Cone-Beam Computed Tomographic Analysis of Shaping Ability of XP Shaper, TRUshape, and Hyflex EDM

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Abstract

Preserving the original canal anatomy is an important parameter when testing any file system, the aim of this study was to investigate the shaping ability of three single file rotary systems using cone beam computed tomography (CBCT). Mesio-buccal canals from sixty human permanent mandibular first molars were scanned using CBCT to detect the canal shape before instrumentation. Samples were randomly divided into 3 equal groups (n = 20) as follow: Group I: roots were shaped using the XP Shaper file, group II; Hyflex EDM single file and group III; TRUShape file. Canals were scanned after the mechanical preparation using CBCT and the degree of transportation as well as the centering ability were calculated. Data were analyzed using Kruskal-Wallis test for comparing the three systems, Friedman's test was used to compare between the root levels.

Results showed that regarding the total amount of transportation, there was no statistically significant difference between the three systems. As for the centering ratio, Hyflex EDM showed the statistically significant highest median centering ability. It could be concluded that the three file systems can be used safely for the treatment of curved root canals.

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Introduction

The ultimate root canal treatment goal is to remove infected pulpal remnants, eliminate microorganisms and adequately shape the root canal system[1]. Ideally, biomechanical preparation should include uniform enlargement of the root canal system in all dimensions to permit thorough cleaning while maintaining the original canal anatomy without inducing any iatrogenic errors.[2]

Recently, there has been a shift towards conserving tooth structure as a critical factor responsible for the fate of root-filled teeth by reducing the amount of tooth structure removed during endodontic treatment with leaning to cut smaller-sized access cavities avoiding complete de-roofing of the pulp chamber and preserving the pericervical dentin, over-flaring of canal orifices as well as avoiding aggressive dentine removal for shaping, alongside with keeping the natural canal anatomy and avoiding aggressive dentine removal during shaping[3,4].

Continuous innovations and techniques are being established aiming to reduce the difficulties encountered during minimally invasive endodontics such as computer-designed guides used for access cavity preparation[5] as well as constant improvements of metallurgy and geometries of nickel titanium instruments which permitted the preparation of root canals with improved adaptation to irregular canals and added cyclic fatigue resistance with maximum preservation of radicular dentin[6,7]. Novel files designs such as XP Shaper (FKG Dentaire SA, Switzerland) and TRUShape (Dentsply Sirona, Tulsa, OK, USA) aim to provide greater contact to canal walls and improve apical cleaning while preserving the original root canal shape and cervical dentin.

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XP Shaper (FKG Dentaire SA, Switzerland) instrument is based on the MaxWire adaptive core technology. The MaxWire alloy allows the instrument to reform its shape from martensitic phase, a relatively soft and straight shape at room temperature, to a stronger form, austenitic phase with increased cutting efficiency at body temperature[6] (Fig 1).

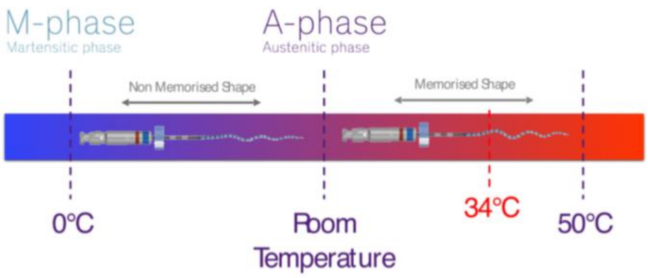

Figure 1. Martensitic—austenitic phase transformation of XP Shaper at different temperatures.

TRUShape 3D Conforming File (Dentsply Sirona, Tulsa, OK, USA) has an innovative design with an S-curve in the longitudinal axis, which produces a line/curve when operated in the root canal to create a larger contact to the canal surfaces. Manufacturers claim that by having a symmetric triangular cross section, the instrument permits greater preservation of dentin during canal shaping, adhering to the principle of minimally invasive endodontics and maintaining the integrity of the root structure[7]. The TRUShape system is available in the following sizes/tapers: 20/.06v, 25/.06v, 30/.06v, and 40/.06v; v stands for a taper of .06 in the apical 2 mm, which is otherwise variable along the instrument working part.

