Canal Transportation, Centering Ability, and Cyclic Fatigue Promoted by Twisted File Adaptive and Navigator EVO Instruments at Different Motions

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Abstract

Introduction: This study compared the cyclic fatigue and the canal transportation promoted by Twisted File (TF) Adaptive and Navigator EVO systems when used with 2 different motions. **Methods:** Forty mesiobuccal roots of maxillary molars were scanned by using micro–computed tomography imaging before and after root canal preparation with the 2 instrument systems used with 2 motions (adaptive and continuous rotation). Samples were divided into 4 groups: TFA, TF Adaptive instruments under adaptive motion; TFC, TF Adaptive instruments under continuous motion; NA, Navigator instruments under adaptive motion; and NC, Navigator instruments under continuous motion. Root canals were prepared until 35.04 instruments. Apical transportation was analyzed by using micro–computed tomography at 3 levels: 3, 6, and 9 mm from the apex. The cyclic fatigue tests were performed by using a custom-made device. Ten instruments of each brand were activated by using a 6:1 reduction handpiece powered by a torque-controlled motor using the preset programs "custom mode" and "TF Adaptive" to activate 25.06 and 35.04 instruments. Kruskal-Wallis and Dunn tests were used to assess canal transportation, centering ability, and canal volume. The Student *t* test was used to evaluate cyclic fatigue (P = .05). **Results:** At 3 and 9 mm, the canal transportation and centering ability were similar in all groups (P > .05). At 6 mm, TFC presented higher canal transportation toward furcal region than NA and NC (P < .05). After canal preparation, TFA promoted great dentinal excision, presenting higher canal volume than NA and NC (P < .05). Higher cyclic fatigue resistance was observed under continuous than adaptive motion regardless of system or tip/diameter of the instrument (P < .05). **Conclusions:** Both systems can be used under adaptive or continuous rotation. However, the life span of the instruments was higher when used under continuous rotation. Small canal transportation occurred when mesiobuccal root canals from maxillary molars were prepared until 35.04 instruments. *(J Endod 2018;■:1–5)*

Key Words

Adaptive movement, continuous rotation, cyclic fatigue, micro-computed tomographic imaging, root canal preparation, root canal transportation

Significance

NiTi instruments made by heat-treated alloy can perform root canal shaping of curved canals in adaptive and continuous rotation up to an apical enlargement of 35.04.

Canal preparation is one of the major steps in root canal treatment, and it is directly related to subsequent disinfection and filling procedures. It must promote a uniform and continuous conical shape from cervical to apical portions, preserving the original canal curvature and the position of the apical foramen (1). These goals become much more challenging in curved canals (2). However, the use of rotary nickel-titanium (NiTi) instruments has enhanced the overall shaping quality and reduced the frequency of procedural errors such as ledges, zips, perforations, and canal transportation (3, 4).

The technological advances in endodontics introduced to the market several NiTi instruments with different alloys (M-Wire, R-phase, and conventional NiTi) (5), which are attached to electric motors in continuous rotation and most recently in reciprocation motion. Yared (6) was the first to propose the use of only one NiTi rotary instrument, the ProTaper F2 (Dentsply Maillefer, Ballaigues, Switzerland), in clockwise (CW) and counterclockwise (CCW) movements to shape root canals. Few years later, reciprocating instruments, WaveOne (DentsplyMaillefer) and Reciproc (VDW, Munich, Germany), were developed with different kinematics by cutting at CCW and performing debris release at CW (7, 8).

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0099-2399/$ - see front matter

https://doi.org/10.1016/j.joen.2018.06.002

The Twisted File (TF) Adaptive (SybronEndo, Orange, CA) system works in a combination of continuous rotation movements and reciprocating motion. The manufacturer aims to maximize the advantages of reciprocation movement while minimizing its disadvantages. They also claim that the design of these instruments increases flexibility and allows the file to adjust to intracanal torsional forces, depending on the amount of pressure placed on it (2). The adaptive motion combines a continuous rotation in a CW direction when the instrument is lightly stressed into the canal, with reciprocation movement in cases that torsional stress increases (4). In reciprocating movement, the instruments develop cutting angles of 370° forward (CW) and 20° to 50° backwards (CCW) (9). Such kinematics enables the instrument to advance into the canal while it cuts dentin (CW movement) and to reduce the risk of instrument fracture by torsional stress (CCW movement). Moreover, TF Adaptive instruments have some specific features to optimize their strength and flexibility: R-phase heat treatment, twisting of the metal, equilateral triangular cross section, and special surface conditioning (10).

