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ORIGINAL ARTICLE

Comparison of Centering Ability and Canal Transportation of TruNatomy Files with Different File Systems

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ABSTRACT

Objective: This study aims to evaluate the centering ability and canal transportation of the ProTaper Next, One Curve, and TruNatomy instruments in curved root canals. **Methods:** Forty-five curved mesiobuccal canals of human mandibular molar teeth were selected, randomly divided into 3 groups, and prepared using the ProTaper Next, One Curve, and TruNatomy files. Cone Beam Computed Tomography images of the cross-sectional planes at 1 mm, 3 mm, 5 mm, and 7 mm from the apical foramen were determined before and after the preparation. For each specified millimeter canal transportation and centering ability were measured. Statistical analysis was performed and compared all groups. **Results:** No significant differences were observed between the groups or root canal levels in both canal transportation and centering ability ($p > 0.05$). **Conclusion:** The TruNatomy system demonstrated comparable results with both predecessor ProTaper Next and One Curve single-file systems.

Key words: centering ability, cone beam computed tomography, dental ınstruments, root canal preparation, transportation

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INTRODUCTION

The purpose of biomechanical preparation of the root canal system is to provide effective root canal disinfection and facilitate appropriate three-dimensional (3D) obturation.[1] An adequate endodontic instrumentation technique requires uniform preparation of all inner root canal wall surfaces to protect the intact dentin and to clean the infected tissue.[2] However, protecting and preserving the original root canal anatomy might be difficult because of the mechanical properties of the instruments, especially in curved canals. Due to insufficient flexibility, instruments fail to bend at the root canal center during preparation and tend to alter the canal curvature and initial pathway.[3] Alteration in the original pathway of the canal increases the risk of ledge formation, zipping, strip perforation, or root perforation, while decreasing the possibility of effective root canal disinfection and fracture resistance.[2]

Nickel-titanium (NiTi) instruments provide effective, fast, and safe mechanical preparation while maintaining the original canal anatomy because of their flexibility.[4] Various instrumentation systems with different designs, alloy properties, and kinematics are being developed to increase the shaping ability and prevent iatrogenic failure. However, none of the instrumentation systems developed to date meet all the requirements of ideal root canal shaping.[2,3] It is therefore important to understand how these metallurgic changes and different designs in instrumentation systems affect shaping ability. ProTaper Next (PTN; Dentsply, Maillefer, Ballaigues, Switzerland) is a multi-file system manufactured with M-Wire NiTi alloy consisting of five files with an off-centered, cross-sectional design with variable tapers (X1; #17/0.04, X2; #25/0.06, X3; #30/0.075, X4; #40/0.06, and X5; #50/0.06). One Curve (OC, Micro-Mega, Besancon, France) is a single-file system produced with a specially heat-treated C-Wire NiTi alloy. According to the manufacturer, this controlled memory alloy allows instrument pre-bending for consistency of root canal anatomy, also conserving the curvature.[5] The file has a tip size of #25 and a 0.06 taper with a variable cross-section design along the blade. The file has an electropolished surface and varying cross-sections with two or three-blades at different levels, which lead to increase the centered ability and cutting efficiency.[6] TruNatomy (TRN; Dentsply Sirona, Maillefer, Ballaigues, Switzerland) is a novel heat-treated NiTi system with three shaping files (small; #20/0.04, prime; #26/0.04, and medium; #36/0.03). The shaping files offer a slim NiTi wire design combined with maximum flute diameter, variable taper, and off-centered cross-section.

Cone-beam computed tomography (CBCT) can provide 3D images for endodontic diagnoses such as periapical lesions, vertical root fracture, complex anatomic root canal systems, resorptions, or accessory canals.[7] CBCT is a non-destructive method and allows for the comparison of endodontic procedures, before and after treatment, by superimposing the images in 3D.[8]

This study aimed to assess the centering ability and the canal transportation of three file systems: ProTaper Next, One Curve, and TruNatomy using CBCT imaging. The null hypothesis of the study was that there was no statistically significant difference between the three file systems.