The novel designs of these files result in different cutting motion, the XP Shaper cuts in a asymmetric rotary motion by taking on a semicircular shape when it expands beyond its core diameter. The TRUShape file possess an S shape design which creates an innovative envelope motion as claimed by the manufacturer[8], it has been reported that both instruments (XP Shaper and TRUShape file) can remove more intracanal bacteria in absence of antimicrobial irrigants[7,9]

Hyflex EDM (Coltene Whaledent, Cuyahoga Falls, OH, USA) manufactured from a controlled memory (CM) wire, which has been proven to significantly increase flexibility and cyclic fatigue resistance. Hyflex EDM is presently the only instrument produced by electrical discharge machining. It's design is characterized by a variable cross section, with a transition from roughly triangular near the shaft (conveying flexibility and fatigue resistance) to rectangular at the tip (granting torsional resistance).[10]

In order to assess the shaping ability of the tested instruments, 2 parameters were selected; root canal transportation, which can endanger the efficient root canal sealing consequently, reducing the treatment outcomes and maintenance of the canal centering remains a basic fundamental in preparing curved canals[11]. Using CBCT images which remains an effective tool in measuring apical transportation and canal centering as it permits detailed three dimensional assessment of the root canal anatomy with high-resolution images, faster acquisition and reconstruction.[11,12,13,14,15]

The null hypothesis tested was that there would be no difference among the three-single file NiTi rotary systems regarding the analyzed parameters.

Materials and methods

Selection of the samples

After the approval of the study protocol by the ethical committee at the Faculty of Dentistry, Minia University, Egypt, a total of sixty human permanent mandibular first molars extracted due to periodontal or orthodontic reasons were collected from the Department of Oral Surgery, Faculty of Dentistry, Minia University. Preoperative periapical radiographs (mesiodistal and buccolingual directions) were taken to inspect the mesial roots and to determine the angle of root curvature according to Schneider's method [16]. The inclusion criteria included complete root maturation with no root caries or resorption and no previous endodontic treatment with angle of root curvature between 20 ° and 35°. Teeth were examined using 2.5X magnification EyeMag Smart Loupes (Carl Zeiss Meditec; Jena, Germany) to exclude any teeth with pre-existing root fractures or cracks.

Preparation of the samples

A diamond saw mounted on a low-speed micromotor were used to decoronate the molars under water coolant leaving 3 mm above the cemento-enamel junction and separate the distal roots from the mesial ones. Root canal patency and the existence of two separate mesial canals were confirmed by simultaneous application of two K-files #10 (Dentsply Sirona, Tulsa, OK) in the canals. Only the mesio-buccal canals were considered in this study. The working length of each canal were determined by subtracting 1 mm from the apical foramen. Group allocation was done randomly into three groups (n=20 per group) using a random group allocation online software (https://www.ramdomizer.org) according to the file system used into group I: The XP Shaper group, group II: Hyflex EDM group and Group III:The TRUShape group. Before scanning, the roots of each group were vertically mounted in transparent auto polymerizing acrylic resin (Acrostone, Dental & Medical Supplies, Cairo, Egypt) mixed according to the manufacturer's instructions inside a silicon mold (10 cm x 10 cm) to fix them. The root apices were sealed with wax (Wilson, Sao Paulo, Brazil) to preserve the apical foramen from the resin penetration.

Pre-instrumentation scanning

All the roots were scanned using cone beam computed tomography (Scanora 3D, Soredex, Palodex group, Finland) at 85 kVp and 15 mA and voxel sizes of 0.1 mm and a small field of view (50x50mm) to detect the canal shape before instrumentation. For each specimen, measurments were taken at 3 levels as follow: 3, 5 and 7 mm from the root apex (representing the apical, middle and cervical third respectively) all of the scans were assessed using the scanner's proprietary software (OnDemand 3D, Cybermed, South Korea).

Root Canal Preparation

A glide path was created using #10 and 15 K-file for all samples.

Group I: The XP Shaper group, where roots were shaped using the XP Shaper file (30/.01) with the electric motor set at 900 rpm and 1-Ncm torque. The file was inserted into the canal using long gentle strokes (5-7mm), 5 strokes were applied till reaching the working length.

