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CONE BEAM COMPUTED TOMOGRAPHIC EVALUATION OF ROOT CANAL TRANSPORTATION AND CENTERING ABILITY USING ROTARY AND RECIPROCATING SYSTEMS

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ABSTRACT

Objectives The aim of the current study was to evaluate the canal transportation and centering ability of Neoniti and WaveOne in curved canals in three levels (apical, middle and coronal) using cone beam computed tomography (CBCT).

Methodology Thirty mandibular first and second molars were collected then access cavity was prepared in each tooth. Only teeth with mesiobuccal canals with angle of curvature ranged between 25- 40° according to Schneider's method were selected then the samples were divided into two equal groups; Group A, Neoniti and Group B, WaveOne. Canal transportation and centric ability of each group were evaluated after instrumentation using CBCT at the three cross-section planes (apical, middle and coronal). Comparisons between the cross-sections and the two instruments were carried out using Oneway-ANOVA, student's t-test and comparison between Categorical data were done by chi square test or fisher exact, $p \leq 0.05$.

Results There was no statistically significant difference between the two single file systems regarding canal transportation in all cross-sections ($p \geq 0.05$) and both instruments were able to remain centered in the canal with different degrees

Conclusion canal transportation and centering ability of Neoniti with full rotation motion did not significantly differ from that of WaveOne with reciprocation motion, other factors than the motion pattern may affect the canal transportation and centering ability of the single-file.

KEYWORDS Canal transportation, Cone Beam Computed Tomograpghy, Curved canal, Neoniti, WaveOne.

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INTRODUCTION

A prepared root canal should have a tapered shape; from apical to coronal region, maintaining the apical foramen and preserving the original canal curvature[1]. The goal of root canal treatment is to remove all the infected and necrotic pulpal remnants and the inner layers of the root canal dentin regardless of the instrumentation technique [2].

Shaping of curved canal is a critical aspect of endodontic therapy [1]. The canal curvature is considered the main cause for procedure errors, such as canal transportation, which is defined as the removal of the dentinal walls on the outside curve in the apical half of the canal due to the tendency of the files to restore their original shape [3], which leads to ledge formation and perforation. In addition, strip perforation and vertical root fractures may be occurred due to the loss of dentine, which resists the lateral forces [4-6]. Despite of the introduction of several preparation techniques to prevent such procedural problems, there are still obstacles to achieve proper endodontic treatment in curved root canals [7, 8].

The introduction of Nickel-titanium (Ni-Ti) to endodontics provided superior flexibility, elastic memory and resistance to torsional fracture [9]. Moreover, Ni-Ti instruments produce a great conical canal preparation, more centered canal, rounded preparations with thick layer of dentin left and reduce the procedural errors in severely curved canal [10-12]. Several systems with different designs have been introduced to achieve proper final shape of the instrumented root canal [13].

Neoniti (NEOLIX, Chatres-la-Foret, France) is a newly introduced single-file system with non-homogenous rectangular cross section, multiple taper, rounded gothic tip and has a continuous rotating movement. This system has been developed using wire-cut electrical discharge machining (WEDM) process, which produces a rough surface and abrasive properties, enhancing the cutting speed of the files [14-16], improving the cutting efficiency without screwing effect and has been thermally treated to increase the flexibility and the shape memory of the file. Another single-file system is the WaveOne (Dentsply Maillefer, Ballaigues, Switzerland); which is a single-file reciprocating system with left handed blades angulation, convex triangle cross section made of thermal-treated M-wire, which increases the flexibility and improves the resistance to cyclic fatigue compared with the conventional Ni-Ti alloy [17]. Reciprocal motion allows the cut of dentin in the large counterclockwise rotating angle, the disengage in the smaller clockwise angle and continuously progresses of the instrument toward the apex of the root canal, which has been claimed for the stress relief for the instrument and minimize the risk of fracture [18-20].

Several methods have been introduced to measure the apical transportation, such as conventional radiographic imaging and cross-sectioning techniques [21, 22]. Recently CBCT has been introduced using low radiation dose and providing a three-dimensional reproduction of the tooth with high accuracy and quality. It has been used in measuring the anatomical structure of the root canal before and after mechanical preparation, to detect any deviation and canal transportation, with assessment of the ability of the instrument to remain centered in the root canal [23-25], thus the aim of this study was to compare canal transportation and centering ability after root canal preparation, using either Neoniti or WaveOne single-file systems in curved mesiobuccal canals of mandibular molars by means of cone-beam computed tomography.

