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Evaluation of Canal Transportation and Centering Ability of RaCe and Af f-one Systems by Cone-beam Computed Tomography: An *in Vitro* Study

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Introduction Rotary systems have made significant advances to improve their root canal preparation efficacy. These instruments can properly preserve the root canal anatomy and morphology. The present *in vitro* study aimed to compare canal transportation and centering ability of RaCe and Af f-one systems using cone-beam computed tomography. **Materials and Methods:** Thirty-six mandibular molars were included. The samples were randomly assigned to two groups (n=18): group 1, RaCe, and group 2, Af f-one. Canal preparation was conducted using the respective files according to the manufacturers' instructions. The cone-beam computed tomographic scanning of the samples was performed before and after preparation. The data were analyzed by using two-way ANOVA. **Results**: In both the RaCe and Af f-one rotary systems, canal centrality and transportation were similar at coronal, middle, and apical cross-sections. In addition, canal transportation and centrality were identical in the RaCe and Af f-one rotary files (P<0.05). **Conclusion:** The two studied rotary systems did not exhibit significant differences in root canal transportation and preservation of root canal centrality in the apical, middle, and coronal thirds.

Keywords: Af f-one; Cone-beam Computed Tomography; RaCe, Root Canal Centrality; Root Canal Transportation

Introduction

Thorough and meticulous instrumentation is an important phase of root canal therapy. Preserving the original morphology is important during this procedure and has always been a significant challenge. However, in root canals with excessive curvature, mechanical preparation that does not adapt to the curved form of root canals, despite their flexibility, can lead to root canal transportation, jeopardizing root canal cleaning or the three-dimensional seal of the root canal space [1, 2]. The file system selection affects the ability to shape the root canal(s), especially curved ones. RaCe files (FKG Dentaire, La Chaux-de-Fonds, Switzerland) have a triangular cross-section with alternating margins, preventing them from being twisted in the root canal and its blockade during complete rotation and creating a more centralized root canal. Furthermore, the surface of these files has been treated electrochemically, increasing their cutting ability [3-5].

Af f-one file (Dental Fanta, Shanghai, China) is a single-file rotary system. Recently, the file handle has been increased to 11 mm for better access to molars. This file is made of R^{TM}-AF wire, which is suitable for curved root canals and has a flat design, efficient cutting, and greater resistance to cyclic fatigue than conventional NiTi wires; it spins at 500 rpm and is compatible with all the rotary motors on the market [6].

Cone-beam computed tomography (CBCT) images are accurate geometrically, and measurements on these images are made without distortions on all the planes. This property makes it possible to carry out non-destructive analyses of the variables with high reproducibility, including volume, surface area, the overall shape of the cross-section, and the conical shape of the root canal system [7, 8].

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Many studies have used the CBCT technique as a measurement tool to evaluate the effects of different root canal preparation methods on root canal transportation and preservation of root canal centrality [2, 9-13]. Rotary file systems have undergone many progressive changes to improve root canal preparation. These instruments can adequately preserve the morphological characteristics of root canals and are safe for root canal preparation [14-16].

The present *in vitro* study compared the extent of root canal transportation with RaCe and Af f-one files using the CBCT technique.

Materials and Methods

Sample selection

Thirty-six mesiobuccal roots of extracted mandibular first molars were included in the present *in vitro* study. The apical foramen was mature (closed), and the mesiobuccal root canal was uncalcified, confirmed using the initial radiograph. The Autocad software (Autocad Version 2007; Autodesk, San Rafael, CA, USA) was used to determine the root curvature on radiographs using the Schneider *et al.* method [17], and the curvature radius was determined using the method explained by Pruett *et al.* [18]. Teeth with 22-40° curvature angle and 5.5-9.9-mm curvature radius were selected for the preparation procedure. All the teeth were stored in 0.9% normal saline solution until the preparation procedures were initiated. An access cavity was prepared with a #016 diamond bur (Dentsply Maillefer, Ballaigues, Switzerland) in a high-speed handpiece under air and water spray. The distal root was removed with a bilateral diamond disk (Comet, Rockhill, SC, USA). A #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was used to determine the working length (WL) of the mesiobuccal root canal until the file tip was visible at the root apex. The WL was recorded at 1 mm shorter than this length.

