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Original Research Article

Comparative evaluation of shaping ability, canal transportation and preparation time of four single: File systems in J shaped simulated canals

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Abstract

Aim & Objectives: To compare the shaping ability, Canal Transportation and preparation time of four single file systems in J shaped simulated canals.
Introduction: Shaping the root canal is a critical step in endodontic therapy, requiring precise instrumentation and technique. Rotary and reciprocating single-file systems have revolutionized endodontics, offering enhanced efficiency, precision, and reduced procedural errors.
Materials and Methods: 40 J shaped simulated canals were selected for the study. Before canal preparation, the canals were stained with black ink and were photographed using a digital camera (Pre-Operative image) at a fixed position. The groups were randomly distributed into four groups (n=10).Group 1: Hyflex EDM file (HEDM), Group 2: One Shape file (OS) Group 3: WaveOne GOLD file (WOG) and Group 4 One RECI file (OR). After canal preparation with the above mentioned files, the canals were stained with red ink and were photographed (Post-Operative Image) from a fixed position. Pre-operative (pre op) and post-operative (post op) images were superimposed using Adobe Photoshop CC imaging software.
Results: In this study, HEDM file revealed a significantly higher canal width at Apical, Middle and Coronal 1/3rd as evaluated against other endodontic file systems ($p < 0.001$) followed by WOG file, OS file and OR file. OR file in reciprocating motion showed the minimum canal transportation (Apical and middle) which was statistically significant at $p<0.05$ followed by OS file, WOG file and HEDM file. OS file recorded the least amount of time required for canal preparation which was statistically significant at $p < 0.001$ followed by OR file, HEDM file and WOG file.
Conclusion: Group 1 (HEDM) resulted in maximum Shaping ability followed by Group 3, Group 2 and Group 4 which was statistically significant at $p<0.05$. All files showed a marked tendency to straighten shaped canal. Group 4 (OR) in reciprocating motion showed the minimum canal transportation at Apical one third which was statistically significant at $p<0.05$ followed by Group 2, Group 3 and Group1. Group 2 (OS) resulted in least preparation time as compared to Group 4, Group 1 and Group 3 which was statistically significant at $p<0.001$.

Keywords: Canal transportation, Canal preparation time, Canal taper, Hyflex EDM file, J shaped simulated canals , One RECI file, One Shape file, Shaping ability, WaveOne GOLD file

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1. Introduction

The goal of instrumentation is to produce a continuously tapered preparation that maintains the canal anatomy, keeping the foramen as small as possible without any deviation from the original canal curvature.[1] Schilder has emphasized that root canal preparation should present a flare shape from coronal to apical, preserving the apical foramen and not altering the original canal curvature.[2] However, in curved canals these goals are not easily attainable, and root canal instrumentation becomes difficult because there is a tendency for all preparation techniques and instruments to divert the prepared canal away from its original axis.[3,4]

Nickel titanium (NiTi) endodontic files possess properties such as super elasticity, shape memory, flexibility, its ability to conform to the canal curvature and fracture resistance that differentiates it from other metals, such as stainless steel.[5,6]

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Resin blocks with simulated root canals are generally used to evaluate the shaping ability of different endodontic files due to its standardized root anatomy.[7,8] One of the common endodontic errors during the biomechanical preparation of curved root canals is Canal transportation. Root canal transportation occurs as two components i.e., direction and deviation. Direction is an excessive root canal dentine off the main tooth axis of the root canal. Deviation is change in original root canal path.[9,10] The single-file systems in endodontic has facilitated the multi file rotary instrumentation procedures into a single-step. The main advantage of single file system is that it decreases the incidence of file separation and cross contamination in patients.[11]

Nickel-titanium (NiTi) instruments have been made to utilize in continuous rotation mode with controlled speed and torque since their introduction in the 1990s. In circumstances of curved or narrow canals, it has good cutting efficiency with safer and more concentrated preparation.[12] Reciprocating mode of rotation has been introduced with the intent to extend the lifespan of NiTi instruments and its resistance to fatigue in comparison to continuous rotation.[13]

