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Research Article

# Comparative Evaluation of Apical Transportation and Centering Ability of 4 NITI Rotary Systems with Different Metallurgy in Severely Curved Root Canals

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## Abstract

**Objective:** The aim of the present study was to compare apical transportation and centering ability of one curve (OC) system with other heat treated NiTi rotary systems; Protaper next (PTN), Hyflex EDM (HFEDM) and 2shape (TS), using CBCT scanning.

**Methodology:** Forty mesiobuccal canals of mandibular molars with an angle of curvature ranging from (25°- 40°) were divided equally according to file system used in canal preparation into 4 groups of 10 samples each: PTN group; HFEDM group, TS group and OC group. Samples were scanned using CBCT scanner before and after preparation to evaluate root canal transportation and centering ratio at 2, 3, 4 and 5 mm from the apex. The significance level was set at $P \leq 0.05$.

**Results:** PTN showed highest statistically significant transportation value than other file systems at 5mm level. There was no statistically significant difference in transportation between HFEDM, TS and OC file systems at all studied levels. There was no statistically significant difference in centering ability between 4 systems at 2, 3 and 4 mm. At 5 mm level, OC and TS showed better centering ability than PTN and HFEDM.

**Conclusion:** The four tested systems safely prepared severely curved root canals, PTN showed highest transportation value and least centering ratio value, while HFEDM, TS and OC showed similar performance.

**Keywords:** ProTaper Next; HyFlex EDM; 2Shape; One Curve; Transportation; Centering Ability

## Introduction

Root canal preparation is the most critical step to achieve objectives of root canal treatment. It includes mechanical debridement, creation space to deliver irrigants and optimized root canal shape for obturation while maintaining original root canal anatomy [1,2].

However, complexity and variation of root canal anatomy represent a major challenge that may jeopardize achieving objectives of root canal preparation and so successful root canal treatment. Preparation of curved root canals with inflexible conventional stainless-steel instruments, usually results in transportation and sebsequent procedural errors [3]. The introduction of super elastic highly flexible nickel titanium (Ni-Ti) instruments has revolutionized root canal treatment that allow fast and safe preparation in curved root canals with less procedural errors [4-6].

Despite flexibility of these instruments, transportation and other procedural errors may occur especially in severely curved canals [7]. Several strategies were developed to improve their clinical performance in complex root canal anatomy, these strategies included change in design, surface treatment, kinematics and modifications in conventional NiTi alloy metallurgy via heat treatment [8,9].

ProTaper Next (PTN; Dentsply Maillefer, Ballaigues, Switzerland) is the successor of the ProTaper Universal system (Dentsply Maillefer), in addition to progressive taper design, it is manufactured from heat treated alloy M-Wire which have higher flexibility and better mechanical properties than conventional NiTi alloy [10-12]. Also, PTN has unique off-centered design, rectangular cross section which gives file strength and unique swaggering movement. The system composed of; X1 (17/.04), X2 (25/.06), X3 (30/.07), X4 (40/.06), and X5 (50/.06), and the tapers are variable (increasing and then decreasing in the apico- coronal direction for X1 and X2, fixed and then decreasing for X3, X4, and X5) [13]. These unique properties give the files high flexibility and resistance to cyclic fatigue [14,15].

HyFlex EDM (HFEDM; Coltene/Whaledent, Altst€atten, Switzerland) is made from CM-Wire (controlled memory) which is a unique highly flexible wire without the shape memory of conventional NiTi alloy, allowing the instruments to be pre-bent with greater fatigue resistance [16,17]. It was the first system that produced by electrical discharge machining. its design is characterized by a variable cross section, with a transition from roughly triangular near the shaft to rectangular at the tip. This system consists of: 25/.12 (Orifice Opener), 10/.05 (Glidepath File), 25/.08 (OneFile), 40/.04, 50/.03, and 60/.02. The OneFile has a .08 taper in its apical 4 mm, which decreases to .04 along the file. These unique features produced a file that is extremely flexible, has uniquely hardened surface and highly resistance to fracture [18-20].