Group II: The Hyflex EDM group, where roots were mechanically prepared using Hyflex EDM single file (size 25/~) with a rotational speed set 500 rpm and a 2.5 Ncm.

Group III: The TRUShape group, where roots were mechanically prepared using TRUShape file (30/.06v) with a rotational speed set at 350 rpm and a 5-Ncm torque in a crown-down technique.

All instruments were operated by X-smart Plus (Dentsply Sirona, Tulsa, OK) endodontic motor. Each instrument was used to prepare 4 canals, Freshly prepared 2.6% sodium hypochlorite solution (Clorox, Cairo, Egypt) was used as an irrigant during the instrumentation procedure with a 30 gauge needle tips (NaviTip, Ultradent, South Jordan, UT, USA) that was placed as deeply as possible into the canal without binding, the irrigant was kept warm using a CanalPro Syringe Warmer (Coltene/ Whaledent, Langenau, Germany). Apical patency was maintained using #10 K-file. Once the rotary instrument had reached the working length and rotated freely, it was removed, then 5 ml of distilled water was used as a final flush. A single operator (AR) with experience in all systems performed all canal preparations which was done in a heated water bath maintained at body temperature (37 °C) to perform instrumentation at body temperature.

Post-instrumentation scanning

The same scanning protocol was employed to scan the samples after mechanical preparation. Pre and post-instrumentation scans were superimposed using the OnDemand 3D software (Cybermed, South Korea) to evaluate the degree of transportation and centering ability of the tested instruments.

Evaluation of Canal Transportation and Centering Ability

Canal transportation corresponds to a deviation of the prepared canal from its natural axis (in millimeters) after instrumentation when compared with pre-treatment measurements.

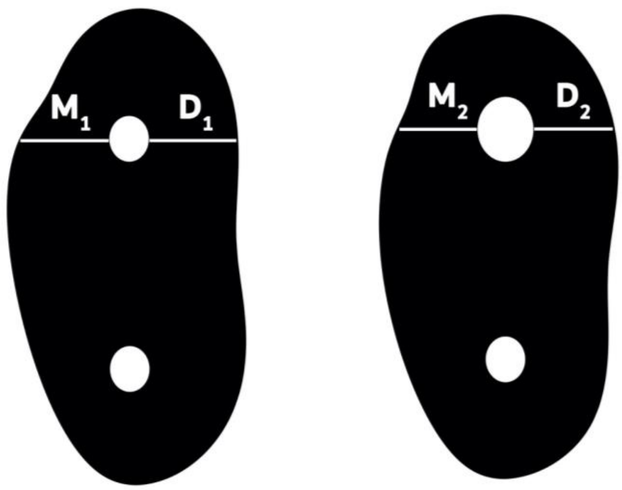

Figure 2. Pre-instrumentation and post-instrumentation diagram with markings showing

points of measurements used for determining canal transportation and centering ratio.

The formula introduced by Gambill et al [17] was used to calculate the degree of canal transportation.

Canal transportation (CT) = (M1- M2) - (D1- D2) (Fig 2)

where M1: refers to the shortest distance from the mesial edge of the root to the mesial edge of the un-instrumented canal.

M2: refers to the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal.

D1: refers to the shortest distance from the distal edge of the root to the distal edge of the un-instrumented canal.

D2: refers to the shortest distance from the distal edge of the root to the distal edge of the instrumented canal.

The result of "0" indicates the absence of canal transportation and other than "0" means that transportation has occurred.

The mean centering ratio indicates the ability of the instrument to stay centered in the canal. Centering ability ratio was calculated using the same values obtained during the measurement of transportation according to the following equation:

Centralization ability ratio = (M1- M2) / (D1 - D2) or (D1-D2) / (M1- M2)

In the assessment of centering ability, a result of 1 indicated perfect centering; the closer the result was to zero, the worse the instrument's ability to remain centered in the canal.

The degree of root canal transportation and centering ability prior to and after instrumentation were measured by a second examiner (RH) who was blinded to all the experimental groups.

