Comparison of canal transportation and centering ability of Xp Shaper, WaveOne and Oneshape: A cone beam computed tomography study of curved root canals

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ABSTRACT
The aim of the present study was to investigate the shaping abilities of XP Shaper and compare it with other single file rotary NiTi systems utilizing full rotation and reciprocation motion, by cone beam computed tomography. Mesiobuccal canals of forty-five mandibular first molars, were allocated into three equal groups (n=15) according to the rotary system applied; WaveOne, OneShape and XP shaper. Pre-and post-instrumentation images were obtained at 3mm, 5mm and 7mm from the apex using cone beam computed tomography and assessed to determine canal transportation and centering ability. Data were analyzed using Kruskal-Wallis test to compare the three systems and Friedman's test to compare the root levels. Results showed that WaveOne and OneShape rotary systems produced greatest mean transportation with no statistically significant difference between them, while XP Shaper produced the lowest statistically significant mean transportation. Canal centering ability differed significantly among the three systems used. It was concluded that XP shaper preserved the original canal anatomy better than WaveOne and OneShape rotary systems.

Key words: *Root canal, Cone beam computed tomography.*

Comparación del transporte apical y la capacidad de conservación de la anatomía del conducto de XpShaper, WaveOne y Oneshape: Estudio de conductos curvos por tomografía computarizada de haz cónico

RESUMEN
El objetivo del presente trabajo fue investigar la capacidad de tallado apical de XP Shaper y compararla con dos sistemas de NiTi, rotatorio y reciprocante, mediante tomografías computarizadas de haz cónico. Se analizaron los canales mesio vestibulares de cuarenta y cinco primeros molares inferiores. Los dientes fueron divididos en tres grupos experimentales (n=15): WaveOne, OneShape and XP shaper. Se obtuvieron imágenes pre y post instrumentación a 3mm, 5mm y 7 mm del ápice utilizando tomografías computadas de haz cónico para determinar la presencia de transporte apical y la capacidad de conservación de la anatomía original del conducto. Se utilizó el test deKruskal-Wallis para comparar los tres sistemas de intrumentación y el test de Friedman para comparar las mediciones en los tres niveles de raíz. XP Shaper mostró la menor cantidad de transporte apical estadísticamente significativa mientras que WaveOne y OneShape mostraron el mayor transporte apical sin diferencia estadísticamente significativa entre los dos grupos. XP shaper permitió conservar la anatomía del canal original mejor que WaveOne y OneShape.

Palabras clave: *Conducto radicular; Tomografía computada de haz cónico.*

INTRODUCTION

The ultimate goal of root canal treatment is to remove infected pulpal remnants, eliminate microorganisms and adequately shape the root canal system[1]. Optimum biomechanical preparation can be achieved through uniform enlargement of the root canal system in all dimensions to permit thorough disinfection while preserving the original curvature without inducing iatrogenic errors[2].

However, endodontic preparation in narrow and curved root canals has always been a challenge, due to the tendency of the prepared canal to deviate from its natural axis[3]. Innovations and techniques are continuously being developed with the aim of reducing the difficulties encountered during endodontic therapy. Nickel-titanium instruments provide satisfactory treatment of curved canals in shorter times through their enhanced properties of shape memory, super elasticity and cutting efficiency[4].

Various single-file systems with different metallurgy and designs have been promoted to prepare the root canals with one instrument using either continuous rotation or reciprocation motion. WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and OneShape (Micro Mega, Besancon, France) are representatives of these single file systems. WaveOne rotary system works in a reciprocating motion and is made of a special NiTi-alloy called M-Wire, which is produced by a novel thermal treatment process. The M-Wire provides the instrument with increased flexibility and improved resistance to cyclic fatigue. The Primary WaveOne file with a tip size of 25 has a fixed 8% taper from D1 to D3 and a gradually decreasing percentage tapered design from D4 to D16.

On the other hand, OneShape rotary system is made of a conventional austenite NiTi alloy with a tip size of 25 and a constant 6% taper. The instrument incorporates several cross-sectional designs and variable pitch along its entire length.

