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Research Article

Preparation Activities of Different Ni-Ti File Systems in Curved Canals

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Abstract

Objective: To compare the effects of HyFlex EDM(HEDM), WaveOne Gold (WOG), XP-Endo Shaper (XP), Reciproc (R) and ProTaper Next (PTN) systems on transportation, centering abilities, and canal volume in the preparation of curved root canals using the micro-CT imaging technique, to evaluate the changes on the surfaces of Ni-Ti instruments after use by SEM, and to compare the preparation times.

Materials and Methods: 40 mandibular molar teeth with Vertucci Type IV were included in this study after the initial micro-ct scanning. Access cavities were opened. The working length was calculated. Five different Ni-Ti systems were used to prepare the samples(n=16): HEDM, XP, WOG, R, PTN. During the preparation, the root canals were irrigated with 5 ml of 5% NaOCl and 10 ml of distilled water. Prepared samples were rescanned by micro-CT. The canal volume, the working times, canal transportation, transportation direction, and centering ability were evaluated for each group.

Results: The transportation of PTN, HEDM, and WOG groups is significantly higher than XP ($p < 0.005$), whereas the transportation of WOG is not significantly differenct than R. No statistically significant difference was found between the centering ability of the groups ($p > 0.05$). Similarly, there is no significant difference in the direction of transportation between PTN, R, WOG, HEDM and XP ($p > 0.05$). there was no significant difference between the post-preparation volume between the groups ($p > 0.05$). the working time of HEDM is significantly longer than PTN, R, WOG, and XP ($p < 0.005$). No instrument fracture was observed in any groups during the preparation of root canals.

Conclusion: the XP caused significantly less transportation than other Ni-Ti systems, but none of the file systems used had an excellent centering ability. No significant difference was found in transportation direction, centering ability, and volume change after preparation between HEDM, XP, WOG, R and PTN.

Keywords: Centering ability; Micro CT; Ni-Ti Files; Transportation

Abbreviations

Ni-Ti: Nickel Titanium; Micro BT: Micro Computerized Tomography

Introduction

The complicated anatomy of root canal systems creates problems in canal preparation, especially in curved canals [1]. Previous studies have shown that as unprepared areas, canal transportation in curved canals and loss of the canal's original anatomy may occur during root canal instrumentation [2,3]. Therefore, mechanized instrumentation systems have been continually developed to search for alternatives that can completely clear the root canal while retaining its original anatomy [1]. Thus, new Ni-Ti files with specialized designs, kinematics, and metallurgical properties, have been introduced in recent years.

The recently introduced XP-Endo Shaper (FKG Dentaire, La Chaux-de-Fonds, Switzerland) file system is a Ni-Ti rotary instrument in the form of a snake. It was made using Max-Wire (Martensite-Austenite Electro-Polishing-Flex) to prepare a 30/04 when used alone for shaping canals after the orifice opener file #15 [4]. HyFlex EDM files (Coltene/Whaledent, Altstantown, Switzerland) are Ni-Ti rotary instruments made from CM-Wire using the electrical discharge machining (EDM) method, designed to shape the root canals using a single file technique [5]. WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland) is a new reciprocal single file manufactured using the gold wire technology, making canal shaping safer, faster, and convenient than the WaveOne file system [6].

Various techniques have been improved to assess the shaping ability of different Ni-Ti systems. Micro-computed tomography (micro-CT) is noted as the gold standard for this objective in recent years [1]. It provides a non-invasive technique for the 3-dimensional (3D) evaluation of mechanical preparation, including the amount of prepared or unprepared surfaces, root canal volume, and root canal anatomy [7].

However, there is a few information on the shaping abilities of the file systems produced in recent years in curved root canals. Therefore, the current study aimed to compare the effects of HyFlex EDM(HEDM), WaveOne Gold (WOG), XP-Endo Shaper (XP), Reciproc (R) and ProTaper Next (PTN) file systems on canal transportation, centering abilities, and canal volume changing in curved root canals using the micro-CT technique, to evaluate the changes occurring on the surfaces of Ni-Ti instruments after use by determining them with scanning electron microscope (SEM), and to compare the preparation times of the Ni-Ti systems.