2Shape (TS; MicroMega, Besancon, France) is manufactured with a different proprietary heat treatment called T-Wire technology which according to manufacturer increased flexibility and gave up to 40% more resistance to cyclic fatigue [21]. It consists of two instruments (#25/.04 and #25/.06), plus two options for wider canals (#35/.06 and #40/.04), with a new triple helix asymmetric cross-section design [22].

In 2017, Micro-Mega has developed the One Curve (OC; Besançon, France) single file system. According to the manufacturer, these instruments are exclusively manufactured from C-Wire using unique proprietary heat treatment which produced instruments with controlled memory, pre-bendable, more flexibile and highly resistance to fracture [23]. It is a single file rotary system with variable cross-section, available in different tip diameter and taper (#25/.04, #25/.06, #35/.04 and #45/.04) [24].

To date only one study that evaluated shaping ability of OC system, which was in moderately curved root canals [25]. Therefore, the aim of the present study was to evaluate transportation and centering ability of OC compared to other heat treated NiTi rotary systems (PTN, HFEDM, TS) in apical and middle thirds of severely curved root canals using cone-beam computed tomography (CBCT) scanning.

## Methodology

### Samples selection and preparation

Extracted human mandibular permanent first molars were collected from department of oral surgery, faculty of dentistry, El Minia university, which were extracted due to reasons unrelated to the present study.

Teeth were radiographed in both mesiobuccally and buccolingually, only teeth that have fully developed roots, separate mesial canals with separate foramina, root curvature ranged from (25°-40°) according to Schneider's method [26] were selected. Any teeth that had calcification, root resorption, or previous root canal treatment were excluded.

Based on these selection criteria, a pilot study was performed to calculate sample size using G*Power Version 3.1.9.2. Three samples were included in each group and transportation was the primary outcome. The effect size (f) = 0.236 was obtained using repeated measures within-between design test with variance within group = 0.9 and variance between groups = 0.05. Using alpha (α) level of (5%) and Beta (β) level of (20%) i.e. power = (80%); the minimum estimated sample size was a total of (40) samples.

Teeth were accessed by an Endo- Access bur (Dentsply Maillefer), and the meisobuccal canals were explored, localized and root canals patency was confirmed with a K-file size #10 (Dentsply Maillefer). Distal roots with the respective part of the crown were sectioned at the furcation level using a low-speed diamond disc under copious irrigation, then discarded.

The working length was determined by inserting #10 K-file into the root canal until the tip of the file was visible through the apical foramen then subtracting 0.5 mm from this measurement. The mesiobuccal cusp tip of all samples were reduced using high speed diamond fissure stone (Mani Inc., Tochigi-kan, Japan) with coolant to secure the reference point and obtain similar working length in all samples.

Samples were coded and randomly divided into four equal experimental groups (n = 10 per group) according to the rotary NiTi file system used in canal preparation; PTN group ; HFEDM group, TS group and OC group.

The degree of homogeneity between the groups regarding the angle of curvature was assessed and confirmed statistically.

### Samples scanning

To ensure standardization of pre and postoperative CBCT scanning, samples were mounted vertically in transparent chemical cured acrylic resin mold (Acrostone, Dental and Medical Supplies, Cairo, Egypt) in which they were aligned to be perpendicular to the scanning beam with the buccal surface facing the same direction. The root apices were sealed with wax to prevent acrylic resin penetration. An orthodontic wire was placed buccally into the resin mold to enable canal orientation during image analysis.

Samples were scanned using a Paxi 3D Green CBCT scanner (VATECH Co, Ltd, Gyeonggi, South Korea). Exposure parameters were 80 kV and 8 mA. The field of view had a 12 cm diameter and was 9 cm high. voxel size was 0.2 mm. The acquired data were viewed, and measurements were performed by the software OnDemand 3D (Cybermed, Seoul, South Korea).