The XP Shaper instrument (FKG, LaChaux-de-faund, Switzerland) was recently presented on the market. It is based on the MaxWire adaptive core technology. The MaxWire alloy enables the instrument to change its shape from a fairly malleable and straight shape at room temperature to a more robust shape at body temperature (Fig 1). This transformation causes the instrument to be flexible and straight at room temperature and to have elevated cutting efficiency at body temperature[5].

The purpose of the study was to compare the shaping ability of the new rotary NiTi instrument (XP-Shaper) with other single file NiTi instruments in different motions utilizing reciprocation (WaveOne) and full rotation (One shape) in terms of canal transportation and canal centering ability, using cone beam computed tomography. The null hypothesis was that there would be no difference among the three single- file Ni-Ti rotary systems regarding the analyzed parameters.

MATERIALS AND METHODS

Sample selection

A total forty-five human permanent mandibular first molars extracted due to periodontal or prosthodontic reasons were collected from the Department of Oral Surgery, Faculty of Dentistry, Cairo University. Preoperative periapical radiographs were taken to inspect the mesial roots and to determine the angle of root curvature according to Schneider's method[6]. Inclusion criteria were the presence of two separate canals in the mesial root with independent apical foramina, complete root formation, no internal root calcification, no internal or external root resorption, and mesiobuccal canal curvatures between 20° and 35°.

Sample preparation

The crowns were removed using a water-cooled safe sided diamond disc leaving 3 mm above the cemento-enamel junction. The distal roots were separated from the mesial roots using diamond discs. Root canal patency and the existence of two separate mesial canals were confirmed by simultaneous application of two K-files #10 (Maillefer, Ballaigus, Switzerland) in the canals. Only the mesiobuccal

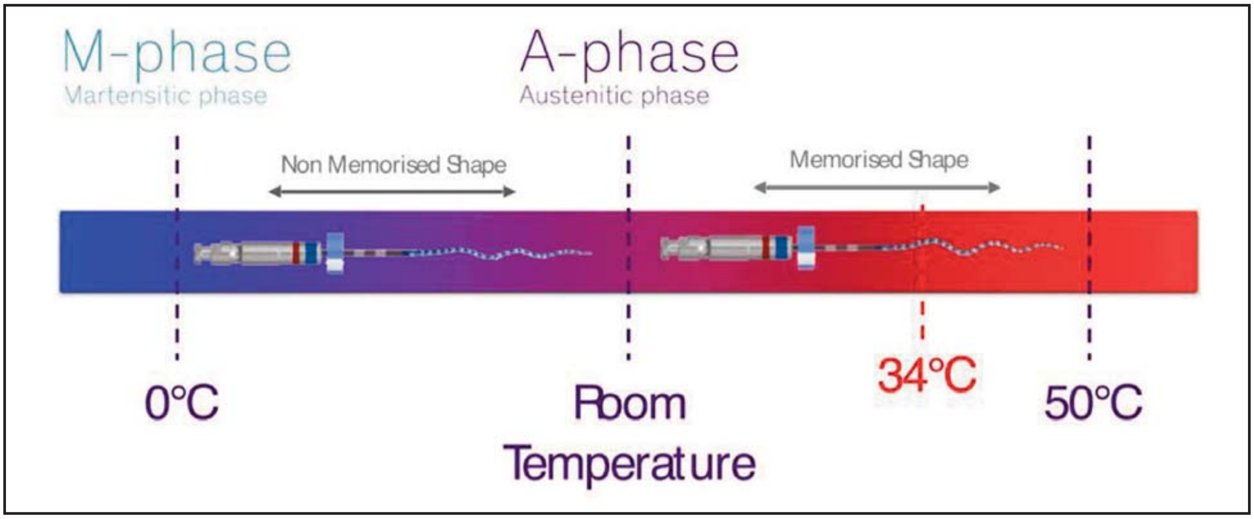

Fig. 1: Martensitic—austenitic phase transformation of XP Shaper at different temperatures.

canals were used in our study. The working length of each canal was determined by subtracting 1 mm from the apical foramen.