The Navigator EVO system (Medin, NovéMěsto na Moravě, Czech Republic) consists of the new generation of the Wizard Navigator system (Medin) (11). According to the manufacturer, this system presents a triangular cross section and an inactive tip to assist the instrument trajectory along the root canal. The Navigator EVO instruments present great flexibility and fatigue resistance because of thermal-treated NiTi (11). Last, according to the manufacturer, continuous rotation is the recommended kinematics for these instruments.

The success of root canal preparation with automated NiTi instruments is linked to their design, flexibility, superelasticity, kinematics, and cyclic fatigue (11–15). Cyclic fatigue consists of repeated tension/compression cycles because of the rotation of the instrument in curved canals and may be an important factor for instrument fracture (16). Resistance to cyclic fatigue of rotary instruments is affected by the angle and radius of canal curvature and the size and taper of the instrument. The instrument life span decreases when the angle and radius of the curve are severe and also when the instrument size and taper increase (17). Cyclic fatigue tests have already been used to assess the behavior of TF Adaptive instruments in adaptive motion (14, 15) but not in continuous rotation. Moreover, the cyclic fatigue of Navigator EVO instruments was not tested either in continuous rotation or in adaptive motion.

This study was designed to assess canal transportation, centering ability, and volume of excised dentin promoted by TF Adaptive and Navigator EVO instruments in continuous and adaptive motion by using micro–computed tomography (CT). Cyclic fatigue test was also performed to evaluate both systems used at the kinematics. The null hypothesis tested was that there are no significant differences in canal transportation, centering ability, volume of excised dentin, and cyclic fatigue between the NiTi systems regardless of the kinematics used.

Materials and Methods

Sample Selection and Initial Micro-CT

This study was previously approved by ethical committee (CAAE: 3102221 4.6.0000.5347). An initial sample of 100 maxillary molars was collected. The teeth were stored in 0.1% thymol solution for 30 days until preoperative radiographs were taken. Roots exhibiting excessive curvatures, incomplete apex formation, calcifications, root fractures, or separated instruments were discarded. Then 40 mesiobuccal roots were selected. Only canals in which a glide path using a K-file #15 was possible were included in this study.

The working length (WL) was measured through visual method. A K-file #15 was inserted into the canals until the tip became visible on the apical foramen. Then the WL was established as being 1 mm shorter than this measure. The angle of curvature was determined by using periapical radiography (18). Roots with similar angles of curvature (10° to 20°) were randomly distributed among the 4 groups according to the instrument and the kinematics used: TFA, TF Adaptive instruments in adaptive motion (n = 10); TFC, TF Adaptive instruments in continuous motion (n = 10); NA, Navigator instruments in adaptive motion (n = 10); and NC, Navigator instruments in continuous motion (n = 10).

TABLE 1. Sequence of TF Adaptive and Navigator EVO Instruments Used for Canal Preparation

TF adaptive	Navigator EVO
#25.08 cervical third	#25.07 cervical third
#20.04 in the WL	#10.04 in the WL
#25.06 in the WL	#15.05 in the WL
#35.04 in the WL	#20.06 in the WL
	#25.06 in the WL
	#35.04 in the WL

Each sample was individually embedded in a high-precision impression material (Speedex; Coltène, Cuyahga Falls, OH) to improve repositioning of the samples during image acquisition by micro-CT (SkyScan 1174v2; SkyScan, Kontich, Belgium). The scanning procedures were performed by using the following parameters: 50 kV, 800 μA, 28.24 μA voxel size. Then scans with 512 × 652 pixels were obtained with 0.7° interval of acquisition, resulting in a total of 360°. The sequences of scans were reconstructed by using the software NRecon v.1.6.3 (Bruker-microCT, Kontich, Belgium).

Root Canal Preparation and Irrigation Procedures

Root canal preparation in all groups was performed by using Elements Motor (SybronEndo). In TF Adaptive groups, cervical preparation was performed with K3 system (25.08) (SybronEndo), followed by Small files sequence from TF Adaptive system. In Navigator EVO groups, cervical preparation was performed with W-XN 25.07 files (Medin), followed by a sequence that is recommended by the manufacturer (Table 1).

Two kinematics were used in this study: continuous motion, speed of 300 rpm and torque of 2.0 N/cm; and adaptive motion, combination of continuous rotation in CW direction when the instrument was lightly stressed into the canal and reciprocation movement in cases that torsional stress increases. In reciprocating movements, the instruments developed cutting angles of 370° forward (CW) and 20° to 50° backwards (CCW). Speed and torque were set according to manufacturer's specifications.