Hyflex EDM file; (HEDM, Coltene/Whaledent, Switzerland) and OneShape file; (OS, Micromega, France) are single file system in continuous rotation motion. WaveOne GOLD file; (WOG, DentsplyMalliefer, Switzerland) and One RECI file (OR, Micromega, France) are single file system in reciprocating motion. Hyflex EDM files (Coltene/ Whaledent, Switzerland) are manufactured using electrical discharge machining (EDM) process. This files distinctive qualities are attributed to a cutting-edge technology known as "Electrical Discharge Machining." Spark erosion is used in this novel manufacturing technique to harden the NiTi file's surface, improving its resistance to fracture, cutting ability and offering controlled memory effect.[14]

One shape file (Micromega , France file) (OS) features an asymmetric horizontal cross-section with 3 cutting edges in the tip region, transitioning to 2 cutting edges in the coronal region via a modified S-shaped cross-section.[15] WaveOne gold (WOG; Dentsply Maillefer, Ballaigues, Switzerland) is the reciprocating single-file systems. WOG files are subjected to a unique heat treatment and have an alternating off-centre parallelogram-shaped cross-section. It is hypothesized that these WOG file design elements increase flexibility while reducing apical transportation and screw-effect. One RECI (Micro mega, France) is a reciprocating single-file system, manufactured from a 1mm diameter wire, heat treated (C-wire) with an asymmetric cross-sectional design and found to be minimally invasive with root canal centring ability.[16]

In our review of literature, there has no study done to compare Shaping ability, Canal Transportation and preparation time of OR file with other reciprocating and continuous motion files in simulated J shaped canals. The null hypothesis of the present study was that there would be no difference between the tested Ni-Ti files in terms of shaping ability, canal transportation and preparation time.

2. Materials and Methods

The study protocol was approved by Institutional Ethical Review Reference no: VIDS/IEC/PG/APP 2022/34. Forty simulated Resin Blocks with J shaped canals ,30° curvature, 0.15-mm apical diameter ,0.02% taper, 10 mm radius of curvature and 16-mm working length (WL) were selected for this study (**Figure 1A)**. The resin blocks were stabilized using a customized jig. Patency of the resin blocks were tested initially using 10K-file for any kind of manufacturing defect in simulated canals and also for ease of flow of ink for capturing of pre-operative image. Subsequently, divided into 4 groups (n=10 canals/group).

Before starting the shaping process, the WL of each root canal was determined using an endodontic ruler using a new 10 K-file .After that, all the canals were stained with 0.5 ml black ink using ink injecting syringe to improve the visibility. Then the images of the stained canal was at a fixed distance and position and photographed using a digital camera. To take the pictures a standardized position was used to fix the resin blocks, with the foramen facing to the left side .Sterile saline was used to remove the dye.

2.1. Instrumentation of simulated J shaped canals

A new instrument was used for each canal in all groups. Glyde prep was used as a lubricant before the utilization of each instrument and 5ml of 3% NaOCl and 5ml sterile saline using 30 G side vented needle was used for irrigation. Final Irrigation was done by 5ml saline after each file usage. Biomechanical preparation were done using X-Smart Plus motor (Dentsply Maillefer) as per the manufacturers' instructions to the WL as follows:

Group 1: The HEDM file (tip size =25, taper 0.08) with continuous motion at 400 rpm and 2.5 torque.

Group 2: The OS File (tip size =25, taper 0.06) with continuous motion at 400 rpm and 4Ncm torque.

Group 3: The WOG File (tip size =25, taper 0.07) with reciprocating motion.

Group 4: The OR File (tip size =25, taper 0.07) with reciprocating motion.

For reciprocating motion groups (Group3 &4), with each pecking motion, the instrument advanced 3mm into the canal (Amplitude less than 3mm, 3 pecks). After three pecking motions debris in the flutes were cleaned using moist cotton. To avoid bias all specimens were instrumented by a single operator.

2.2. Post-operative setting

After canal preparation, 0.5 ml of red ink was used to stain the canal using ink injecting syringe to make the root canal trajectory more visible. The images were taken from a fixed distance to standardize the position of the images. Preparation time was taken as the sum of total active instrumentation, cleaning of the flutes of the instrument and irrigation time which was recorded using a digital stopwatch.

2.3. Image analysis, assessment of shaping ability, canal transportation and preparation time

Pre-operative and post-operative images of all the resin blocks were obtained and saved as JPEG format files. After instrumentation of each resin canal the pre-op and post-op images of canals were superimposed using Adobe Photoshop CC software. A measurement scale was made to determine 11 measuring points at 1 mm interval (each measuring point depicts X1 as inner and X2 as outer wall) using Image J software (**Figure 1B)**.