### Root preparation

All files were operated by a 1:16 gear reduction handpiece powered by an electric torque control motor (MM-control; Micro-Mega). A glide path was secured by a manual stainless steel #10 K-file (Dentsply Maillefer). Each canal was prepared to the working length in a crown-down sequence and the final apical preparation was set to size 25 in each group. Each NiTi rotary file system was used according to the manufacturers' recommendations [13,18,22,24] as follows.

- **Group I (PTN):** The canals were prepared using PathFile (16/02) followed by PTN X1 (17/04), then PTN X2 (25/06) to the full working length at 300 rpm speed and 2 Ncm torque.
- **Group II (HEDM):** The coronal third of canals were prepared using orifice opener (25/.12), followed by the glide path file (10/05) to the working length, and final preparation with HyFlex OneFile (25/~) at 400 rpm speed and 2.5 Ncm torque.
- **Group III (TS):** The coronal third of canals were prepared using one flare file (25/09) followed by TS1 (25/04) and TS2 (25/06) files to the full working length at 300 rpm speed and 2.5 Ncm torque.
- **Group IV (OC):** The coronal third of canals were prepared using one flare file (25/09) followed by the OC file (25.06) to the full working length at 300 rpm speed and 2.5 Ncm torque.

Between each file size, copious irrigation with 3 mL 2.5% NaOCl (Clorox, Egyptian company for house detergents, 10th of Ramadan, A.R.E) was performed using a 30-gauge max-i-Probe needle tips (Dentsply-Rinn, Elgin, IL, Switzerland) placed as apical as possible into the canal without binding. Patency was maintained using a size #10 K-file. Each instrument was discarded after use in 5 canals.

After preparation, all canals were rinsed with 3 ml distilled water, followed by 5 ml 17% EDTA (PREVEST Dent Pro, Indea) for 1 minute and final flush with 3 ml distilled water. Subsequently, the samples were dried with absorbent paper points and submitted to postoperative scans using the same parameters described in the initial scanning and data were analyzed.

### Image analysis and evaluation

After root canal instrumentation, samples were scanned under the same conditions and parameters as pre-instrumentation.

Canal transportation and centering ability were calculated at 4 cross sections levels according to the distance from the root apex; 2 mm, 3 mm (Representing the apical third) and 4 mm, 5 mm (Representing the middle third) using equations provided by Gambill., *et al.* (1996) [27] (Figure 1).

**Figure 1:** CBCT image at 5mm; A: pre-instrumentation measurements, B: post-instrumentation measurements.

For canal transportation

(M1-M2) - (D1-D2); in which a value equal to 0.0 indicated the absence of transportation.

For centering ratio

(M1-M2) / (D1-D2); in which a value of 1 indicated the optimal centering ability, whereas the closer the value to 0, the more reduced the ability of the instrument to remain in a central position within the root canal.

M1 is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, M2 is shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, D1 is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented canal, and D2 is the shortest distance from the distal edge of the root to the distal edge of the instrumented canal.

### Statistical analysis

Numerical data obtained were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). All data showed non-normal (non-parametric) distribution. Therefore, data were presented as median and range values. Kruskal-Wallis test was used to compare between the four systems. Friedman's test was used to compare between different root levels. Dunn's test was used for pair-wise comparisons. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

## Results

The median and range values of transportation and the centering ratio of all experimental groups at the four studied levels, are presented in table (1), and table (2) respectively.

### Transportation

At two, three as well as four mm levels; there was no statistically significant difference between the four experimental groups, in which the highest median value of transportation ( 0.14) ) was recorded by PTN at 4mm, while the lowest median value of transportation ( 0.01) was recorded by HFEDM at 2mm and TS at 3mm.

At five mm root level PTN recorded highest median value of transportation (0.15) which was statistically significant than other experimental groups (HFEDM, TS, OC). There was no statistically significant difference between HFEDM, TS, OC at this level in which OC recorded the lowest median value of transportation (0.04).