METHODS

The study protocol was approved by the Research Ethics Committee of the University of Zonguldak Bülent Ecevit University (protocol number: 2020-04-11/21). Extracted mandibular first molar teeth were collected for reasons other than this study. The curvature and radii of mesiobuccal canals were evaluated with image analysis software (ImageJ 1.48v; National Institutes of Health, Bethesda, MD, USA) and recorded following published methods described by Schneider[9] and Pruett et al.[10] Curvature angles between 25° and 40° with radii ≤ 10 mm, were included. Image J analysis to evaluate curvature was performed by a radiologist (GG). The presence of a single apical foramen for mesiobuccal canal was evaluated by an endodontist (EH) using a dental operated microscope (Leica Microsystems, Wetzlar, Germany) under ×25 magnification. Only teeth with an independent mesiobuccal canal with a single apical foramen were used. Teeth with visible cracks or fractures, calcification, or resorption were excluded from the study after radiographic and microscopic evaluation. In total, 45 teeth satisfied the inclusion criteria and were included in the study. Access cavity preparation was performed, and the apical patency was detected for the mesiobuccal canal with a #8 K file (Dentsply Maillefer, Ballaigues, Switzerland). The crowns were removed between 1 mm and 3 mm above the cementoenamel junction using a diamond disk to obtain a standardized specimen length. The distal roots were then removed. The working length was determined as 1 mm shorter than the visible file length at the apical foramen. All samples were placed into putty silicone impression material (Zetaplus, Zhermack Spa, Italy) for stabilization and numbered. The buccal and lingual sides of the teeth were marked for subsequent stages. The teeth were scanned by CBCT (Veraviewapocs 3D R100, Morita Corp., Kyoto, Japan) with the specific settings of 60–90 kVp, 0.125 mm axial thickness, 1–10 mA, and 0.125 mm voxel size exposure. The cross-sectional images were acquired at 1 mm, 3 mm, 5 mm, and 7 mm from the apical foramen using i-Dixel software (i-Dixel3DX, 3D, Version 1.691; J Morita Mfg Corporation).

Root canal preparation

The specimens were randomly divided into three equal groups randomly (n=15). In all groups, the same endodontic motor (X-Smart plus, Dentsply Maillefer, Switzerland) was used during the preparation. A glide-path was created using a size #10 hand file for each canal.

Group 1: ProTaper Next (PTN): The X1 file (17/0.04) followed by the X2 file (25/0.06) were used at 300 rpm speed and 2 Ncm torque.

Group 2: One Curve (OC): The OC (25/0.06) file was used with at 300 rpm speed and 2.5 Ncm torque.

Group 3: TruNatomy (TRN): The TRN files 20/0.04 (small) and 26/0.04 (prime) were used with 500 rpm speed and 1.5 Ncm torque.

In all groups, in and out pecking motion was used with an amplitude of approximately 3 mm until the files reached the working length. After three pecking movements, the file was taken out of the canal and cleaned with sterile gauze. During the instrumentation, 2 mL of 2.5% sodium hypochlorite (NaOCl) was used for irrigation between using the files. Following NaOCl irrigation, 2 mL of 17% ethylenediaminetetraacetic acid for 5 min, 2 mL of distilled water was used for final irrigation. After the root canal preparation was completed, postoperative CBCT images were taken with the same image settings. All specimens were placed in the same position as before instrumentation. The cross-sectional images at 1 mm, 3 mm, 5 mm, and 7 mm from the apical foramen were analyzed using i-Dixel software after instrumentation. An endodontist (EH) and a radiologist (GG) independently evaluated the CBCT images twice. An experienced endodontist (MMK) was invited to make a third assessment and reach a final consensus if there were disagreements.

For each specified mm, the distance of the inner canal wall to the external mesial and distal root walls were

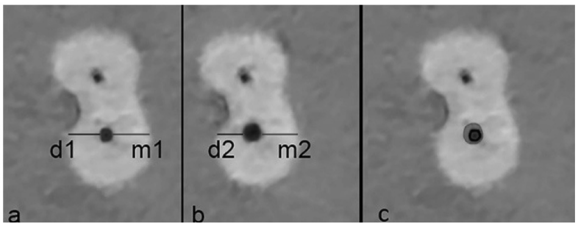

Figure 1. CBCT images of (a) preinstrumentation, (b) postinstrumentation, and (c) superimposed canal. Black (preoperative canal) and red (postoperative canal) lines represent the points of measurement for assessing canal transportation and centering ability on uninstrumented and instrumented canals, respectively.

Canal transportation = (m1 - m2) - (d1 - d2)

Canal centering ratio = (m1 - m2) / (d1 - d2) where (d1 - d2) > (m1 - m2)
(d1 - d2) / (m1 - m2) where (m1 - m2) > (d1 - d2)

Figure 2. The formula to evaluate the canal transportation and centering ability.

measured and analyzed using Photoshop software (Photoshop CC2019, Adobe Systems, San Jose, CA), before and after preparation.

The distances of inner and external surfaces before and after instrumentation were measured (Figure 1a and 1b). The definitions of measurements were (m1) the shortest distance between the mesial line of the root and the canal before preparation, (m2) the measurement of the same points as m1 after the preparation, (d1) the shortest distance between the distal line of the root and the canal before preparation, and (d2) the measurement of same points as d1 after preparation.

