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Effect of movement kinematics on canal transportation: reciprocation with different angles, adaptive motion, and continuous rotation

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Objective: The aim of this study was to compare canal transportation in mesiobuccal root canals of extracted human mandibular molars instrumented with Twisted File Adaptive instruments with different kinematics.

Methods: A total of 60 extracted human permanent mandibular first molars with curved mesial root canals (25<a<40) were selected. The teeth were assigned to 5 root canal shaping groups as follows: adaptive motion, 150° clockwise (CW)–30° counterclockwise (CCW), 210° CW–30° CCW, 270° CW–30° CCW, and continuous rotation. The canals were scanned using cone-beam computed tomography (CBCT) before and after instrumentation. The degree of canal transportation at three levels and the canal centering ratio were analyzed statistically using one-way analysis of variance and Tukey's post hoc tests at a significance level of p<0.05.

Results: There was no significant difference in canal transportation among the groups at the three studied levels (1, 4, and 7 mm from the root apex) (p>0.05). The data for the centering ratio showed that there was no significant difference among the tested groups after instrumentation in each section of the root canal (p>0.05).

Conclusion: The TF Adaptive instruments produced similar canal transportation and centering ratio when used with different movement kinematics.

Keywords: Continuous rotation; kinematics; reciprocation; transportation; twisted file adaptive.

Cleaning and shaping are the most important steps of a root canal treatment that aims removing debris and microorganisms which are responsible for endodontic pathosis from the root canals.[1] Root canal preparation should present a flare shape from apical to coronal, maintaining the apical foramen in its original spatial relationship to the periapical tissues and to the root surface, and not changing the original canal curvature.[2] However, in curved canals, iatrogenic errors, such as ledges, zips, perforations, and root canal transportation, might occur because there is a tendency for all preparation techniques and instruments to divert the prepared canal away from its original axis.[3,4] Canal transportation increases the risk of blockage, perforation, and ledge creation, may weaken the root structure, and may compromise the obturation of the root canal system, resulting in a poor apical seal.[5]

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Many root canal preparation techniques together with rotary nickel-titanium (NiTi) systems and different kinematics have been developed to overcome these problems, to maintain the original canal shape and to provide a better canal centralization.[6,7]

Recently, the Twisted File Adaptive system (TF Adaptive) (SybronEndo, Orange, CA) was introduced that uses continuous rotation when the amount of pressure based on the file is minimal. When the system engages the dentin and a load is applied, the system can change to a reciprocation mode, with specifically designed clockwise (CW) and counterclockwise (CCW) angles, which vary from 600–0° up to 370–50°.

According to our knowledge, an evaluation of canal transportation with different movement kinematics (reciprocating movements in various angles, adaptive motion, and continuous rotation) has not been reported. Therefore, the aim of this study was to compare the canal transportation in mesiobuccal root canals of extracted human mandibular molars instrumented with TF Adaptive instruments with different kinematics. The null hypothesis is that changing the angles of reciprocation does not change the amount of root canal transportation.

Materials and methods

A total of 60 extracted human permanent mandibular first molars with completely formed apices and curved mesial root canals were selected. Inclusion criteria included no significant calcifications and two separate mesial canals with two separate apical foramina and with severe angles of curvature (25<a<40). Radiographs of teeth in the buccolingual and mesiodistal directions were taken, and canal curvature was calculated by using Schneider's technique.[8] Distal roots and crowns were removed with a high-speed bur (KG Sorensen, Barueri, SP, Brazil), and a final 15-mm working length (WL) was achieved for each tooth. After access cavities were prepared in each tooth, a size 10 K-file (Mani Inc. Tochigi, Japan) was placed in the canal until the file was visible at the apical foramen and the working length was established 0.5 mm short of this length. For all teeth, the root canal width near the apex was compatible with a size 15 K-file. This was checked by moving a 15 K-file down to the working length. When the instrument extruded beyond the apex, the tooth was excluded from the study. The roots were randomly assigned to five experimental groups (n=12).

All roots were fixed in a silicone impression material, in which each root was placed in the same position before and after instrumentation, and scanned by using the cone-beam computed tomography (CBCT) scanner (NewTom FP QR-DVT 9000, Verona, Italy) operating at 110 kVp and 15 mA. The field of view was 17 cm in diameter and 13 cm in height.

In all groups, the root canals were instrumented using TF Adaptive instruments (SM1 [20/.04], SM2 [25/.06], and SM3 [35/.04]) at full WL. The canals were irrigated with 2 mL 5.25% sodium hypochlorite (NaOCl) after each instrument change, and each instrument was used to prepare four canals.