Regardless of root level as overall median values of transportation in four experimental groups, PTN recorded highest median value of transportation (0.11) which was statistically significant different than other groups. HFEDM, TS and OC; showed lowest median values of transportation; (0.04), (0.05), (0.05) respectively, which wasn't statistically significantly different.

| Root level | ProTaper Next (n = 10) | | Hyflex EDM (n = 10) | | 2Shape (n = 10) | | One Curve (n = 10) | | P-value | Effect size (Eta Squared) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range | Median | Range | | |
| 2 mm | 0.04 | 0 - 0.17 | 0.01 | 0 - 0.18 | 0.06 | 0.01 - 0.11 | 0.04 | 0 - 0.05 | 0.267 | 0.026 |
| 3 mm | 0.07 | 0.01 - 0.1 | 0.06 | 0 - 0.08 | 0.01 | 0 - 0.12 | 0.06 | 0.01 - 0.1 | 0.745 | 0.049 |
| 4 mm | 0.14 | 0.01 - 0.19 | 0.05 | 0.04 - 0.12 | 0.07 | 0 - 0.23 | 0.05 | 0.03 - 0.09 | 0.217 | 0.04 |
| 5 mm | $0.15^{A}$ | 0.03 - 0.19 | $0.05^{B}$ | 0 - 0.1 | $0.08^{B}$ | 0 - 0.28 | $0.04^{B}$ | 0 - 0.06 | 0.011* | 0.227 |
| P-value | 0.090 | | 0.888 | | 0.073 | | 0.063 | | | |
| Effect size (w) | 0.216 | | 0.021 | | 0.232 | | 0.177 | | | |
| Overall | $0.11^{A}$ | 0.05 - 0.12 | $0.04^{B}$ | 0.03 - 0.1 | $0.05^{B}$ | 0.05 - 0.18 | $0.05^{B}$ | 0.02 - 0.07 | 0.009* | 0.241 |

**Table 1:** The median, range values and results of Kruskal-Wallis test for comparison between amounts of canal transportation (mm) after using different systems and Friedman's test for comparison between different root levels

*: Significant at $P \leq 0.05$. A,B superscripts in the same row indicate statistically significant difference between systems.

### Centering ratio

At two, three as well as four mm levels; there was no statistically significant difference between the four experimental groups in the median values of centering ratio, in which the highest median value of centering ratio (0.92) was recorded by HFEDM at 2mm and by TS at 3 mm while PTN showed the lowest median value (0.39) at 4 mm.

At five mm root level TS and OC systems showed the highest median value of centering ratio (0.74), (0.75) respectively, which was statistically significant different than PTN and HFEDM. There was no statistically significant difference between PTN and HFEDM in which PTN showed the lowest median value (0.46) of centering ratio.

Regardless of root level as overall median values of centering ratio; there was no statistically significant difference between the four systems.

| Root level | ProTaper Next (n = 10) | | Hyflex EDM (n = 10) | | 2Shape (n = 10) | | One Curve (n = 10) | | P-value | Effect size (Eta Squared) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Median | Range | Median | Range | Median | Range | Median | Range | | |
| 2 mm | 0.85 | 0.26 - 1 | 0.92 | 0.25 - 1 | 0.6 | 0.35 - 0.88 | 0.75 | 0.5 - 1 | 0.397 | 0.001 |
| 3 mm | 0.61 | 0.29 - 0.91 | 0.56 | 0.5 - 1 | 0.92 | 0.29 - 1 | 0.59 | 0.38 - 0.91 | 0.229 | 0.037 |
| 4 mm | 0.39 | 0.24 - 0.91 | 0.55 | 0.37 - 0.69 | 0.53 | 0.28 - 1 | 0.71 | 0.43 - 0.75 | 0.182 | 0.052 |
| 5 mm | $0.46^{B}$ | 0.36 - 0.67 | $0.55^{B}$ | 0.31 - 1 | $0.74^{A}$ | 0.13 - 1 | $0.75^{A}$ | 0.65 - 1 | 0.027* | 0.171 |
| P-value | 0.112 | | 0.682 | | 0.540 | | 0.051 | | | |
| Effect size (w) | 0.2 | | 0.05 | | 0.072 | | 0.115 | | | |
| Overall | 0.56 | 0.5 - 0.66 | 0.65 | 0.49 - 0.74 | 0.72 | 0.31 - 0.82 | 0.71 | 0.57 - 0.86 | 0.101 | 0.09 |