During canal preparation, the canals were irrigated with 2 mL 2.5% sodium hypochlorite (NaOCl) after each instrument change. The irrigant was delivered into the canals by using a 5-mL silicon syringe (Ultradent Products Inc, South Jordan, UT) and Endo-Eze tips (Ultradent Products Inc) placed 3 mm shorter than the WL.

Canal Transportation, Centering Ability, and Canal Volume

After canal preparation, the roots were scanned once again by using the same sets described in the first analysis. Reconstructed images captured before and after root canal preparation were geometrically aligned by using 3D True registration of the DataViewer v.1.5.1 software (Bruker MicroCT) as previously reported (19, 20). This function allows the alignment of the sagittal, coronal, and axial planes, ensuring accurate superposition of the images before and after preparation.

Canal transportation and centering ability were assessed by using the CT Analyzer software (Skyscan) at 3 root levels 3, 6, and 9 mm from the apex. One calibrated evaluator measured all values (intraclass correlation coefficient = 0.88). Both outcomes were determined by measuring the shortest distance from the edge of the canal to the periphery of the root (ie, mesial and distal) before and after canal preparation (21).

The following formulas were used to calculate canal transportation and centering ability: $[(m_1\text{-}m_2) - (d_1\text{-}d_2)]$ and $[(m_1\text{-}m_2)/(d_1\text{-}d_2)]$ or $[(d_1\text{-}d_2)/(m_1\text{-}m_2)]$, respectively. In these formulas, m_1 and m_2 are the shortest distance from the mesial edge of the root to the mesial edge of the pre-prepared and post-prepared canal, respectively; and d_1 and d_2 are the shortest distance from the distal edge of the root to the distal edge of the pre-prepared and post-prepared canal, respectively. The numerator for the centering ratio formula was the smaller of the 2 numbers $(m_1\text{-}m_2)$ or $(d_1\text{-}d_2)$ if these numbers were unequal (21). A result other than 0 indicates canal transportation, and a result equal to 1 indicates perfect centering (21).

In the canal volume assessment, the CT Analyzer software (Skyscan) was used to compare the canal volume before and after preparation. Canal volume was calculated by subtracting the total volume of the prepared canal from the total volume of the canal previous to the preparation to obtain the volume of dentin removed (mm^3). The pre-preparation and post-preparation scans were evaluated at 1.0 mm below the furcation level until 1.0 mm above the apical foramen. Canal volume was measured for each root third and for the whole canal (180 scans for each specimen). The values were obtained in mm^3 and were later transformed into a percentage for pre-instrumentation and post-instrumentation comparison.

Cyclic Fatigue

The cyclic fatigue test was performed by using a custom-made that allowed reproducible simulation of an instrument confined in curved canal. An artificial canal was manufactured by reproducing the instrument size and taper, thus providing the instrument with a suitable trajectory with 60° angle of curvature and 5-mm radius of curvature. The curvature of the stainless steel artificial canal was fitted into a guide cylinder made of the same material (angle of curvature, 60°; radius, 5 mm). The arch had a 1-mm-deep groove located 5 mm from the top to match the height of the counter-angle. The groove served as a guide path for the instrument, which remained curved and free to rotate between the cylinder and external arch.

Ten instruments of each brand were activated by using a 6:1 reduction handpiece powered by a torque-controlled motor (Elements Motor) using the preset programs “CUSTOM MODE” and “TF ADAPTIVE” to activate the TFA 25.06 and 35.04 and Navigator 25.06 and 35.04 instruments. The “CUSTOM MODE” was used with 300 rpm and torque of 2 N/cm and the “TF ADAPTIVE” per the manufacturer’s instructions. To reduce friction between the instrument and the metal (canal walls), high-flow synthetic oil was sprayed into the simulated canal (Super Oil; Singer Co Ltd, Elizabethport, NJ). The time to fracture was recorded in seconds by a chronometer with accuracy of 0.1 seconds. During this step, a video was recorded simultaneously, and the recordings were analyzed to ensure the accurate time of instrument fracture.

Statistical Analysis

Data analysis was performed by using SPSS 17.0 software (IBM, New York, NY). Shapiro-Wilk normality test indicated normal distribution only for centering ability data. Thus, Kruskal-Wallis and Dunn tests were performed to compare the canal transportation and volume. Centering ability was assessed by using one-factor analysis of variance and Tukey test. Finally, Student *t* test was used to analyze cyclic fatigue. The significance level was set at 5%.

