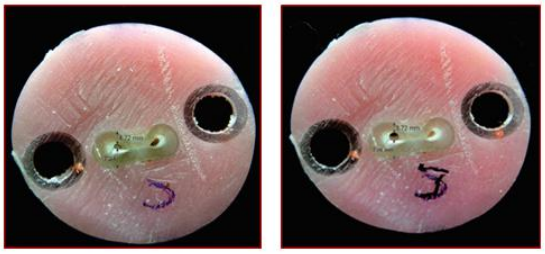

Figure 1: Preparation of coronal third.1a: pre-instrumentation and 1b: post-instrumentation

Figure 2: Preparation of middle third. 2A: pre-instrumentation. 2B: post-instrumentation.

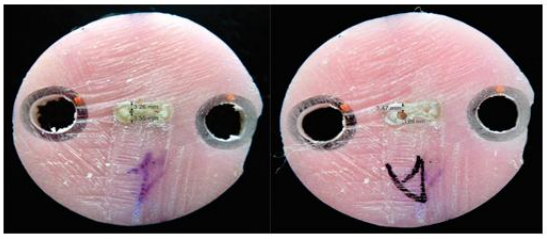

Figure 3: Preparation of apical third. 3A: pre-instrumentation. 3B: post-instrumentation.

The statistically significant intergroup difference was observed at coronal, middle and apical level (P <0.05).

At coronal level, Reciproc (0.636±0.084) showed better canal centering ability followed by WaveOne (0.572±0.071), OneShape (0.446±0.066) and F6 SkyTaper instruments (0.449±0.087m).

At middle level, Reciproc (0.619±0.069) showed better canal centering ability followed by WaveOne (0.605±0.104), OneShape (0.471±0.056) and F6 SkyTaper instruments (0.12±0.04 mm).

At apical level, WaveOne (0.652±0.107) showed better canal centering ability followed by Reciproc (0.625±0,074), F6 SkyTaper (0.496±0.105) and OneShape instruments (0.483±0.086).

Table 3: Intergroup comparison of canal centering ability among various groups.

Intergroup Comparison	P-value		
	Coronal	Middle	Apical
1 vs 2	0.055	0.942	0.802
1 vs 3	<0.001*	<0.001*	<0.001*
1 vs 4	<0.001*	<0.001*	<0.001*
2 vs 3	<0.001*	0.002*	<0.001*
2 vs 4	<0.001*	<0.001*	<0.001*
3 vs 4	0.767	0.825	0.972

*Statistically Significant Difference (P-value<0.05)

Reciproc and WaveOne exhibited better centering ability than OneShape and F6 SkyTaper ($p < 0.05$). There were no significant differences in the centering ratio between Reciproc and WaveOne instruments. And also there were no significant difference between OneShape and F6 SkyTaper instruments.

Thus the order of centering ability in different groups was as follows:

Reciproc>WaveOne>OneShape>F6 SkyTaper.

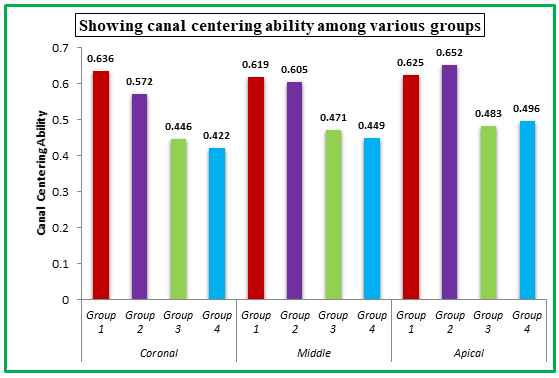

Table 4: Descriptive statistics of canal transportation among various groups.