Before scanning, the roots were fixed by mounting them vertically halfway in transparent autopolymerizing acrylic resin (Acrostone, Dental & Medical Supplies, Cairo, Egypt) mixed according to the manufacturer's instructions in a silicon mold (10 cm x 10 cm). The root apices were sealed with wax (Wilson, Sao Paulo, Brazil) to preserve the apical foramen from resin penetration. To ensure standardization of the specimens during tomographic scanning, each root was placed in the unset acrylic resin such that its long axis was parallel to the long axis of the mold. In addition, an amalgam filling was inserted into the resin at the bucco-distal line angle of the roots, to enable the orientation of the canal during scanning.

Pre-instrumentation scanning

All roots were scanned using cone beam computed tomography (CBCT) (Scanora 3D, Soredex, Palodex group, Finland) at 85 kVp and 15 mA to detect canal shape before instrumentation. For each specimen, three tomograms were chosen according to the distance from the root apex, as follows: 3 mm from the root apex (Representing the apical third), 5 mm from the root apex (Representing the middle third) and 7 mm from the root apex (Representing the cervical third). All scans were assessed using a Software program (OnDemand 3D, Cybermed, South Korea).

Root Canal Preparation

A glide path was created using #15 K-file (Maillefer, Ballaigus, Switzerland). Then samples were randomly divided into 3 equal groups (n = 15 canals per group) as follows:

- Group I: The WaveOne group, where roots were mechanically prepared using Primary WaveOne file (size 25) operated by X-smart plus endodontic motor (Dentsply, Tulsa Dental, Tulsa, OK) using the reciprocation pre-set mode.

- Group II: The OneShape group, where roots were mechanically prepared using OneShape file (size 25, taper 0.06) operated in continuous rotation motion using an electric motor with a rotational speed set at 350 rpm and a 5-Ncm torque in a crown-down technique.

  Both instruments were used with a slow in-and-out pecking motion with an amplitude of about 3 mm. After three pecks, the flutes of the instruments were cleaned and reinserted, and the process was repeated until full working length was reached.

- Group III: The XP-Shaper group, where roots were shaped using the XP-shaper file with the electric motor set at 900 rpm and 1-Ncm torque. The file was inserted into the canal using long gentle strokes (5-7 mm); 5 strokes were applied until working length was reached.

X-smart plus endodontic motor (Dentsply, Tulsa Dental, Tulsa, OK) was employed for root canal preparation of all samples, following the manufacturer's instructions for each instrument. Each instrument was used to prepare only four canals. Freshly prepared 2.6% sodium hypochlorite solution (Clorox, Cairo, Egypt) was used as an irrigant during the instrumentation procedure, placed with 30-gauge needle tips (NaviTip, Ultradent, South Jordan, UT, USA) as deeply as possible into the canal without binding. Apical patency was retained using a #10 K-file. Once the rotary instrument reached the working length and rotated freely, it was removed. Then 10 ml of distilled water were used as a final flush.

Post-instrumentation scanning

The root canals were scanned after mechanical preparation using CBCT, similarly to the pre-instrumentation scanning protocol. Pre- and post-instrumentation scans were superimposed using the aforementioned software program to evaluate the degree of transportation as well as the centering ability of the tested instruments. The shortest distance from the periphery of the root (mesial and distal) to the edge of the canal was measured using the length measuring tool on the reconstructed cross-sectional scans.

The degree of canal transportation was calculated according to the formula provided by Gambill *et al*.[7].

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

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 (Fig. 2).
Regarding the transportation direction, CT equal to 0 (zero) denoted lack of transportation, a negative value denoted transportation towards the distal direction, and a positive value denoted transportation towards the mesial direction.
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)

The formula was selected in such a manner that the lowest of the results acquired through the difference should be the numerator. A result equal to 1.0 signified perfect centralization. When the value was closer to zero, it denoted that the instrument had lower capacity to maintain itself in the central axis of the canal.