According to the null hypothesis of this study, there would be no difference in the shaping abilities in curved root canals and the systems' working times among different Ni-Ti file systems.

Materials and Methods

The approval to conduct this research was obtained from Tokat Gaziosmanpaşa University Faculty of Medicine Clinical Research Ethics Committee (16-KAEK-028).

A total of 135 mandibular molar teeth of similar sizes with no caries, resorption extracted due to prosthetic or periodontal reasons were collected for this study. The mesial roots of the collected teeth had an angle of between 25°-35° by using Schneider's method [8]. Soft tissues and residues were removed from the teeth and stored in saline at 4°C until use.

The samples were embedded in polyvinyl siloxane (CharmFlex Putty, Dentkist, Korea) blocks so that 3-4 mm sections of the crowns would be inside the prepared molds to place the micro CT scanner unit in its holder on a fixed vertical plane to allow images to be taken in the same position from the roots in the second scan. After that, the samples were scaned by the micro-CT device to determine the canal morphologies before preparation.

Micro CT scans were performed at 33 µm isotropic resolution and 50 kV and 800 mA with the SkyScan 1174 micro-CT device (SkyScan, Kontich, Belgium). The scans were performed with a rotation angle of 0.7° and a total vertical rotation angle of 360°. Each scan of the samples took approximately 70 minutes. At the end of the scans, 600-700 images were obtained for each sample, and they were recorded in TIFF format. Image reconstruction was performed using NRecon software (Version 1.6.9.4, Bruker-microCT, Skyscan).

As a result of the first micro-CT scan, the mesial roots of 40 mandibular molar teeth with Vertucci Type IV canal configuration were included in this study. Access cavities were opened using diamond burrs (Diatech, Swiss Dental Instruments, Heerbrugg, Switzerland). The apical patency of the teeth was checked using

ISO #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). The working length was calculated as 1 mm shorter from the root length for each tooth. Five different Ni-Ti systems were used to prepare the samples, with eight samples for each Ni-Ti system, and 16 canals were prepared (n = 16).

- **Group 1: HyFlex EDM (HEDM):** Preparation was made with OneFile 25/~ file. The shaping of root canals was completed at 2.5 Ncm torque and 500 rpm.
- **Group 2: XP-Endo Shaper (XP):** The canals were prepared with XP-Endo Shaper (30/04) single file after the access was created with a 20 K file. The preparation of root canals was completed at 1 Ncm torque and 800 rpm. NaOCl was stored at 35°C in the canal during preparation with XP. The preparation was terminated through 5 pecking motion until the working length was achieved.
- **Group 3: WaveOne Gold (WOG):** The preparation was performed with WaveOne Gold Primary (25/07) file. 'WAVEONE ALL' reciprocating program, which is stored in the endomotor memory, was used to shape root canals in this group.
- **Group 4: Reciproc (R):** The preparation was performed with the Reciproc R25 file. The enlargement of canals was completed using the 'RECİPROC ALL' program in the endomotor.
- **Group 5: Protaper Next (PTN):** The preparation was performed with X1 (17/04) and X2 (25/06) files. The preparation of root canals was completed at 4 Ncm torque and 300 rpm in this group.

The files were used with the VDW Gold Reciproc endodontic motor (VDW, Munich, Germany) following the manufacturer's instructions. The files were replaced with the new ones after they were used in two canals. During the preparation, the root canals were irrigated with 5 ml of 5% NaOCl and 10 ml of distilled water (Polifarma, Tekirdag, Turkey) after each file change. After that, the samples were reinserted in the same position in the micro-CT scanner holder, and prepared samples were scanned for the described parameters. The canal volume, canal transportation amount, and centering ability were evaluated on micro-CT images before and after preparation. The working times of the Ni-Ti files were also recorded for each group.