Teeth with an apical foramen diameter less than that of the #10 manual stainless steel file or a #20 manual NiTi file with 0.02 taper (Nitiflex; Dentsply-Sirona Endodontics, Ballaigues, Switzerland) and easily placed at the apical foramen were excluded. In addition, roots with canals in which the hand #10 stainless steel K-file did not make the apical foramen patent were excluded. The samples were randomly assigned to two groups (*n*=18): group 1: RaCe and group 2: Af f-one. The samples were fixed with silicone putty impression material (Speedex; Coltene/Whale dent, Altstatten, Switzerland). Before cleaning the root canals, CBCT images were prepared in the axial cross-section at a distance of 3 mm from the radiographic apex with 0.5-mm thickness at a right angle to the root long axis. The mounted base was placed in the scale of the CBCT unit (NewTom VGi, QR Verona, Cefla, Imola, Italy). The exposure conditions were as follows: mA=19, kVp=110, and time=5.4 sec. Three cross-sections were prepared from each sample at a distance of 3 mm (apical third), 6 mm (middle third), and 9 mm (coronal third) after initial preparation up to file #25. Three other cross-sections were prepared in the same areas after preparation up to file #40. Then the images were evaluated using NTT Viewer 0.08 software for the required measurements. When there were two root canals in the mesiobuccal root, only separate root canals with separate apical foramina were included in the study.

Root canal preparation

One operator prepared the root canals in all the samples.

Group 1 (RaCe files)

The root canal preparation process was initiated with a #40/0.01 NiTi RaCe file (FKG Dentaire, La Chaux-de-Fonds, Switzerland) at a torque of 2 N.cm at 600 rpm according to the manufacturer's instructions, followed by #35/0.08, #25/0.06, and #25/0.04 files. Finally, the root canals were completely prepared with #25/0.06 and #30/0.06 files.

Group 2 (Af f-one file)

Root canal preparation was initiated with #20/0.04, #25/0.04, and #35/0.06 Af f-one files and NiTi RaCe file (FKG Dentaire, La Chaux-de-Fonds, Switzerland), respectively, using the step-back technique.

The root canals were irrigated with 5 mL of 2.5% NaOCl during the instrumentation procedures. Each file was used to instrument two root canals. The root canal patency was checked with an ISO #10 NiTi file during and after instrumentation. After chemomechanical preparation, the smear layer was removed with a final irrigation protocol: 2 mL of 2.5% NaOCl for 30 sec, 2 mL of 17% EDTA (Calcinase, LegeArtis Pharma Dettenhausen, Germany) for 2 min, 2 mL of 2.5% NaOCl for 30 sec, and 2 mL of normal saline solution. The irrigation procedures were carried out using a 30-G needle (Steri Tips, DiaDent) placed at a distance of 2 mm from the apical foramen. The remaining irrigant after each step was aspirated using the same needle.

Evaluation of root canal transportation and centering ability

After preparing the root canals, new CBCT images were prepared using the initial parameters that were previously described.

The technique explained by Gambill *et al.* was used to determine root canal transportation extent with each file [15].

The thickness of instrumented and uninstrumented root

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canal walls was measured at 3-, 6-, and 9-mm distances from the apex, and root canal transportation in the mesiodistal direction was calculated using the following formula:

CT=(A1-A2)-(B1-B2)

Where A1 is the minimum distance between the external surface of the root cross-section and the mesial external border of the unprepared root canal,

B1 is the minimum distance between the external surface of the root cross-section and the distal external border of the unprepared root canal,

A2 is the minimum distance between the external surface of the root cross-section and the mesial external border of the prepared root canal,

And B2 is the minimum distance between the external surface of the root cross-section and the distal external border of the prepared root canal.

A radiologist evaluated all the CBCT cross-sections before and after root canal preparation procedures to determine the extent of root canal transportation based on the technique explained by Gumbill *et al.* [19]:

Root canal transportation=(X1-X2)/Y

Where X1 is the maximum root canal transportation in one direction, X2 is the maximum root canal transportation in the opposite direction, and Y is the final diameter of the prepared root canal.

One operator prepared all the root canals, while another operator, blinded to the study groups, carried out the root canal measurements.