150° CW–30° CCW: In this group, instrumentation was performed using an electric motor (Satelec Endo Dual, Acteon, France) that allows the user to modify and set the reciprocating angles in the CW and CCW directions. The angles of reciprocation were set at CW=150° and CCW=30° for root canal preparation.

210° CW–30° CCW: The angles of reciprocation were set at 210° CW and 30° CCW on the Acteon motor.

270° CW–30° CCW: The angles of reciprocation were set at 270° CW and 30° CCW on the Acteon motor.

TF Adaptive: The root canals were instrumented using the Elements Motor TF Adaptive program (SybronEndo, Glendora, CA, USA).

Continuous Rotation: In this group, the root canals were instrumented using the Acteon motor at continuous rotation.

All root canals were instrumented by one operator. After the root canal instrumentation procedures, CBCT imaging of the prepared samples was repeated using the same position and parameters in order to compare pre- and post-images. Canal transportation and the centering ratio were analyzed at three cross-section levels that corresponded to 1, 4, and 7 mm distances from the apical end of the root by using the following formulas.[9]

Degree of canal transportation = $(m_1-m_2)\leftrightarrow(d_1-d_2)$

Canal centering ratio = $(m_1-m_2) / (d_1-d_2)$ or $(d_1-d_2) / (m_1-m_2)$;

m_1 and m_2 represented the shortest mesial distances from the mesial margin of the curved root to the mesial margin of the uninstrumented and instrumented canals, respectively; d_1 and d_2 represented the shortest distal distances from the distal margin of the curved root to the distal margin of the uninstrumented and instrumented canal, respectively (Fig. 1).

According to the degree of canal transportation formula, a result of 0 indicates no canal transportation, and a result other than 0 means that transportation occurred in the canal.[9] According to the centering ratio formula, a result of 1 indicates perfect centering.[10]

The degree of canal transportation and the canal centering ratio were analyzed statistically using one-way analysis of variance and Tukey's post hoc tests at a significance

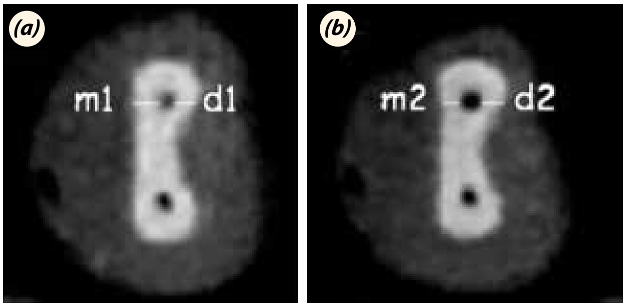

Fig. 1. Root canal transportation and centering ratio measurements **(a)** before instrumentation and **(b)** after instrumentation.

level of $p<0.05$. All statistical analyses were performed with IBM SPSS Statistics 20 software (IBM SPSS Inc., Chicago, IL, USA).

Results

Table 1 shows the mean and standard deviation of the canal transportation at the 1, 4, and 7 mm levels for each group. There was no significant difference in canal transportation among the groups at the three studied levels ($p>0.05$). The data for the centering ratios showed that there was no significant difference among the tested groups after instrumentation in each section of the root canal ($p>0.05$). Table 2 shows the mean and standard deviation of the centering ratios at the 1, 4, and 7 mm levels for each group.

The mean preparation times for all groups are shown in Table 2. Statistical analysis showed that there were significant differences among the groups in terms of prepara-

Table 1. Statistical Analysis of Mean Transportation Values (mm) for Tested Groups

Groups	n	Level	Mean	Standard deviation	Preparation time (min)
150°CW-30°CCW	12	1 mm	0.21	0.13	2.8
	12	4 mm	0.16	0.14	
	12	7 mm	0.23	0.2	
210°CW-30°CCW	12	1 mm	0.16	0.17	2.6
	12	4 mm	0.14	0.16	
	12	7 mm	0.23	0.25	
270°CW-30°CCW	12	1 mm	0.28	0.27	2.0
	12	4 mm	0.13	0.14	
	12	7 mm	0.19	0.13	
Adaptive motion	12	1 mm	0.18	0.09	1.0
	12	4 mm	0.08	0.12	
	12	7 mm	0.23	0.17	
Continuous rotation	12	1 mm	0.30	0.14	1.5
	12	4 mm	0.21	0.15	
	12	7 mm	0.19	0.2	