The measurement points were at 11 different points at 1mm interval, points 0 to 3 constituted the apical curvature, points 4 to 7 constituted the middle curvature, and points 8 to 10 constituted the coronal portion of the canal. A second examiner who was blinded to all experimental groups performed the assessments of the canal shapes before and after instrumentation. Assessments of instrument fracture and formation of ledge was also done during the study.

After shaping, the total width of the canal was calculated as the distance between the internal side of the curvature(X1) till the external side of the curvature(X2) and was added (X1+X2) using Image J software in mm **(Figure 1C)**. Canal Transportation was calculated by the formula X1-X2, where X1 represents the maximum extent of the canal movement on the inner curve, while X2 is the movement on the outer curve in mm.[17] **(Figure 1D)** Canal transportation was calculated as follows:[17]

1. Resin removed at the inner and outer parts was equal to 0 : NO Transportation
2. Resin removed at the inner and outer parts was positive : Transportation toward the inner part
3. Resin removed at the inner and outer parts was negative : Transportation toward the outer part

2.4. Statistical analysis

One-way ANOVA Test followed by Tukey's post hoc test was used to compare the mean Canal Shaping Ability, Canal Transportation & mean Preparation time (in sec) between 4 groups. The level of significance was set at P<0.05.

3. Results

Shaping Ability: Canal Width: There found to be statistically significant difference between 4 groups at Apical, Middle and Coronal third (p<0.001).

Apical third (Point 0-3) : At point 3 ,Group 1 showed maximum canal width (1.58mm) which was statistically significant at p<0.001 followed by Group 3 , Group 2 and Group 4.(**Table 1**)

Middle third (Point 4-7) : At point 7 , Group 1 showed maximum canal width (3.75mm) which was statistically significant at p<0.001 followed by Group 3 , Group 2 and Group 4.(**Table 1**)

Coronal third (Point 8-10): At point 8 , group 1 showed maximum canal width (4.01mm) which was statistically significant at p <0.001 followed by Group 3 , Group 2 and Group 4.(**Table 1**)

Multiple comparisons between the Groups revealed that Group 1 showed the maximum Canal Width at Point 3, 7 and 8 (Apical, Middle and Coronal) which was statistically significant at p <0.05 followed by Group 3, Group 2 and Group 4. Canal Transportation: There found to be statistically significant difference between 4 Groups at Apical, Middle and Coronal third (p<0.001).

At Apical third (Point 0-3) and Middle third (Point 4-7), Group 4 showed minimum Canal Transportation i.e. 0.13mm and 0.39mm which was statistically significant at p<0.001 followed by Group 2, Group 3 and Group 1

At Coronal third (Point 8-10): At point 8, Group 2 showed minimal canal transportation(0.64mm) which was statistically significant at p <0.001 followed by Group 4 , Group 3 and Group 1

Multiple comparisons between the Groups revealed that Group 4 showed the minimum canal transportation at points 0 and 4 (Apical and Middle third) which was statistically significant at p<0.05 followed by Group 2, Group 3 and Group 1. Group 2 showed the minimum canal transportation at point 8 (Coronal third) which was statistically significant at p< 0.05 followed by Group 4, Group 3 and Group 1. Preparation Time: The mean Preparation Time showed significant difference between 4 groups at p<0.001. Group2 showed the least Preparation time (92sec) which was statistically significant at p <0.001 followed by Group 4, Group 1 and Group 3. Multiple comparison between Groups revealed that Group 2 showed significantly least Preparation time as compared to Group 1, Group 3 & Group 4 and the mean difference were statistically significant at p<0.001 respectively.