Assessment of root canal preparation
Root canals were prepared by one operator, while canal curvatures prior to and after instrumentation were assessed by a second examiner who was blind to all the experimental groups.

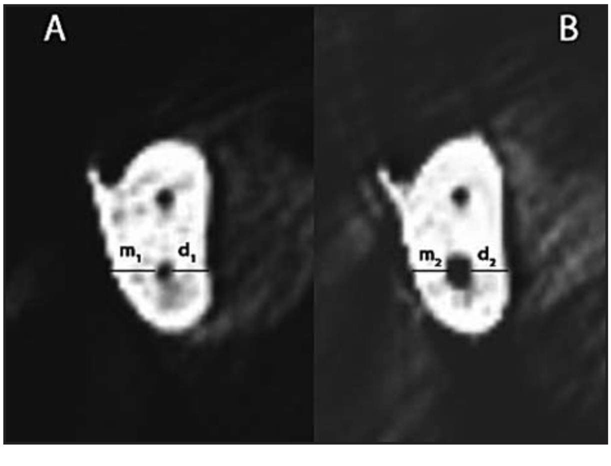

Fig. 2: (A) Pre-instrumentation and (B) post-instrumentation CBCT images with markings showing points of measurements used for determining canal transportation and centering ratio.

Statistical analysis
Data were presented as mean and standard deviation (SD) values. Kruskal-Wallis test was used to compare the three systems. Friedman's test was used to compare the different root levels. Dunn's test was used for pair-wise comparisons. Fisher's Exact test was used to compare frequency data of the three systems. The significance level was set at $P \leq 0.05$.

RESULTS
Canal Transportation
At 3 and 5 mm from the apex, WaveOne and OneShape had highest mean transportation, with no statistically significant difference between them, while the XP Shaper had significantly lower mean transportation (Table 1).
At 7 mm from the apex, all three groups differed significantly. WaveOne had the highest mean transportation (0.22 ± 0.09), followed by OneShape (0.14 ± 0.11), and finally XP Shaper with the lowest value (0.08 ± 0.06).
With regard to the root canal levels; our results showed that preparing the canal with WaveOne instrument created a statistically significant difference between different levels (*p*-value = 0.035). The highest distal transportation was found at 3 mm from the apex, while the highest mesial transportation was observed at the 7 mm level. However, OneShape and XP Shaper instruments showed no statistically significant difference among the different root levels (*p*-value = 0.061 and 0.175 respectively) (Table 2).

Centering Ability
The maintenance of canal curvature was better with One Shape (0.54 ± 0.11) and XP Shaper (0.41± 0.15) than with WaveOne, which had the statistically significant lowest mean centering ratio (0.31 ± 0.12) (Table 3).
Regarding different root canal levels, at the level of 3 mm from the apex, One Shape had the highest mean statistically significant centering ratio (0.51± 0.32), while there was no statistically significant difference between WaveOne and XP Shaper instruments. At the 5 mm level there was no statistically significant difference among the three systems. At 7 mm level, OneShape had the statistically significantly highest mean centering ratio, followed by XP Shaper, and lastly, WaveOne.

Table 1: Mean, standard deviation (SD) and results of Kruskal-Wallis test for comparison between canal transportation values (mm) after using the three systems.

Root level	WaveOne		One Shape		XP Shaper		P-value
	Mean	SD	Mean	SD	Mean	SD	
3 mm	0.14 ^{A}	0.10	0.12 ^{A}	0.16	0.07 ^{B}	0.06	0.023*
5 mm	0.19 ^{A}	0.13	0.21 ^{A}	0.15	0.05 ^{B}	0.04	0.001*
7 mm	0.22 ^{A}	0.09	0.14 ^{B}	0.11	0.08 ^{C}	0.06	0.001*
Total	0.18 ^{A}	0.07	0.16 ^{A}	0.11	0.07 ^{B}	0.04	<0.001*

*: Significant at P ≤ 0.05. Different superscripts in the same row denote statistically significant differences.