**Table 2:** The median, range values and results of Kruskal-Wallis test for comparison between centering ratio (CR) after using different systems and Friedman's test for comparison between different root levels

*: Significant at P ≤ 0.05. A,B superscripts in the same row indicate statistically significant difference between systems

## Discussion

Root canal transportation was simply defined as "any undesirable deviation from natural canal paths" which resulted in many procedural errors; Zip-and-elbow formation, ledges, strip-perforations, or excessive thinning of canal walls [28]. Transportation and subsequent procedural errors result in improperly cleaned canals with persistent infection or thinning canal walls with possibility of perforation or vertical fracture [29,30]. Several factors affect incidence of transportation; root canal anatomy, file design, alloy of root canal instruments and instrumentation technique [31]. Heat-treated NiTi instruments are expected to perform better severely curved root canals and maintain original root canal anatomy with less procedural errors [32-34]. Therefore, the aim of the present study was to compare performance of 4 file systems with different heat treated NiTi alloy; M wire, CM wire, T wire and C wire, regarding transportation and centering ability in apical and middle thirds of severely curved root canals of extracted human teeth using CBCT scanning.

CBCT scanning was used as it is effective noninvasive imaging tool in evaluation of changes in dentin thickness and so detection of transportation and measuring centering ability [35-37].

Mesiobuccal root canals of extracted human mandibular teeth were used to evaluate performance of tested file systems in realistic conditions [38,39], also these teeth are most frequently indicated for root canal treatment with many risk factors for procedural errors [40]. Crowns were maintained to mimic clinical conditions [41]. Evaluation was performed on four levels; 2,3,4 and 5mm from the root apex representing the apical and middle thirds of root canal, in other words apical half in which preparation errors usually occur [42,43].

To compare shaping ability of the four tested rotary systems, it was essential to have the same apical preparation diameter in all groups which was set to tip size 25 [25,42,44]. The systems used in the present study represent advancements in NiTi metallurgy via different heat treatment techniques producing different wires; M wire (PTN), CM wire (HFEDM), T wire (TS), C wire (OC).

In the present study there was no statistically significant difference in transportation and centering ratio at 2 mm, 3 m and 4 mm levels from apical foramen between the four systems, which might be attributed to no cutting tip design of all file systems used and standardized apical preparation size [45]. However, at 5 mm level; PTN caused highest median value of transportation (0.15) which was statistically significant than other file systems. A possible explanation that; PTN X1 and X2 files have a progressive taper in their apical part which decreasing coronally, therefore produced highest value of transportation in the most coronal level 5 mm which was in accordance with other studies in which PTN produced higher transportation values coronal to curvature [46,47].

Although PTN caused highest statistically significant value of transportation (0.15), this value was considered acceptable [28], and didn't exceed critical level of transportation (0.3) that may negatively affect clinical prognosis [48].

There was no statistically significant difference in centering ability between PTN and HFEDM at 5 mm level, which was statistically significantly lower than that of TS and OC systems, this might be because PTN X2 and HFEDM one file have similar apical taper about 0.08 [47] which larger than apical taper of TS and OC systems that have 0.06 fixed taper.

HFEDM, TS and OC recorded lowest median values of transportation with no statistically significant difference between them at any studied level. None of the four tested systems could produce perfectly centered preparation and as overall comparison between four systems regardless of root level there was no statistically significant difference between them. These results could not be compared with other studies as there is no previous published data have compared these 4 systems.

Therefore, based on these findings, the four evaluated file systems can be safely used in severely curved root canals without significant procedural errors.

## Conclusion

Within limitation of the present study OC system showed promising performance in severely curved root canals which was comparable to HFEDM and TS systems and better than PTN.

## Conflict of Interest

There is no any conflict of interest exists.

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