		Mean	SD	Min	Max	P-value
Coronal	Group 1	0.110	0.022	0.03	0.13	<0.001*
	Group 2	0.109	0.032	0.03	0.16	
	Group 3	0.154	0.043	0.08	0.30	
	Group 4	0.174	0.048	0.12	0.33	
Middle	Group 1	0.100	0.026	0.06	0.16	<0.001*
	Group 2	0.105	0.021	0.07	0.15	
	Group 3	0.131	0.042	0.05	0.19	
	Group 4	0.137	0.021	0.09	0.18	
Apical	Group 1	0.052	0.015	0.02	0.07	<0.001*
	Group 2	0.054	0.015	0.02	0.07	
	Group 3	0.078	0.021	0.04	0.12	
	Group 4	0.124	0.020	0.09	0.17	

*Statistically Significant Difference (P-value<0.05)

The statistically significant intergroup difference was observed at coronal, middle and apical level (P <0.05).

At coronal level, WaveOne (0.109±0.032) showed less canal transportation followed by Reciproc (0.110±0.022) and OneShape (0.154±0.043) and F6 SkyTaper instruments (0.174±0.048).

At middle level, Reciproc (0.100±0.026) showed less canal transportation followed by WaveOne (0.105±0.021) and OneShape (0.131±0.042) and F6 SkyTaper instruments (0.137±0.021 mm).

At apical level, Reciproc (0.052±0.015) showed less canal transportation followed by WaveOne (0.054±0.015) and OneShape (0.078±0.021) and F6 SkyTaper instruments (0.124±0.020).

Table 5: Intergroup comparison of canal transportation among various groups.

Intergroup Comparison	P-value		
	Coronal	Middle	Apical
1 vs 2	0.998	0.960	0.985
1 vs 3	0.002*	0.025*	<0.001*
1 vs 4	<0.001*	0.001*	<0.001*
2 vs 3	0.002*	0.034*	<0.001*
2 vs 4	<0.001*	0.004*	<0.001*
3 vs 4	0.346	0.694	<0.001*

*Statistically Significant Difference (P-value<0.05)

Reciproc and WaveOne exhibited less canal transportation than OneShape and F6 SkyTaper instruments ($p < 0.05$). There were no significant differences in the canal transportation between Reciproc and WaveOne. And also there were no significant differences between OneShape and F6 SkyTaper instruments.

Thus the order of canal transportation in different groups was as follows:

Reciproc<WaveOne<OneShape<F6 SkyTaper.

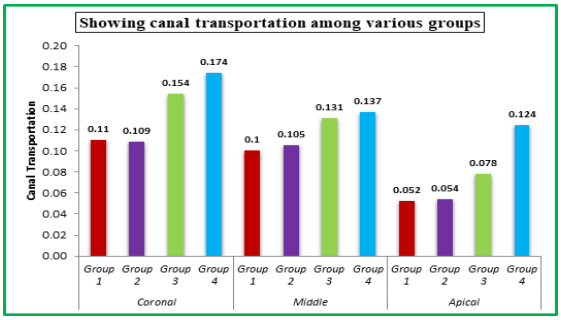

Table 6: Descriptive statistics of preparation time (seconds) among various groups

	Mean	SD	Min	Max	P-value
Group 1	76.4	7.03	65	87	<0.001*
Group 2	102.7	4.67	96	115	
Group 3	61.7	2.91	57	67	
Group 4	120.6	3.19	115	126	

*Statistically Significant Difference (P-value<0.05)

Table 7: Intergroup comparison of preparation time among various groups

Intergroup Comparison	P-value
1 vs 2	<0.001*
1 vs 3	<0.001*
1 vs 4	<0.001*
2 vs 3	<0.001*
2 vs 4	<0.001*
3 vs 4	<0.001*

*Statistically Significant Difference (P-value<0.05)

The mean time taken for canal preparation with Reciproc and OneShape files was significantly lesser than the time taken by the WaveOne and F6 SkyTaper ($P < 0.05$). The mean time taken for canal preparation with WaveOne was significantly lesser than the time taken by the F6 SkyTaper files ($P < 0.05$).

Thus the order of mean time taken in different groups was as follows: OneShape< Reciproc< WaveOne< F6 SkyTaper.