Transportation and centering ability

Transportation and centering ability were measured before and after sample preparation using DataViewer (Version 32 bit, Bruker-microBT, Skyscan). 3, 5, and 7-mm horizontal cross-sections were selected in the apico-coronal direction after reconstructing the roots (Figure 1). Transportation and centering ability measurement were calculated using the following formula at the selected three levels

Transportation= $(m_1\text{-}m_2)\text{-}(d_1\text{-}d_2)$

ratio= $(m_1\text{-}m_2)/(d_1\text{-}d_2)$ Or $(d_1\text{-}d_2)/(m_1\text{-}m_2)$

With m1 = nearest distance of the mesial margin of the non-prepared canal to the mesial margin of the root was, d1 = the nearest distance of the distal margin of the non-prepared canal to the distal margin of the root was, m2 = the nearest distance of the mesial margin of the prepared canal to the mesial margin of the root was, and d2 = the nearest distance of the distal margin of the prepared canal to the distal margin of the root was [9].

A "0" value of the transportation means that the canal transportation was not realized, while a negative value means that the transportation was realized in the distal direction, and a positive value means that it was realized in the mesial direction. In the formula used for the centering ability, "1" indicates perfect centering ability, while the values near "0" signified a reduction in the instrument's centering ability [9].

Canal volume measurement

The total canal volume was measured before and after the canal shaping procedure using the CTAn (Versiyon 1.12, Bruker-microBT, Skyscan) image analysis software program. The canal volume change was calculated by subtracting the canal volume before shaping from the canal volume after shaping and recorded in mm^3.

SEM Examination

The changes on the surfaces of Ni-Ti files were examined via SEM. Two Ni-Ti files from each group were randomly selected and covered with gold. Then, images were obtained from the coronal, middle and apical regions of the instruments in SEM analysis using x 500 magnification.

Statistical analyses

For the statistical evaluation of measurements, the normality of data was checked using the Shapiro Wilk test. The Kruskal Wallis and Bonferroni corrected Dunn's test to determine differences between groups at $p < 0.005$ for statistical significance. IBM SPSS version 21.0 was used for the statistical analysis.

Results and Discussion

The transportation, direction of transportation, centering ability of instruments, volume change in root canals and the working times of file systems were evaluated in this study. A comparison of transportation between groups is presented in table 1. According to the results obtained, there is a statistically significant difference between total transportation between the groups ($p < 0.05$). The transportation of PTN, HEDM and WOG groups is significantly higher than XP ($p < 0.005$), whereas the transportation of WOG is not significantly different than R. Meanwhile, the comparison between centering ability between the groups is presented in table 2. No statistically significant difference was found between the centering ability of the groups ($p > 0.05$). Similarly, there is no significant difference in the direction of transportation between PTN, R, WOG, HEDM and XP groups ($p > 0.05$), the comparison between transportation direction between the groups is presented in table 3. The comparison of the volumes of root canals before and after preparation are presented in table 4. No significant difference was observed between groups volumes before preparation ($p > 0.05$), which means the samples were evenly distributed. Furthermore, there was no significant difference between the post-preparation volume change between the groups ($p > 0.05$). The comparison results of the working time with different file systems are detailed in table 5. According to the findings, the working time of HyFlex EDM is significantly longer than ProTaper Next, Reciproc, WaveOne Gold and XP-Endo Shaper ($p < 0.005$). No instrument fracture was observed in any groups during the preparation of root canals. Images were obtained from the coronal, middle and apical regions of the instruments used in SEM analysis at x 500 magnification. No significant deformation was observed on the surface of any instrument (Figure 2-4).

	3mm		5mm		7mm		Total	
	Mean	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**
PN	-0.04	0.24	-0.1	0.29	-0.01	0.38	0.68^{A}	0.43
REC	0.02	0.19	-0.08	0.22	-0.14	0.28	$0.51^{A,B}$	0.4
WOG	-0.04	0.23	0.01	0.21	-0.11	0.22	$0.54^{A,B}$	0.26
HEDM	0.08	0.28	0.08	0.26	0.04	0.23	0.63^{A}	0.29
XPS	0.03	0.13	0.02	0.14	-0.03	0.18	0.31^{B}	0.19

Table 1: Mean ± Standard Deviation (SD) canal transportation (mm) values at 3,5, and 7mm levels. Superscripts indicate statistically different at p = 0.05.