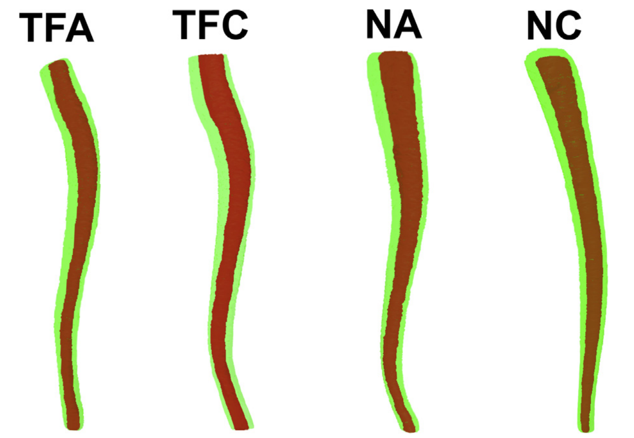

Figure 1. Representative illustration of internal anatomy of mesiobuccal canals from maxillary molars. *Red* and *green* colors represent root canals before and after preparation, respectively.

Results

Little canal transportation was observed toward distal region at 3 mm, even though at 6 and 9 mm it occurred toward the opposite side. At 3 and 9 mm, the canal transportation was similar in all groups ($P > .05$). But at 6 mm, TFC presented higher transportation toward distal wall of the canal than the other groups ($P < .05$) (Figs. 1 and 2). Centering ability occurred in all groups, but it was similar regardless of the rotary system, the kinematics, and the canal third ($P > .05$) (Table 2).

The overall canal volume in TFA group was higher than in NA and NC ($P < .05$). TFC presented intermediate values. At 6 mm, NA presented the highest canal volume ($P < .05$), but at 3 and 9 mm, the volume was similar for all groups ($P > .05$).

The cyclic fatigue test showed that continuous motion promoted significantly higher time to failure in comparison with adaptive movement ($P < .05$). The brand of the rotary system and taper/diameter of the instrument were not determinant for this outcome ($P > .05$) (Table 3).

Discussion

New NiTi systems have been marketed to look for improvements in root canal preparation. This study assessed 2 rotary systems: TF Adaptive, which works with a specific reciprocating kinematics, and Navigator EVO instruments. which are used with continuous rotary movement. Adaptive movement aims to provide better security during

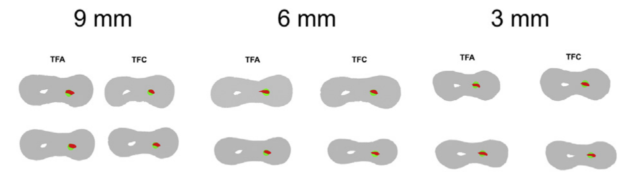

Figure 2. Representative illustration of cross sections of superimposed root canal systems before (*red*) and after (*green*) preparation at 9, 6, and 3 mm from apical end of the root.

TABLE 2. Canal Transportation (Median, Minimal, and Maximal Values in mm), Centering Ability (Mean ± Standard Deviation in mm), and Canal Volume (Median, Minimal, and Maximal Values in mm^3) after Canal Preparation with TF Adaptive and Navigator EVO Instruments in Different Motions

	TFA	TFC	NA	NC
Canal transportation, 3 mm	0.017 (−0.027 to 0.067)	0.029 (−0.133 to 0.512)	0.060 (−0.014 to 0.012)	0.050 (0.030 to 0.160)
Canal transportation, 6 mm	0.020^{A} (−0.051 to 0.114)	-0.092^{B} (−0.154 to 0.059)	-0.003^{A} (−0.093 to 0.090)	-0.027^{A} (−0.111 to 0.065)
Canal transportation, 9 mm	−0.071 (−0.266 to 0.016)	−0.025 (−0.152 to 0.073)	−0.111 (−0.377 to 0.041)	−0.063 (−0.170 to 0.039)
Centering ability, 3 mm	0.868 (±0.248)	0.813 (±0.259)	0.595 (±0.173)	0.627 (±0.284)
Centering ability, 6 mm	0.645 (±0.268)	0.448 (±0.212)	0.815 (±0.365)	0.704 (±0.359)
Centering ability, 9 mm	0.543 (±0.311)	0.640 (±0.163)	0.461 (±0.225)	0.576 (±0.238)
Canal volume, 3 mm	289.1 (209.5 to 393.2)	253.2 (232.6 to 305.1)	278.8 (54.6 to 426.5)	308.2 (218.8 to 362.8)
Canal volume, 6 mm	150^{A} (140.7 to 204.7)	142.7^{A} (112.6 to 261.0)	296.3^{B} (131.1 to 368.9)	134.5^{A} (119.4 to 149.1)
Canal volume, 9 mm	136.1 (63.9 to 121.8)	136.4 (119.9 to 163.7)	209.5 (113.6 to 342.4)	134.9 (110.6 to 165.9)
Canal volume, overall	227.7^{A} (192.7 to 274.6)	196.7^{AB} (154.9 to 267.0)	166.3^{B} (129.1 to 201.4)	178.6^{B} (166.3 to 210.4)

Different letters in the row denote significant differences after Kruskal-Wallis and Dunn tests (canal transportation and volume) and after one-factor analysis of variance and Tukey (centering ability) ($P < .05$).

canal preparation by decreasing risks of instrument fracture and little canal transportation. Therefore, an experimental design was developed to investigate these characteristics for both systems.