DISCUSSION

Cleaning and shaping is a critical aspect of endodontic treatment as it influences the outcome of the subsequent phases of canal irrigation and filling and the success of the treatment itself. The goal of instrumentation is to produce a continuously tapered preparation that maintains the canal anatomy, without any deviation from the original canal curvature, facilitating optimal irrigation, debridement, and placement of local medicaments and permanent root filling, at the same time retaining the integrity of the radicular structures.[57] Although several techniques have been developed to minimize errors deriving from root canal instrumentation there are still difficulties in effectively preparing curved and flattened canals because of their complex internal anatomy.

The introduction of nickel-titanium (NiTi) instruments allowed a safer and easier preparation of canals with complex anatomic characteristics. The rotary techniques of instrumentation significantly improved during the last few years, especially with the development of new rotary file designs.[60]

Instruments that can follow the path of the canal and are able to remain centered in the canal, are good choices for root canal preparation.[61] Many studies have shown better efficacy of rotary instruments in comparison with hand instruments.[62]

The aim of our study was to compare the shaping ability of two reciprocating single file systems, Reciproc and WaveOne, and two continuous rotation single file systems, OneShape and F6 SkyTaper, in mandibular teeth. Size 25 files were selected for all systems in this study according to the recommendations of the manufacturers because this size is designated for majority of canals. Although increasing the apical preparation size may improve the cleaning efficiency and irrigation of the apical portion of the root canals, the risk of canal transportation also increases because the flexibility of the root canal instruments decreases.[63]

In the present study we evaluated the canal preparation using four NiTi rotary single file systems on natural human teeth. The parameters assessed were canal transportation, canal centering ability and the time taken for instrumentation. Human teeth were chosen as they simulate clinical conditions better than acrylic blocks. Acrylic resin is not an optimum material to reproduce the micro hardness of testing rotary instruments because it does not emulate dentin or the anatomic variations (enlargements, oval root canals, etc).[38] It has been mentioned that shape of the flutes of NiTi files was altered when used in plastic blocks, which was not seen with natural teeth 64; moreover, rotary instrument generated heat when used inside the resin block, which softened the resin material.[65] Other studies have shown that the softening of the resin block lead to binding of cutting blades and increased chance of instrument fracture.[66]

Despite the variations in the morphology of natural teeth, attempts were made in the present study to ensure comparability of the experimental groups. Therefore, the teeth in all groups were balanced with respect to the apical diameter and the length (distance between apex and CEJ) of the root canal, and based on the initial radiograph, the teeth were also balanced with respect to the angle of canal curvature. The curvatures of all root canals ranged between 20° and 35° were used in the study.

The results of the present study revealed that the use of Reciproc and WaveOne instruments resulted in significantly better canal centering ability than the use of OneShape instruments and F6 SkyTaper ($P < 0.05$). The statistically significant intergroup difference was observed at coronal, middle and apical level ($P < 0.05$). At coronal level and middle level, Reciproc (0.619±0.069) showed better canal centering ability followed by WaveOne (0.605±0.104), OneShape (0.471±0.056) and F6 SkyTaper (0.12±0.04 mm). At apical level, WaveOne (0.652±0.107) showed better canal centering ability followed by Reciproc (0.625±0,074), F6 SkyTaper (0.496±0.105) and OneShape (0.483±0.086).

Reciproc and WaveOne exhibited less canal transportation than OneShape and F6 SkyTaper ($p < 0.05$). There were no significant differences in the canal transportation between Reciproc and WaveOne. And also no significant difference between OneShape and F6 SkyTaper. The statistically significant intergroup difference was observed at coronal, middle and apical level ($P < 0.05$). At coronal level, WaveOne (0.109±0.032) showed less canal transportation followed by Reciproc (0.110±0.022) and OneShape (0.154±0.043) and F6 SkyTaper (0.174±0.048). At middle level, Reciproc (0.100±0.026) showed less canal transportation followed by WaveOne (0.105±0.021) and OneShape (0.131±0.042) and F6 SkyTaper (0.137±0.021 mm). At apical level, WaveOne (0.052±0.015) showed less canal transportation followed by Reciproc (0.054±0.015) and OneShape (0.078±0.021) and F6 SkyTaper (0.124±0.020).