	3mm	5mm	7mm	Total
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
PN	0.29 ± 0.39	0.47 ± 0.39	0.25 ± 0.4	0.34 ± 0.25
REC	0.53 ± 0.46	0.44 ± 0.47	0.44 ± 0.34	0.47 ± 0.28
WOG	0.4 ± 0.46	0.38 ± 0.4	0.25 ± 0.34	0.34 ± 0.25
HEDM	0.43 ± 0.32	0.33 ± 0.3	0.58 ± 0.52	0.45 ± 0.27
XPS	0.42 ± 0.46	0.61 ± 0.39	0.47 ± 0.45	0.5 ± 0.24

Table 2: Mean ± Standard Deviation (SD) centering ability at 3,5, and 7mm levels.

		PN	REC	WOG	HEDM	XPS	*p*
3 mm	Distal	9	4	8	7	5	0.199
	Mesial	5	5	3	8	6	
	None	2	7	5	1	5	
5 mm	Distal	6	8	7	7	3	0.295
	Mesial	6	3	6	8	6	
	None	4	5	3	1	7	
7 mm	Distal	7	9	10	4	6	0.293
	Mesial	6	5	4	9	4	
	None	3	2	2	3	6	
p		0.841	0.255	0.552	0.613	0.766	

Table 3: Transportation direction (distal, mesial, none).

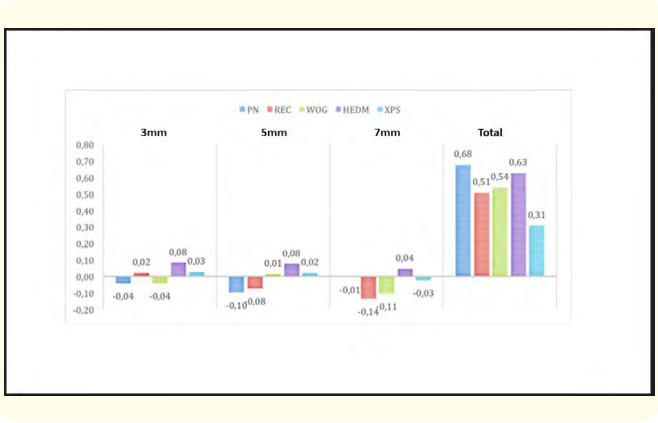
	Pre-op Volume					Δ Volume				
	Mean	**SD**	**Min**	**Max**	**p**	**Mean**	**SD**	**Min**	**Max**	**p**
PN	1,73	0,42	1,02	2,8	1.000	2,12	0,65	1,27	3,38	0.124
REC	1,72	0,63	0,59	2,92		2,14	0,59	0,86	3,15	
WOG	1,7	0,39	0,82	2,21		2,03	0,98	0,85	3,7	
HEDM	1,73	0,52	0,83	2,59		2,38	0,69	1,47	3,54	
XPS	1,71	0,43	1,07	2,69		1,68	0,67	0,32	3,24	

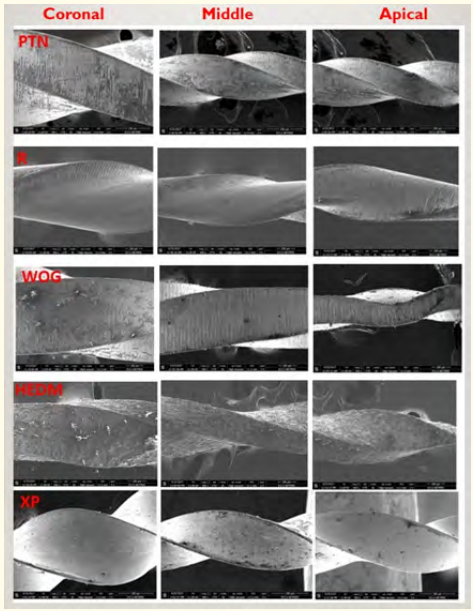
Table 4: Comparison of pre-op volume and post-op volume changes (mm^3).