Table 2: Frequencies (n), percentages (%) and results of Friedman's test for comparison between direction of transportation among different root levels.

System	Direction	3 mm		5 mm		7 mm		*P*-value
		n	%	n	%	n	%	
WaveOne	Distal	10	66.7	6	40	2	13.3	0.035*
	Mesial	5	33.3	7	46.7	13	86.7	
	No transportation	0	0	2	13.3	0	0	
One Shape	Distal	13	86.7	9	60	7	46.7	0.061
	Mesial	2	13.3	6	40	8	53.3	
	No transportation	0	0	0	0	0	0	
XP Shaper	Distal	8	53.3	11	73.3	6	40	0.175
	Mesial	5	33.3	4	26.7	9	60	
	No transportation	2	13.3	0	0	0	0	

*: Significant at P ≤ 0.05

Table 3: Mean, standard deviation (SD) and results of Kruskal-Wallis test for comparison between centering ratio after using the three systems.

Root level	WaveOne		One Shape		X Shaper		P-value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
3 mm	0.29 ^{B}	0.19	0.51 ^{A}	0.32	0.24 ^{B}	0.34	0.016*
5 mm	0.40	0.29	0.46	0.22	0.49	0.26	0.571
7 mm	0.23 ^{C}	0.16	0.64 ^{A}	0.07	0.51 ^{B}	0.30	<0.001*
Total	0.31 ^{C}	0.12	0.54 ^{A}	0.11	0.41 ^{B}	0.15	<0.001*

*: Significant at P ≤ 0.05. Different superscripts in the same row denote statistically significant differences.

DISCUSSION

Ever since Schilder supported the concept of preparing the root canal in a funnel shape, while preserving its original curve[8]; ideal cleaning and shaping of the root canal systems has remained a very challenging procedure.

The American Association of Endodontics defined transportation 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"[9]. The inappropriate pattern of dentin removal adversely affects the treatment prognosis, as it causes high risk of straightening the original canal curvature, and increases the rate of debris extrusion and subsequent postoperative discomfort[10].

In the present study, mesiobuccal canals of extracted first mandibular molars were chosen to provide conditions similar to the clinical situation and to allow realistic evaluation of the instruments' performance[11]. CBCT was used because it allows detailed three-dimensional (3D) observation of the root canal anatomy with high-resolution images, faster acquisition and reconstruction scheme. CBCT is an effective tool for measuring dentin thickness, apical transportation and canal centering [12,13].

Two parameters were selected to assess the shaping ability of the instruments tested in this study: (1) Apical transportation, which can endanger efficient root canal sealing, thereby reducing the treatment outcomes, and (2) maintenance of canal centering, which is basic in preparing curved canals[11].

Results showed no statistically significant difference between WaveOne and OneShape rotary systems at the levels of 3 and 5 mm from the apex, where both instruments produced high mean transportation compared to the XP Shaper instrument. This could be credited to the tip diameter corresponding to a size 25 for both WaveOne and the primary OneShape instruments, comparable to size 17 which XP Shaper initially starts with. At the level of 7 mm from the apex; WaveOne produced the highest statistically significantly mean transportation, followed by OneShape, while the XP Shaper produced the lowest mean transportation.

There is an inverse relationship between instrument tapering and canal transportation[14]. The primary WaveOne instrument has an 8% taper over the first 3 millimeters. This is greater than the other two rotary instruments, which decrease 4.3% and 5.5% respectively. The OneShape instrument has a constant 6% taper along its entire length and the XP shaper possesses an initial 1% taper along its whole length, which expands to a final 4% taper[5,15].

For overall canal transportation, this study showed that the XP Shaper produced the lowest statistically significantly mean transportation, while the WaveOne and OneShape instruments produced highest mean transportation, with no statistically significant difference between them.

The outstanding results of the XP Shaper can be attributed to its Adaptive Core technology, thanks to which it can expand while preserving the original canal anatomy and curvature[5]. The XP Shaper is believed to apply minimal stresses on the dentin walls, and can thus adapt easily to the canal irregularities[16].