Data analysis

The sample size was calculated using G*Power 9.3.34 software (Franz Faul, Christian-Albrechts-Universität Kiel, Kiel, Germany) according to previous studies [20], assuming 10% as the type I and 5% as the type II error. The data were reported using descriptive statistics, *i.e.*, means, standard deviations, frequencies, and percentages. Two-way ANOVA was used to compare root canal transportation and preservation of root canal centrality. SPSS software version 24 (SPSS, Chicago, IL, USA) was used for data analysis at a significance level of $P<0.05$.

Results

There was no file separation during the study. The results (Table 1) in the Af f-one rotary file group showed no significant differences in the root canal transportation between 3-, 6-, and 9-mm distances from the apex. In addition, there were no significant differences in the root canal centrality between the 3-, 6-, and 9-mm distance from the apex.

According to Table 1, in the RaCe rotary file group, there were no significant differences in the root canal transportation between the 3-, 6-, and 9-mm distances from the apex. In addition, there were no significant differences in the root canal centrality between the 3-, 6-, and 9-mm distances from the apex.

The results of two-way ANOVA (Table 2) suggested no difference between the two groups ($P>0.05$).

Table 3 shows no significant differences in the root canal centrality at 3-, 6-, and 9-mm distances from the apex between the two rotary file systems. In addition, there were no significant differences in root canal transportation at 3-, 6-, and 9-mm distances from the apex between the two rotary file systems.

Discussion

Our findings suggested no statistically significant differences in canal transportation and centrality by RaCe and Af-f rotary systems in all the coronal, middle, and apical thirds; also, there was no difference in canal centrality between the two systems.

Root canal transportation is an error that affects preparation procedures, resulting in inadequate root canal debridement and jeopardizing the apical seal [21-24]. Root canal transportation during root canal preparation mainly occurs due to the rigidity of endodontic instruments, resulting in uneven distribution of tensions at contact points between the instrument and root canal wall. Therefore, the file tends to regain its straight form within the root canal, which leads to more force concentration on the external aspect of the curve [25].

Different techniques have been used to evaluate the final prepared root canal, including simulated root canals in resin blocks [26], optical microscope serial sectioning technique [20], and radiographic evaluations [24]. However, when these techniques are applied, a part of or the whole structure of the sample is destroyed. In addition, these techniques might only make it possible to evaluate the root canal two-dimensionally [27]. Recently, the CBCT technique has increased the accuracy and resolution of 3D evaluations, enabling the reproducibility of evaluations with no damage to the samples [28, 29].

This study aimed to compare root canal transportation and the preservation of root canal centrality with RaCe and Af f-one rotary files using the CBCT technique. The RaCe rotary system has already been studied, and its efficacy in cleaning and shaping the root canals and preserving the root canal centrality has been confirmed [30].

A study by Mamede-Neto *et al.* [31] on eight different NiTi rotary file systems, including RaCe, using the CBCT technique

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showed similar performance of these file systems regarding root canal transportation and the ability to preserve root canal centrality during the canal preparation procedures of mandibular premolars. The results of a study by Mamede-Neto *et al.* [32] on reciprocating and continuous NiTi files showed that all the systems resulted in root canal transportation, and none could preserve excellent root canal centrality during root canal preparation. Reciproc files resulted in the highest transportation of mesiodistal and buccolingual directions.

Discrepancies in some results might be attributed to differences in sample sizes. The method used for calculations in the study above differed from that in the present study. In the present study, the central axis points on root canal cross-sections were calculated, and the extent of root canal transportation was determined by measuring the distance between the points determined before and after preparation. The methods used to determine root canal transportation in the two studies and the imaging technique might have affected these differences. In addition, in the present study, both instruments were operated with the same motor and similar movements, speed, and torque to eliminate the effects arising from cinematics.

Some studies have shown the efficacy of RaCe rotary files in preserving the centrality of root canals [33]. In this context, Junior *et al.* [30] showed that RaCe rotary files make it possible to prepare curved root canals with diameters larger than that possible with minimum canal transportation and the ability to preserve root canal centrality.

Af f-one is a single-file system manufactured with a new thermochemical alloy, such as the AF-R (Fanta Dental) wire. One of its advantages is its superior flexibility and fatigue resistance. The flat design and S-shaped cross-section of the f-one system can affect the amount of root canal transportation and preservation of the root canal centrality. However, limited studies have evaluated the effect of flat characteristics on the shaping ability of these new rotary files.