Statistical analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov-Smirnov and Shapiro-Wilk tests). For non-parametric data; Kruskal-Wallis test was used to compare between the three systems. Friedman's test was used to compare between the different root levels. Dunn's test was used for pair-wise comparisons. The significance level was set at $P \leq 0.05$.

Results

Amount of canal transportation

At 3 mm root level; there was no statistically significant difference between the three systems, while at 5 mm root level; Hyflex EDM showed the statistically significantly lowest median amount of transportation, while at 7 mm root level; TRUShape showed the statistically significantly lowest median amount of transportation. **(**table 1)

As regards the total amount of transportation (mean of the three root levels); there was no statistically significant difference between the three systems (*P*-value = 0.581, Effect size = 0.016). (Fig 3)

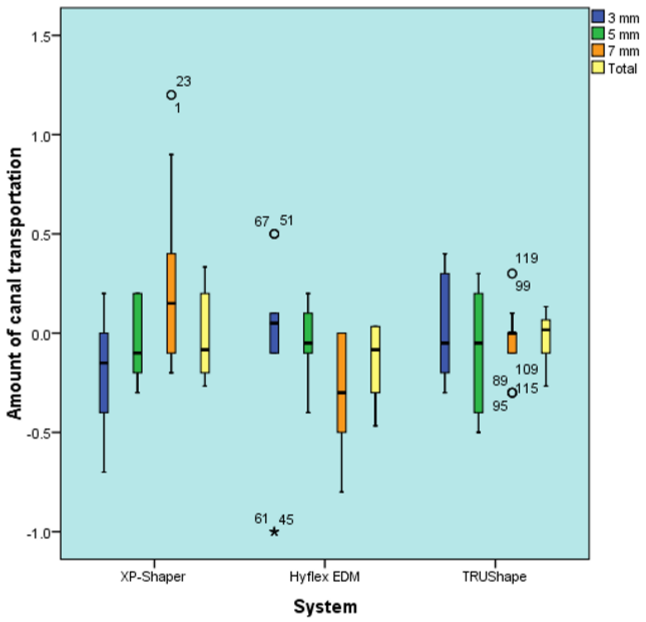

Figure 3. Box plot representing median and range values for amounts of canal transportation with the three systems (Circles and stars represent outliers).

Centering Ratio (CR)

As for the total CR (mean of the three root levels); there was a statistically significant difference between the three systems (*P*-value = 0.025, Effect size = 0.094). Pair-wise comparisons between the systems revealed that Hyflex EDM showed the statistically significantly highest median CR. XP Shaper showed statistically significantly lower value. TRUShape showed the statistically significantly lowest median CR (table 2).

Discussion

The purpose of chemo-mechanical preparation is to clean and disinfect the root canal, eliminating microbial irritants that are the main cause of apical periodontitis, and give it a conical shape for proper placement of root canal filling. An evolutional approach of using single file in completing the root canal instrumentation was proposed in order to provide a quick and efficient way to prepare the root canal with minimum liability of instrument failure or fracture due to reduced instrument fatigue in addition to elimination of possible cross-contamination.

Transportation according to the American Association of Endodontists is defined as "Removal of the canal wall structure on the outside of the curve in the apical half of the canal due to the files tendency to restore their original shape during canal preparation"[18] . Canal transportation can negatively affects the prognosis of the endodontic treatment, straightening the original canal curvature increases the rate of debris extrusion, and subsequent post-operative pain[19]. The present study aimed to measure the transportation and centering ability of XP Shaper and TRUShape and compare it to Hyflex EDM NiTi rotary system using mesio-buccal canals of first mandibular molars with curvature ranging from 25º-35º immersed in heated water bath to provide close circumstances to the clinical situation and to allow true assessment of the instruments performance[11].

Micro-CT remains the gold standard and the reference method for assessment of transportation and centering ability, as it allows the acquisition of the images within the range of 5- to 50-mm voxel size, the small voxel size permits the evaluation of accumulation of hard tissue debris, untouched root canal walls and the amount of dentin removed [20]. However, these systems are expensive and need longer scanning and reconstruction times compared to CBCT, yet keeping in consideration that there is no in vivo scanning available because of the high radiation dose of micro-CT machines. When comparing CBCT and micro- CT, using maxillary molars on cadaver, there was no significant difference between 76-mm voxel size at CBCT and 20- mm voxel size at micro-CT in studying the tooth anatomy[21], thus CBCT was used in the current study as it provides a precise and reproducible calculations of root canal changes before and after instrumentation[21,22].