Although the results of our investigation cannot be compared directly with those of Azim *et al.*[5] because of the different systems and methodology applied, their results were consistent with ours. They reported that XP Shaper was superior to Vortex Blue in terms of shaping ability, where the file created non-uniform preparation adapting to the complex canal anatomy.

On the other hand, the attitude of the OneShape instrument in the canal could be explained by its asymmetrical cutting edges. When combined with continuous rotation at a relatively high speed (350 rpm), this design feature causes the instrument to progress into the curved canals, creating some stress that might result in the observed apical transportation [15].

Similar results were drawn in by Agarwal *et al.*[17] and Alrahabi and Alkady[18], who found no statistically significant difference between WaveOne and OneShape instruments regarding canal transportation. Likewise, You *et al.* [19] and Capar *et al.* [20] reported similar transportation results for reciprocation motion and conventional continuous rotation technique. However, there have been contradictory results with Saber *et al.*[15] who report that the use of OneShape file caused a significantly greater apical transportation than WaveOne file. Still other studies report that WaveOne system preserved the original canal curvature better than the OneShape system did[21,22].

Our results confirm the increasing tendency of canal transportation as the diameter of the files increases[10]. OneShape and XP Shaper instruments showed no statistically significant difference among the different root levels. On the other hand, WaveOne instrument showed more distal canal transportation at the level of 3 mm from the apex and higher tendency toward mesial transportation at the 7 mm level. It is therefore suggested that instruments with taper greater than 0.06 should not be used for apical enlargement of curved canals.

Sinai reported that aggressive instrumentation in the cervical third of the root canal may lead to strip perforations and subsequent inflammatory complications[23]. Less transportation towards this area can be considered a favorable feature for the Wave One and the XP Shaper instruments. Agarwal *et al.*[17] showed that at 3 mm above the apex, ProTaper and WaveOne groups showed transportation towards the lateral side of the canal curvature, while the OneShape group remained centered, which agrees with the results of the present study. This result differs from previous studies that report that the apical segment usually has more canal transportation toward the outside of the curve[24].

It should be noted that from a clinical standpoint, Wu *et al*.[25] reported that apical transportation of more than 0.3 mm can negatively affect the sealability of the root canal filling material. In the present study none of the tested rotary systems caused more than 0.2 mm apical transportation.

Our results demonstrated that at the level of 3 mm from the apex; OneShape instrument showed the highest mean statistically significant centering ratio and there was no statistically significant difference between WaveOne and XP Shaper instruments. At the 5 mm level; there was no statistically significant difference among the three systems. At the 7 mm level; OneShape showed the statistically significant highest mean centering ratio followed by XP Shaper, and lastly by WaveOne instrument. These findings proved that instruments with constant taper in the apical section had good centering ability compared to instruments with progressive tapers along the cutting surface [26].

With regard to total centering ratio; OneShape showed the statistically significant highest mean centering ratio followed by XP Shaper followed by WaveOne. The superiority of OneShape instrument can be credited to its design, which progressively changes from variable 3-cutting edges at the tip to S-shaped 2 cutting edges near the shaft[27]. The snake-like motion helps preserve the original canal anatomy due to the offset rotation center, causing the file to engage and disengage along the canal wall, thus reducing the stresses between the file and the canal wall[18].

WaveOne instrument showed low centering ability, as it is a relatively large rigid single file with more taper that moves apically until it reaches the working length, creating a piston effect[28].

The findings of this research are consistent with previous results reported by different authors, such as Saleh *et al.*[29] who showed that canals prepared with the F360 and OneShape systems were better centered than those prepared with Reciproc and WaveOne systems, and Agarwal *et al.*[17] who showed that a OneShape group had less transportation and remained more centered than a WaveOne group, although the differences were not statistically significant. However, they are contradicted by Dhingra *et al.*[22] and Tambe *et al.*,[21] who showed the superiority of WaveOne system over OnesShape in terms of centering ability.

It can be concluded that overall, XP Shaper produced less canal transportation than WaveOne and OneShape instruments.

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