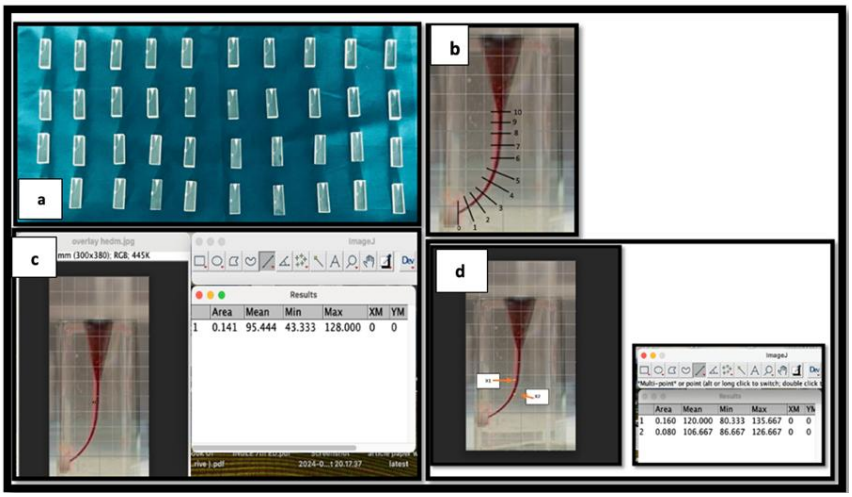

Figure 1: (A) Forty simulated J shaped canals in clear resin blocks, (B) Measurement scale using Adobe Photoshop cc software, (C) Measurement of canal width using Image J software, (D) Measurement of canal transportation in mm using Image J software

Table 1: Canal width after preparation with the different instruments: Mean (mm) and Standard Deviation (SD) at the Different Measuring points using One-way ANOVA test

Distance from the apex	**Group 1**		**Group 2**		**Group 3**		**Group 4**		**P-Values**
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
0mm	1.01	0.35	0.53	0.13	0.46	0.13	0.32	0.09	<0.001*
1mm	0.61	0.20	0.68	0.18	0.74	0.25	0.30	0.13	<0.001*
2mm	0.68	0.15	0.60	0.19	0.78	0.33	0.40	0.13	<0.001*
3mm	1.58	0.49	0.87	0.23	1.40	0.22	0.46	0.12	<0.001*
4mm	2.50	0.28	1.09	0.18	2.06	0.41	0.72	0.18	<0.001*
5mm	2.89	0.32	1.70	0.23	2.43	0.39	0.97	0.24	<0.001*
6mm	3.62	0.17	2.32	0.25	3.24	0.27	1.22	0.16	<0.001*
7mm	3.75	0.27	3.07	0.19	3.52	0.24	1.57	0.34	<0.001*
8mm	4.01	0.15	3.07	0.22	3.61	0.25	1.58	0.35	<0.001*
9mm	3.96	0.21	3.17	0.18	3.54	0.23	2.13	0.21	<0.001*
10mm	3.80	0.24	3.22	0.15	3.40	0.42	2.25	0.32	<0.001*
*Statistically Significant Group 1 : HEDM , Group 2 : OS , Group 3 : WOG , Group 4 : OR									

Table 2: Canal Transportation after preparation with the different instruments: Mean (mm) and standard deviation (SD) at the different measuring points using one-way test

Distance from the apex	**Group 1**		**Group 2**		**Group 3**		**Group 4**		**p-value**
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
0mm	0.28	0.13	0.14	0.07	0.21	0.07	0.13	0.05	0.001*
1mm	0.26	0.10	0.16	0.07	0.28	0.08	0.17	0.09	0.005*
2mm	0.30	0.08	0.20	0.12	0.54	0.21	0.22	0.06	<0.001*
3mm	0.48	0.23	0.30	0.11	0.73	0.30	0.18	0.04	<0.001*
4mm	1.01	0.53	0.51	0.19	0.91	0.34	0.39	0.12	<0.001*
5mm	0.94	0.25	0.44	0.14	0.69	0.19	0.47	0.13	<0.001*
6mm	1.19	0.38	0.62	0.31	0.69	0.19	0.61	0.20	<0.001*
7mm	1.21	0.35	0.64	0.32	0.94	0.34	0.61	0.15	<0.001*
8mm	1.27	0.44	0.64	0.14	1.15	0.26	1.10	0.17	<0.001*
9mm	1.08	0.46	0.68	0.20	1.15	0.21	1.32	0.18	<0.001*
10mm	1.28	0.25	0.80	0.18	1.16	0.46	1.38	0.11	<0.001*
*Statistically Significant Group 1 : HEDM , Group 2 : OS , Group 3 : WOG , Group 4 : OR									

4. Discussion

To compare the shaping abilities of various NiTi files, natural teeth and simulated resin canals are used. However, using natural teeth in studies it is very difficult to maintain standardization because of the anatomic variations of the teeth.[18-20] The apical region of the root canals may be easier to clean and irrigate if the apical preparation size is increased, but there is also a greater chance of canal transportation.[21-22] In this study, we found that single file system with higher taper resulted in higher canal width and also caused canal transportation.(**Table 1**,**Table 2**)