Canal transportation and centering ability were measured with the formula[11] (Figure 2). The removed dentin after the preparation was marked in red and the canal borders before instrumentation were marked in black (Figure 1c). The value/ratio nearest to 1 represents excellent centering ability. A transportation value nearest to 0 represents no transportation. The higher values presented in +/- directions indicated greater transportation. Negative values show transportation in the distal direction, whereas positive values show transportation in the mesial direction.

Statistical analysis

Statistical analysis was performed with SPSS 19.0 software (IBM Corp, Armonk, NY, USA). Differences between the three groups at 1 mm, 3 mm, 5 mm, and 7 mm in both transportation and centering ability were evaluated using one-way analysis of variance and the Kruskal-Wallis test, with $p < 0.05$ considered significant for all evaluations.

RESULTS

No instrument fracture occurred during the instrumentation. The mean and standard deviation values of centering ability and transportation at four different levels for each group are presented in Tables 1 and 2. No significant difference was observed between the groups at the 1 mm, 3 mm, 5 mm, and 7 mm levels by both evaluated criteria ($p > 0.05$). Similarly, intragroup analysis of all instruments showed no significance in all tested instrumentation levels of the root canals, in both canal transportation and centering ability ($p > 0.05$).

Table 1. Mean and standard deviation values of centering ratio after root canal preparation with the 3 systems (in millimeters).

	ProTaper Next		One Curve		TruNatomy		p
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
1 mm	0.3463	0.35202	0.2806	0.32152	0.4844	0.27800	0.119
3 mm	0.4387	0.36238	0.2286	0.20378	0.4232	0.32081	0.199
5 mm	0.4215	0.40358	0.3027	0.27578	0.3826	0.35639	0.963
7 mm	0.4157	0.47061	0.2899	0.29063	0.3511	0.34852	0.288
p	0.841		0.331		0.554		

Table 2. 2 Mean and standard deviation values of transportation after root canal preparation with the 3 systems (in millimeters).

	ProTaper Next		One Curve		TruNatomy		p
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation	
1 mm	0.0047	0.09643	-0.0100	0.10107	-0.0080	0.05609	0.615
3 mm	0.0400	0.10637	0.0207	0.14868	0.0233	0.17855	0.664
5 mm	-0.0407	0.15073	0.0600	0.11711	0.0307	0.14360	0.289
7 mm	-0.0933	0.14421	-0.0520	0.22609	-0.0120	0.25855	0.589
p	0.283		0.131		0.111		

DISCUSSION

Differences in root canal morphology can limit teeth cleaning and shaping procedures.[12] It is crucial to clean the canal walls effectively for successful treatment while preserving its original anatomy. The original canal anatomy should be prevented during instrumentation to allow for efficient irrigation, root canal obturation, and to prevent iatrogenic complications such as apical transportation and stripping.[2]

A tendency to straighten is common for instruments, which can result in undesirable changes in canal morphology, particularly in curved canals.[13] The presence of curvature might cause stress to certain points of the instruments and can cause unequal preparation at the root canal walls. In general, transportation occurs in curved canals resulting in an altered and incorrect pathway. This situation often leads to excess preparation on the outer surface of the curvature.[2] The altered pathway can subsequently cause insufficient cleaning in the apical area, redundant removal of dentin on the concave surface of the root curvature, and zipping or perforation.[14]

Resin blocks differ to dentine structures in their mechanical properties, such as microhardness, surface roughness, and particle size.[15] As a result, both structures could vary at different stress values from the instruments. Although using resin blocks can provide a consistent standard for experimental design, the difference in microhardness, surface roughness, or particle size limits the use of resin blocks to mimic clinical conditions. Thus, to provide the closest clinical conditions for our experiments, we used extracted teeth for our study. The mesiobuccal roots of mandibular first molar teeth were selected in particular because of their high probability of showing curvature.

Various techniques are available to evaluate canal transportation and centering ability, including electron and light microscopy, radiography, micro-computed tomography, and CBCT.[14,16–19] CBCT analysis is the frequently preferred method for examining the centering ability of the instrumentation systems.[19–21] CBCT analysis offers the possibility of evaluating 3D, non-invasive images before and after dental treatment. CBCT provides 3D diagnostic information at the cost of a low quantity of radiation dosage, minimal fields of view, and detailed information about root canal morphology.[7,12]