Table 2. Statistical Analysis of Mean Centering Ratio Values (mm) for Tested Groups

	n	Level	Mean	Standard Deviation
150°CW-30°CCW	12	1 mm	0.35	0.36
	12	4 mm	0.13	0.31
	12	7 mm	0.17	0.39
210°CW-30°CCW	12	1 mm	0.32	0.42
	12	4 mm	0.14	0.33
	12	7 mm	0.35	0.25
270°CW-30°CCW	12	1 mm	0.23	0.45
	12	4 mm	0.06	0.19
	12	7 mm	0.26	0.41
Adaptive motion	12	1 mm	0.24	0.37
	12	4 mm	0.33	0.49
	12	7 mm	0.15	0.36
Continuous rotation	12	1 mm	0.21	0.31
	12	4 mm	0.20	0.39
	12	7 mm	0.29	0.40

tion time ($p<0.05$). The adaptive motion and continuous rotation groups were faster than the reciprocation groups ($p<0.05$). Additionally, there was a significant difference among the reciprocation groups ($p<0.05$). The 270° CW–30° CCW group was faster than 210° CW–30° CCW and 150° CW–30° CCW groups. The adaptive motion and continuous rotation groups had similar mean preparation times ($p>0.05$).

Discussion

The present study aimed to evaluate the effect of various kinematics on canal transportation and the centering ratio in curved root canals.

Previous studies on canal transportation evaluated various file systems used in reciprocation or continuous rotation motion.[11–15] However, these studies did not isolate the effect of kinematics on transportation because they compared different file systems. Numerous factors such as the design of the file, manufacturing method, metallurgic properties, and number of files might influence the amount and direction of apical transportation.[11,16–18] In the present study, these variables were isolated by using TF Adaptive instruments in all groups. Morever, the root canal preparations were performed by the same operator. Thus, the operator had no effect.[19]

In the present study, there were no significant differences among the groups in terms of apical transportation and the centering ratio. This finding is in accordance with the findings of a previous study that evaluated the shaping ability of reciprocating and continuous rotation motion in curved root canals using ProTaper instruments (Dentsply Maillefer, Ballaigues, Switzerland).[20] This previous study concluded that the application of reciprocating motion during instrumentation did not result in increased apical transportation when compared with continuous rotation motion. The cutting ability of the instrument may affect the amount of canal transportation. Adaptive motion and continuous rotation have similar cutting ability.[21] This might be an explanation for the results of the present study.

The results of this study might have been different with less flexible instruments. Saber Sel et al.[22] evaluated the effect of changing the reciprocation range of the WaveOne instrument (Dentsply Maillefer) (size 25, taper 0.08) on its fatigue life and shaping ability. They reported that decreasing the reciprocation range of WaveOne instruments resulted in increased cyclic fatigue resistance with less canal transportation. However, according to the results of the present study, changing the reciprocation range of the TF Adaptive instruments did not affect the amount of canal transportation. The conflicting results may be due to the different design and flexibility of the instruments used in the studies. More flexible files maintain the original root canal better with less canal transportation.[23] The TF Adaptive instruments have superior flexibility due to the manufacturing process.[24] The superior flexibility might led to similar canal transportation with different movement kinematics. The WaveOne instrument has a modified triangular cross section with radial lands at the tip and a convex triangular cross section in the middle and coronal portions of the instrument. However, the TF Adaptive instrument is characterized by a triangular cross section. Additionally, while the WaveOne technique use a large, rigid, single file with increased taper (0.08 taper, size 25) that directly reaches the apex, the TF Adaptive technique is a three-file technique.[25] A multiple-file system with smaller tapered instruments has an effect on the amount of canal transportation.[14,15,26]

The study results showed reciprocation was slower than adaptive motion and continuous rotation in terms of preparation period. Reciprocation motion needed more time for one entire rotation compared with continuous rotation.[27] Thus, the file needed more time to reach the working length. This may explain the increased preparation period in the reciprocation groups.

Cone-beam computed tomography (CBCT), which provides an accurate, reproducible, three-dimensional evaluation of root canal changes before and after instrumentation without the destruction of specimens, was used in the present study to evaluate the transportation and centering ratio values.[28] When irregular apical preparation is performed, infected debris that can cause improper canal obturation may remain in the root canal.[29,30] To observe this effect, apical transportation was assessed at three levels (1, 4, and 7 mm from the root apex) representing the apical and middle thirds of the root canal. Wu et al.[31] reported that the sealability of the obturating material could be negatively affected by apical transportation of more than 0.3 mm. In the present study, no apical transportation value exceeded this limit.

Conclusion

Within the limitations of this study, the TF Adaptive instruments produce similar canal transportation and centering ratios when used with different movement kinematics (reciprocation, continuous rotation, and adaptive motion). Further studies should be conducted to confirm the results.

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World Medical Association Declaration of Helsinki.

Conflics of Interest: No conflicts declared.

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