Mesiobuccal roots of maxillary molars were used because their anatomic features can challenge the canal preparation because of the high incidence of canal flattening in the mesiodistal direction and canal curvatures (22). Micro-CT is considered to be the gold standard method to assess shaping ability of endodontic instruments because it is a noninvasive technique that allows analysis before and after preparation. In addition, it also allows image reconstruction in 2-dimensional and 3-dimensional (23–26).

TF Adaptive and Navigator EVO instruments work with different kinematics. The literature has reported better results when continuous rotary movement is used (4, 27, 28). This study did not show differences with regard to canal transportation and centering ability at 3 mm from the apex between TF Adaptive and Navigator EVO, irrespective of the kinematics used ($P > .05$). On the other hand, TFC presented higher canal transportation toward distal wall of the canal at 6 mm ($P < .05$). This finding assumes particular importance as long as the distal wall of mesiobuccal roots has thin dentin thickness. Thus, wide wearing in this region might lead to root weakening or even perforation. Other studies confirm this finding because they demonstrated low prevalence of canal transportation when TF Adaptive system was used in adaptive motion (4, 5, 27, 28). Silva et al (28) found good centering ability and little canal transportation promoted by TF Adaptive and ProTaper Next in adaptive and continuous motion, respectively.

It must be highlighted that previous studies used up to 25.06 instruments for canal preparation in adaptive or continuous motion (27, 28). In this study, the root canals were prepared up to 35.04 instruments, and then little canal transportation and good centering ability were observed. Navigator EVO is a new rotary system, and there are no data in the current literature concerning the outcomes that were evaluated in this study. Navigator EVO showed promising behavior on the basis of the results of this study. Such results may be attributed to its good flexibility promoted by the thermal pretreatment of the NiTi alloy and the triangular cross section. According to the manufacturer, these features contribute to the increased resistance of cyclic fatigue presented by Navigator EVO instruments.

The canal volume was higher when TF Adaptive instruments were used in adaptive motion in comparison with NA and NC ($P < .05$). Such results can be explained because of the different aspects involving the cross sections of the instruments, metallurgical properties, and kinematics used. Pedullà et al (27) demonstrated lower canal volume after preparation with TF Adaptive instruments in continuous motion compared with adaptive movement. On the other hand, this study showed similar canal volume after canal preparation with TFA and TFC ($P > .05$). These conflicting results possibly occurred because of the different loads applied to the TF instruments. The moderate curvatures (10° to 20°) that were used in this study transfer less load to the instruments than the severe curvatures (25° to 35°) used by Pedullà et al.

Few studies have evaluated cyclic fatigue of TF Adaptive and compared it with other reciprocating or continuous instruments. Moreover, there is no study that assessed the cyclic fatigue of Navigator EVO system. In this study, TF and Navigator EVO 25.06 and 35.04 instruments in continuous rotary motion presented higher resistance to cyclic fatigue than in adaptive motion ($P < .05$). A plausible explanation for this finding may be the lower speed of rotation during continuous motion (300 rpm) in comparison with adaptive motion (440 rpm), which may generate little stress to the instrument during preparation.

TABLE 3. Mean and Standard Deviation of Time, in Seconds, to Fracture during Cyclic Fatigue Test

	25.06 Navigator EVO	35.04 Navigator EVO	25.06 TF adaptive	35.04 TF adaptive
Adaptive motion	65.7^{A} (±11.5)	126.0^{A} (±12.9)	92.1^{A} (±8.5)	145.4^{A} (±10.5)
Continuous motion	83.0^{B} (±15.3)	144.2^{B} (±8.9)	155.9^{B} (±11.0)	175.0^{B} (±6.1)

Different letters in the row denote significant differences ($P < .05$) after Student t test.

Under the conditions of the current study, both systems can be used in adaptive and continuous rotation. However, the life span of the instruments was higher when used under continuous rotation. Good centering ability and little canal transportation occurred when mesiobuccal root canals from maxillary molars were prepared up to 35.04 instruments.

Acknowledgments

The authors deny any conflicts of interest related to this study.

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