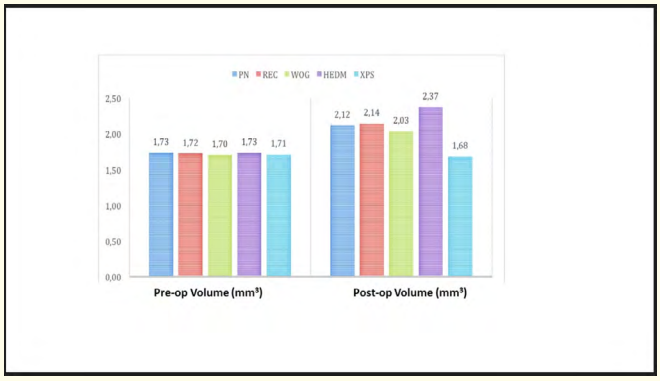
	Mean ± SD	Min	Max	p
PN	101,13 ± 6,48^{B}	90,5	109	< 0.001
REC	123,13 ± 45,19^{B}	79,5	230	
WOG	133,31 ± 45,51^{B}	75	201,5	
HEDM	170,81 ± 47,3^{A}	114	250	
XPS	121,5 ± 17,39^{B}	94,5	153,5	

Table 5: Comparison of working times (sec).

Different superscripts indicate statistically different at p = 0.05.







Discussion

Many complications such as canal transportation and perforation may occur due to the deviation of the inflexible instrument from the canal's original axis during the preparation of curved canals [10]. Therefore, it is important to select the most suitable Ni-Ti system for quality preparation, especially in curved canals [11]. Ni-Ti instruments decrease the risk of deviation from the canal's original axis in curved root canals and help preserve the original canal shape. Preparation of a root canal with complex anatomies, like mesial roots of mandibular molar teeth, would be challenging due to anatomical differences and canal curvature in dental practice [12]. Therefore, the current study found that it was appropriate to use mesial root canals with 25-35 degrees to prepare different Ni-Ti files. Micro CT scanning is a scientific technique used in many studies to evaluate the effectiveness of canal shaping techniques. It is also preferred due to its many advantages such as repeatability, accuracy and objective results [11]. Based on the literature, very few studies have evaluated the effects of HEDM, XP, WOG, R and PTN systems on root canal preparation by using the micro-CT imaging technique. In the present study, while no significant differences were found in transportation direction, centering ability, and volume change after preparation among HEDM, XP, WOG, R and PTN file systems, there was a significant difference between groups in terms of transportation and working times. Therefore, the hypothesis predicting that there would be no difference between the file groups in this research was rejected.

Identifying factors that might impact canal transportation, such as root canal anatomy, file design or kinematics and alloys used for instrument manufacturing, have been widely evaluated in many research [13-15]. Rosa., *et al.* used the micro-CT technique to compare the shaping abilities of single-file systems used with different kinematics of root canals of maxillary molar teeth. No significant difference was found between the WaveOne and OneShape file regarding canal volume change and transportation. It was observed that different kinematics did not affect the shaping ability of file systems to prepare curved root canals [15]. Sauso Neto., *et al.* evaluated three different Ni-Ti systems within the parameters (volume, area and SMI) [16]. The same shaping ability was observed when preparing samples using Reciproc, OneShape and WaveOne systems in the mesial curved root canals of mandibular molars, similar to the current study.

Besides, few studies have evaluated the effect of alloys used in rotary file systems on the shaping abilities in the preparation of curved root canals [16,17]. A previous study indicated that different Ni-Ti alloy might be partially responsible for the performance and mechanical behavior of Ni-Ti instruments in curved canals [17]. Yamamura., *et al.* used the micro CT to evaluate the canal transportation and centering abilities of the rotary file systems made of M-wire and traditional Ni-Ti alloy at the mesial root canals mandibular molar teeth [18]. They found that no significant difference was found between the groups in terms of

transportation and centering ability [18]. According to the study of Yamamura et al., the files' different metallurgical properties have no significant effect on root canal shaping abilities, which was also proven true in the present study. Poly., *et al.* (2019) reported the WOG canal transportation and centering ability ratio with XP-Endo Shaper file in the mesial root canals of mandibular molar teeth [17]. The XP was found to be superior in terms of canal transportation and centering compared to WOG. Similarly, the present study discovered that the XP file's transportation was significantly less compared to HEDM, WOG, and PTN file systems. This resutls may be related to the fact that the XP file has a lower taper and a design that can adapt to the canal's shape compared to other groups.