In the present study, the root canal transportation rate and root canal centrality preservation with Af f-one files were similar to RaCe files, indicating the efficacy of f-one files in root canal transportation and adequate preservation of root canal centrality Nardo *et al.* [34] compared instruments with flat-side design and non-flat design regarding the preservation of root canal centrality and reported that the Af f-one file system had better shaping ability than the Prototype system in simulated L-shaped resin canals.

Table 1. Comparison of canal transportation and centering ability between Af f-one and Race

	Group	Distance (mm) from the root apex		
		3 mm	6 mm	9 mm
Centering Ability	Af f-one	0.011 (0.107)	0.05 (0.12)	0.01 (0.12)
	RaCe	0.01 (0.13)	0.02 (0.15)	0.72 (3.12)
Transportation	Af f-one	0.30 (0.24)	0.29 (0.14)	0.20 (0.12)
	RaCe	0.30 (0.24)	0.23 (0.15)	0.22 (0.15)

Table 2. Comparison of groups using two-way ANOVA

Source	Type III sum of squares	df	Mean square	F	*P*-value
Group	1.68	1	1.68	1.00	0.32
Distance from apex	3.80	2	1.90	1.12	0.32
Group - DFA	2.98	2	1.49	0.88	0.41
Error	176.98	105	1.68		
Total	186.94	111			

Table 3. Comparison of canal transportation and centering ability between Af f-one and Race

	Groups	Location(mm) From the Root Apex			*P*-value*
		3mm	6mm	9mm	
Centering Ability	Af f-one	0.01 (0.10)	0.05 (0.12)	0.01 (0.12)	0.258
	RaCe	0.01 (0.13)	0.02 (0.15)	0.72 (3.122)	0.35
	***P*-value**	**0.98**	**0.53**	**0.34**	
Transportation	Af f-one	0.30 (0.24)	0.29 (0.14)	0.20 (0.12)	0.20
	RaCe	0.30 (0.24)	0.23 (0.15)	0.22 (0.15)	0.35
	***P*-value**	**0.99**	**0.28**	**0.70**	

P-value: Refers to One Way Anova; P-value: Refers to Independent T Test*

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Kaddura *et al.* [35] compared the shaping abilities of single-file NiTi systems in S-shaped canals and reported that Af f-one and Blue Reciproc systems (VDW, Munich, Germany) exhibited a higher rate of deviation in the middle third than OneCurve(Micro-Mega, Besançon, France) and WaveOne Gold systems (DentsplyMaillefer, Ballaigues, Switzerland).

In the present study, measurements were made at three cross-sections for each sample (the apical, middle, and coronal thirds) [36, 37]. During the root canal preparation procedures, the position and shape of the apical foramen should be preserved to create an ideal apical seal. However, all the instruments used to prepare the root canal change the position of the root canals. According to many studies, the dimensions, metallurgic characteristics, design, and technique to use these instruments affect the amount of root canal transportation (26). The present study results did not reveal significant differences between the two rotary file systems in the three cross-sections. On the other hand, it should be noted that the flat-side design of the Af f-one file decreases metallic debris on the instrument, increases flexibility, and increases resistance to cyclic fatigue. In addition, the lower rate of blade entanglement due to the smooth cross-section of the file can explain this instrument's more conservative shaping ability [18].

The present study showed the greatest extent of root canal transportation in the apical area with both file systems. Apical transportation >0.3 mm results in the loss of the apical seal, compromising the treatment prognosis [38]. In the present study, the canal transportation range was <0.3 mm, which does not affect the apical seal.

Conclusion

Under the limitation of the present study and based on the results, there were no significant differences in root canal transportation and the preservation of root canal centrality in the apical, middle, and coronal thirds between the two studied rotary file systems during root canal preparation.

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Conflict of interest

None.

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None.

Author contributions

Mokhtari H: Devised the project, the main conceptual ideas and proof outline, supervised the project, Razi S: Designed the model and the computational framework and analyzed the data, performed the measurements, Rahimi S: Developed the theory, involved in planning, Haghighat P: Designed and performed the experiments, derived the models and analyzed the data, Abed A: Co-responding author, wrote the manuscript, Behrouzpour E: Contributed to sample preparation, aided in interpreting the results and worked on the manuscript. All authors discussed the results and commented on the manuscript.

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