HEDM file and OS file have a taper of 0.08 and 0.06, respectively, whereas the two reciprocating instruments i.e. WOG and OR have a taper of 0.07 and 0.06, respectively. The shaping ability evaluation was done in our study at three different areas namely apical 0-3mm, middle 4-7mm and coronal 8-10mm.[23] According to the results of the present study, when shaping ability was compared HEDM file showed the maximum Canal Width at Point 3 , 7 and 8 (Apical , Middle and Coronal) as compared to other file systems followed by WOG file, OS file and OR file ($p<0.05$).

And when canal transportation was compared, HEDM file showed the maximum canal transportation at point 0-3mm(Apical) and at point 4-7mm(Middle) followed by, WOG file, OS file and OR file($p<0.05$).

HEDM file and WOG file resulted in wider canal widths after preparation compared to OS file and OR file, that can be explained by the increasing taper at the tip region of these two instruments.

According to the results of the present study, when shaping ability was compared HEDM file showed the maximum Canal Width at Point 3, 7 and 8 (Apical, Middle and Coronal) as compared to other file systems followed by WOG file, OS file and OR file ($p<0.05$).

And when canal transportation was compared, HEDM file showed the maximum canal transportation at point 0-3mm (Apical) and at point 4-7mm (Middle) followed by, WOG file, OS file and OR file ($p<0.05$). HEDM file and WOG file resulted in wider canal widths after preparation compared to OS file and OR file that can be explained by the increasing taper at the tip region of these 2 instruments.

According to the results of the present study, HEDM file in continuous motion revealed a significantly higher canal width at point 3, 7 and 8 i.e. Apical, Middle and Coronal as compared with other file systems. This observation is in agreement with the previous study that compared the shaping ability of different single file systems with HEDM which can be attributed to greater taper of HEDM files (25/0.08), which is in accordance to the previous study done by Gomaa et al in 2021.[24] HEDM also showed the maximum canal transportation when compared to other three groups in this study. This can be attributed to the greater taper over the first 3mm.[21]

Group 3 (WOG file) in reciprocating motion revealed more canal width 3, 7 and 8 (Apical , Middle and Coronal) as compared to other files because of the greater taper of WOG (0.07) which is in accordance to the previous study done by Lu Shi et al in 2022.[25] OS file and OR file resulted in lesser canal width preparations and less canal transportation which can be attributed to the difference in the tapers and cross section design of the files as OS and OR files have a lesser taper (0.06).

This can be due to the difference in the tapers and cross section design of the files as OS file has a lesser taper (0.06) as compared to HEDM (0.08) and WOG (0.07). One Shape file works with a continuous motion and has a non- working (safety) tip which ensures an effective apical progression avoiding obstructions thus leading to less canal transportation.[26]

It was observed that during shaping, taper of the endodontic instrument is directly proportional to the canal width. The total preparation time is depends on the technique and the number of instruments used.[21] Single file instrumentation takes less time compared to the multiple file systems.[23]

In our study, OS file showed least amount of time (92 sec) required for canal preparation which was statistically significant at $p<0.001$ followed by OR file, HEDM file and WOG file. The preparation time for continuous rotary in comparison to file reciprocating file was found to lower, this may be due to the increased time required for cleaning the flutes of the file.[23]

However, the results of studies using simulated canals must be extrapolated cautiously to clinical conditions because of the differences that exist between resin and dentin in hardness and anatomical variations compared to clinical scenarios.[21] Due to the differences in the mechanical characteristics of the resin blocks compared to human dentine, care should be taken when extrapolating the results of the present study to clinical cases. Further studies should be conducted comparing different endodontic files with varying tapers, metallurgy and motion in simulated canals with varying taper, diameter, length, angle and radii of curvature.

5. Conclusion

In this study HEDM file resulted in maximum shaping ability followed by WOG file, OS file and OR file. HEDM file showed the maximum canal transportation followed by WOG file, OS file and OR file in the apical and middle third. OS file resulted in least preparation time followed by WOG file, HEDM file, and OR file.

6. Source of Funding

None.

7. Conflict of Interest

None.

8. Ethical Approval

This study was approved by institution ethical committee with ref. no. VIDS-IEC/PG/APP/2022/3

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