The PTN system is commonly used and accepted for instrumentation of root canals and various studies have evaluated the centering ability and canal transportation of PTN system.[22–24] Htun et al.[21] reported that apical transportations of PTN, HyFlex EDM (Coltene-Whaledent, Allstätten, Switzerland), and Gentle File (MedicNRG, Kibbutz Afikim, Israel) were similar at 5 mm, 6 mm, and 7 mm levels, and apical transportations of PTN and HyFlex EDM were similar at 1 mm, 2 mm, 3 mm, and 4 mm. Yılmaz et al.[22] stated that PTN, EdgeFile (Edge Endo, Albuquerque, NM), and One Shape (MicroMega, Besançon, France) systems caused similar transportation at apical 1 mm. Similarly, de Albuquerque et al.[24] reported that PTN, Vortex Blue (Dentsply Sirona, Ballaigues, Switzerland), and WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland) caused similar transportation at 3 mm, 6 mm, and 9 mm. These studies have shown that, despite different metallurgical properties and with cross-section or taper, that the instruments demonstrated comparable results in terms of apical transportation. In the current study, the degree of canal transportation did not differ among the three groups. Our finding was consistent with previous studies, which reported that PTN exhibited similar canal transportation with different file systems. The OC file used in the study is manufactured from C-wire using a special heating process with CM feature, its cross-section is variable, and the file has a 0.06 taper. The PTN system is manufactured from a M-Wire NiTi alloy, with rectangular cross-section, and the file has variable 0.06 taper. The TN files are made of a T-Wire NiTi alloy, have a square cross-section, and a variable 0.04 taper. PTN and TN systems have an off-centered design and rotate asymmetrically. Despite these different designs or metallurgic features, all files showed similar transportation, but the direction of transportation demonstrated variations, especially at apical 1 mm. A positive value demonstrated that transportation was towards the mesial, whereas a negative value represented transportation towards the distal. At apical 1 mm, transportation occurred in the mesial direction in the PTN system and in the distal direction with the TN and OC systems. Similar results were recently published by Kabil et al.,[25] who investigated the effects of using TN and PTN instruments on root canal transportation in curved maxillary molar canals. The difference between file systems in both studies might be related to the pre-bending feature of TN files and also the OC files, which were used in the same manner by pre-bending the file before the instrumentation, in the present study.

TN is a novel instrumentation system and a survey of the literature demonstrated that limited information is available concerning its centering ability or canal transportation. Based on the results of the present study, TN demonstrated comparable results with the other systems and at all levels. Therefore, the null hypothesis of this study was accepted. Similar to the current study, Kabil et al.[25] found no statistically significant difference between the PTN and TN instruments at a 3 mm, 5 mm, and 7 mm distance from the apical. In another study, no differences were found in apical transportation between TN and five different NiTi file systems: [WaveOne Gold, Reciproc Blue (VDW), TRUShape (Dentsply), XP-endo Shaper (FKG), and iRace (FKG)] that were not found in this study.[26] Furthermore, limited information is available for the canal transportation and centering ability of the OC system. Razcha et al.[18] compared the centering ability and canal transportation of OC, HyFlex EDM, HyFlex CM, and WaveOne Gold systems in moderately curved canals. No difference was reported between systems in terms of centering ability. In parallel with the mentioned study, we found that the centering ability of OC, TN, and PTN systems were also similar. Razcha et al.[18] also reported no difference in canal transportation between OC and other systems at apical 3 mm and 5 mm sections, but transportation of OC in the lingual side was greater than HyFlex CM at 7 mm. In the present study, no difference was found between OC and other systems in terms of canal transportation in any section. These differences might be due to the varied file systems being compared with the OC system.

Tufenkçi et al.[27] evaluated that the shaping ability of both the OC and PTN systems in resin blocks at an angle of 45°, and found that the OC system caused less transportation in the apical section compared to the PTN. There was no difference between the files at 5 mm and 8 mm. Similarly, Gomaa et al.[28] reported that the OC file caused significantly less apical transportation than PTN, with no statistically significant difference between the files in the straight section of the 'S' shaped canals in resin blocks. In the current study, extracted mandibular molar teeth with curvature angles between 25° and 40° were used and no difference was found between PTN and OC systems in the apical region. Although similar results were shown in other regions, the difference in the apical region could be due to different curvature angles or the diverse test materials.

None of the evaluated file systems performed ideal centered instrumentation. In PTN and TN groups, a value of 1 was observed at all root levels, while only at the 1 mm level in the OC group, without statistical significance. Despite different mechanical properties, all file systems exhibited similar centering ability. A canal transportation less than 0.3 mm does not negatively affect the prognosis of endodontic treatment.[29] Current results showed that mean transportation values are less than 0.3 mm for each group, therefore, we can conclude that ProTaper Next, One Curve, and TruNatomy systems can be used in curved canals without altering the original root canal anatomy.
Within the limitations of the present study, no significant difference was found in terms of root canal transportation and centering ability in three file systems made from different heat-treated alloys and presenting various cross-sections. However, as new file systems are produced, improved alloy properties or modified cross-section designs should be investigated to evaluate how they can meet ideal root canal shaping requirements.

CONCLUSION

All tested files demonstrated acceptable results for the instrumentation of curved canals. The novel TruNatomy files demonstrated comparable results with both ProTaper Next and OneCurve files for the preparation of curved canals.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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