Thus the findings that Reciproc and WaveOne instruments resulted in significantly better canal centering ability and less canal transportation can be explained by the following reasons: first Wave One and Reciproc instruments are made from M-wire alloy whereas OneShape is made from conventional martensitic NiTi. M-wire NiTi is characterized by superior flexibility compared with conventional NiTi.[67] M-Wire has physical and mechanical properties that can render root canal instruments more flexible and fatigue resistant than those made from conventionally martensitic

NiTi.[68] Secondly, WaveOne and Reciproc were used in a reciprocal motion. This working motion has been associated with well centered preparations and reduced incidence of procedural errors.[69] Furthermore, this motion extends the lifespan of instruments in comparison with continuous rotation.[70,71] Thirdly, the differences may be explained by the different design features of the instruments used. WaveOne instruments have variable cross-sections along the working part that change from a concave triangular cross-section with radial land at the tip to a neutral rake angle with a triangular convex cross- section in the middle part and near the shaft.[72] The radial lands in combination with the reciprocating working motion are claimed to keep the WaveOne instrument centred whilst advancing apically into the root canal.[73] Reciproc instruments have an S-shaped cross-section with two sharp cutting edges along the entire working part.[72] Obviously, instruments having this S-shaped cross-sectional design are characterized by a relatively good shaping ability when used either in full clockwise rotation or in a reciprocating motion.[73,74]

The OneShape instruments have a variable 3 cutting-edge design at the tip region that progressively changes from 3 to 2 cutting edges in the middle part, whilst near the shaft, the instrument has 2 cutting edges.[74] This design used in continuous rotation at a relatively higher speed allows the instruments to rapidly progress into the curved root canals. This could create some stress that might have resulted in the observed canal straightening and apical transportation. The results of this study are in agreement with several previous studies.[72-77] Burklein et al reported that WaveOne, Reciproc and OneShape maintained the original curvature of severely curved canals in extracted teeth well.[65,67] Also Capar et al using cone-beam computed tomographic (CBCT) imaging found that WaveOne, Reciproc and OneShape maintained root canal curvature equally well and produced similar canal transportation during the preparation of mesial canals of mandibular molars.[77] However, the present results obtained with WaveOne and Reciproc are in contrast with other studies, in which the continuous single file systems showed better shaping ability than reciprocating single file systems.[78,79] This might be attributed to the use of resin blocks which don't simulate clinical condition better as compared to natural teeth. Study findings may vary because of the different hardness between simulated resin canals and human root dentin.[80]

The preparation time is dependent on the technique, the number of instruments used, operator experience, and other details regarding the study design.[78] In our study, the preparation time included active instrumentation as well as the time required for changing instruments, and cleaning the flutes of the instruments. OneShape instruments required significantly less time to prepare the root canals followed by Reciproc, WaveOne and F6 SkyTaper ($P < 0.05$). Our results are in agreement with previous studies.[75,76] In general, all single file systems were able to prepare the canals relatively fast; thus, from a clinical perspective, the obtained differences might be of subordinate importance.

To date very limited literature exists to evaluate the shaping ability of these reciprocating rotary single file systems and continuous rotary single file system. Extensive review of literature shows, no such study have been done which compares the shaping ability of F6 SkyTaper file with Reciproc, WaveOne and OneShape file systems. Further studies are required to provide more information about the preparation technique, new instruments, and methodologies used to evaluate the action of the endodontic instruments inside the root canals, aiming at solving the problems inherent to such an important and difficult phase of endodontic therapy.

CONCLUSION

Within the limitations of the study, it can be concluded that:

- Reciproc and WaveOne instruments respected the original canal curvature better than OneShape and F6 SkyTaper files.
- The use of OneShape and Reciproc instruments required less time to prepare the curved canals compared with WaveOne and F6 SkyTaper.
- All the instruments maintained original canal curvature, enlarge the canals three dimensionally, and were safe to use with limited applications.

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