Another methodology that has been employed earlier in the literature is using simulated canals in resin blocks and performing a direct comparison of the shapes obtained before and after preparation, while this methodology could rule out the variations in canal anatomy which might influence the preparation outcome, however the difference in hardness between dentine and resin in addition to the heat generated by the rotary instruments in the resin blocks which might soften the resin material leading to binding of the cutting blade and separation of the instrument are some of the limitations of this technique[23].

Results showed that there was no statistically significant difference between the three systems regarding the total amount of transportation (P-value = 0.581, Effect size = 0.016) (table 1). At the level of 5 mm from the apex; Hyflex EDM showed the lowest statistically significantly median amount of transportation. The same result could be found in a study by Turkistani et al[24], they found that Hyflex EDM showed significantly less mesiodistal canal transportation and improved centering ability especially in cross section 6 mm from the apex which coincide with the result from our study. While some studies credited this result to a higher flexibility of the nature of CM alloy of Hyflex EDM[25,26], unfortunately we could not find a study comparing the flexibility of Hyflex EDM to MaxWire or TRUshape. One other explanation could be the change in cross section from rectangular at the tip to more triangular cross section near the shaft causing more flexibility.

On the other hand, at the level of 7 mm from the apex; TRUShape presented the lowest median amount of transportation. The decreasing taper along its shaft and the maximum fluted diameter limitation of 0.80 mm which limits the removal of dentin in the coronal third could justify this result, which should allow for limited removal of dentin in agreement with a recent study by *Guimaraes et al*[27].

The current study showed that using XP Shaper system; canal transportation was not significant and there was no statistically significant difference between amounts of transportation at the different root levels, this could be expected due to the adaptive core technology of MaxWire alloy proven to make the

XP-shaper file highly flexible, its small mass could expand beyond its core size, expanding with preservation of the original canal anatomy and curvature[28]. Using CBCT, Arıcan Öztürk *et al* [11]found that, XP shaper had less canal transportation and better centering ability compared with Protaper Next at all levels of all apical sizes. They correlated their results to the Adaptive Core technology, which provides maintenance of original root canal anatomy. Using Micro-CT, Alkahtany *et al*[29] revealed less mesial transportation in preparation of mesial root canals of lower molars using XP shaper compared to ProTaper Universal (Dentsply Tulsa Dental Specialties, Tulsa, OK).

In terms of total centering ability, the tested hypothesis was rejected as Hyflex EDM showed the statistically significantly highest median CR (Table 2). We assume that, the type of alloy could justify this result, as Hyflex EDM files are made of controlled memory (CM) wire which is known to increase the file flexability, in addition to the rectangular cross section of Hyflex EDM which provides better centralization of the rotary file in curved canals consistent with the study made by Ozyurek *et al*.[30] Elnaghy *et al* found less transportation and better centering ability of Protaper Next compared to TruShape, they also credited this result to the difference of the type of NiTi alloy, as the Protaper Next is made of M-Wire which increases the instrument flexibility while the TRUShape is manufactured of a conventional NiTi.[31]

When comparing XP Shaper and TRUShape, XP Shaper showed better statistically significant higher median centering ratio (*P*-value = 0.025, Effect size = 0.094), which contradicted the result of Morales *et al*[32] who found no difference regarding the centering ability of both instruments. This might be caused by differences in the canals tested, they used upper premolars with angle of curvature ranging from 10° to 20° according to Schneider's method, while we used mesio-buccal canals of mandibular molars with more severe angle of root curvature between 20 ° and 35°, which increases the level of difficulty during mechanical preparation[31] .

Conclusions

Within the limitation of our study, it can be concluded that the three rotary systems preserved the original canal anatomy with minimum apical transportation and can be used safely for the treatment of curved root canals, pointing out that Hyflex EDM possess the highest centering ability.

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Declaration of Interest

The authors report no conflict of interest.

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