Centering ability indicates whether the original canal remains in the center after shaping like transportation. A centering value of "1" indicates a perfect centering ability [9]. The instruments that do shaping by centering will create less transportation. Morales., *et al.* used Trushape and XP to compare the preparation efficiency in curved canals and reported that these two files produced similar results in terms of centering ability and transportation [19]. Additionally, Turkistani., *et al.* indicated that HEDM and PTN showed equal centering ability in curved canals while protecting the original canal shapes [20]. Similarly, there was no statistically significant difference for centering ability between the sections evaluated for each file system in the present study. Several studies have also shown that more flexible instruments produce more centered preparations [21,22]. All of the file systems used in the current study are much more flexible than the traditional Ni-Ti files due to the alloys and extra surface improvement processes, hence their similar centering abilities. On the other hand, Hwang., *et al.* used the root canals of maxillary molar teeth and compared the canal volume between Reciproc, one of reciprocation file systems, and Mtwo, one of the traditional Ni-Ti file systems via micro-CT [23]. No significant difference was observed between the groups in terms of volume changes. Meanwhile, Alves., *et al.* used the moderately curved mesial root canals of mandibular molar teeth and evaluated single file reciprocating systems' shaping abilities and heat-treated multiple file systems through micro-CT [24]. This study included Reciproc, WaveOne, Twisted File and HyFlex CM file systems, but no significant difference was found between the groups in terms of volume changes [24]. The results of both studies supported the findings of the present research.

Other studies also compared the shaping abilities of different rotary instrument systems due to their importance in shaping the groups with similar taper. ProTaper Next (25/06), Reciproc (25/08), HyFlex EDM (25/~), WaveOne Gold (25/07), and XP-Endo Shaper (30/04) file systems used in the present study had different apical sizes and different taper, but no significant difference was found in terms of canal volume change. Even though the XP file system had the lowest taper between the groups and produced the least volume change, the difference was not statistically significant. This finding may be due to the fact that this file system removes more dentin from the canal walls despite its low taper since it performs 3D shaping. Similarly, the ProTaper Next file system demonstrated a canal volume change similar to other systems with a higher taper because it removed more dentin through snaky movements since it has an asymmetric cut.

Many preparation techniques, devices, and files have been developed to make root canal preparation easier and shorter [25]. The working time depends on the shaping technique, the number of files used, and the clinician's experience [26]. In this study, all groups' active preparation time was recorded in seconds with a digital stopwatch. To reflect the clinical environment, irrigation, cleaning of residue on the files, and file change time was valid only for the ProTaper Next group were added to the study period. While evaluating the working time, the average of the working time with two files was taken since only two files were used in the PTN group. The working time of HEDM was significantly higher than PTN, R, WOG, and XP. Although HEDM had variable taper on the file, its taper was higher. As the taper increases, the file's hardness increases; thus, it may take more time to move through narrow root canals. A gentle pecking movement may have extended the working time, especially in areas where the root canal was curved, to avoid fracture risk.

Most importantly, surface deformation and instrument fracture were not observed in this study because the file systems were used following the manufacturer's recommendations and each file was used in the shaping of one sample at one time.

Conclusion

Within the limitations of the present study, the XP file system caused significantly less transportation than other Ni-Ti systems. According to the literature data, the transportation values for each

file group were within the acceptable limits, but none of the file systems used had an excellent centering ability. No significant difference was found in transportation direction, centering ability, and volume change after preparation between HEDM, XP, WOG, R and PTN file systems.

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Conflict of Interest

No conflict of interest.

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