MATERIALS AND METHODS

Samples selection:

In the current study, twenty-eight freshly-extracted mandibular first and second molars due to periodontal disease or prosthodontics problem were collected from the outpatient clinic of the departments of oral and maxillofacial surgery and orthodontic, Faculty of Oral and Dental Medicine, Cairo University. Initial radiographs were performed to ensure that all the samples had mature apices with no calcification and/or internal resorption. All the teeth were shortened to length 19 mm and then they were assessed to determine the degree of curvature of the mesiobuccal canal, only canals with angle of curvature ranged between 25- 40 degrees according to Schneider's method were selected. [1]

Samples preparation:

Coronal access cavities were prepared using high speed hand-piece with a diamond round bur followed by Endo-Z bur (Endo-Z bur, Dentsply, Tulsa dental, Dentsply Maillefer, USA), then a #15 K-file (Mani, Japan) was inserted into the mesiobuccal canals to check patency until it was visible at the apical foramen. One millimeter was subtracted from the length of the file and considered as the working length (WL) for canal preparation. Canals that did not allow placement of the #15 file to the apex and those wider than #20 file at the apex were excluded. All the specimens were shortened to length 19 mm using a diamond stone. Schneider's method was used to determine the degree of canal curvature, where the file in the mesiobuccal canal was adjusted to the working length, two radiographs were taken for each tooth (buccolingual and mesiodistal view) using direct digital radiography with exposure parameters: 60 kVp, 8 mA and 0.1 sec. exposure time. The digital images were analyzed using the digora software (Digora optime, Sordex, Tuusula, Finland), then the samples were divided into two equal groups; 14 teeth in each, according to the type of instrument used in the root canal preparation; Group A, Neoniti and Group B, WaveOne. Teeth were coded then embedded into the auto polymerizing acrylic resin mold (4 teeth in each mold). All the teeth were vertically aligned parallel to the wall of the mold. To ensure standardization of the specimens for the tomographic images before and after root canal instrumentation, small pieces of orthodontic wire were inserted parallel to the long axis of the tooth adjacent to the MB line angle for adjustment of scan orientation.

Pre and post-instrumentation imaging:

Each mold was placed on the chin support and adjusted so that the occlusal plane is parallel to the plate. Three-Dimension image acquisition was performed using a Promax® 3DMid CBCT device (PlanmecaOy, Helsinki, Finland). The Planmeca CBCT unit was set to 90 kVp, 10 mA, 18.51 seconds, 200 mm voxel size and 1001×1001×511 image size. All CBCT measurements were performed by "PlanmecaRomexis viewer 3.5.1.R" software. CBCT images were captured before and after instrumentation with the same protocol, the coronal and sagittal CBCT images were adjusted so that the long axis of each tooth is aligned vertically and then three points were selected on each assessed specimen on the coronal images at 3mm (apical third), 6 mm (middle third) and 8 mm (coronal third) from the root apex (Figure 1).

In the axial planes the following measurements were assessed at the selected root lengths for each tooth: M1 which is the dentin thickness measured from the uninstrumented root canal boundary till the external aspect of the mesial root surface, M2 which is the dentin thickness measured from the instrumented root canal boundary till the external aspect of the mesial root surface, D1 which is the dentin thickness measured from the uninstrumented root canal boundary till the external aspect of the distal root surface, D2 which is the dentin thickness measured from the instrumented root canal boundary till the external aspect of the distal root surface, B1 which is the dentin thickness measured from the uninstrumented root canal boundary till the external aspect of the buccal root surface, B2 which is the dentin thickness measured from the instrumented root canal boundary till the external aspect of the buccal root surface, L1 which is the dentin thickness measured from the uninstrumented root canal boundary till the external aspect of the lingual root surface and finally L2 which is the dentin thickness measured from the instrumented root canal boundary till the lingual root surface boundary (Figure 1).

Root canal preparation:

The mesiobuccal canals of all the teeth were prepared using the X-Smart Plus micro-motor (Dentsply Maillefer, Ballaigues, Switzerland), following the recommendations of the manufacture. In Group A, Neoniti; a glide path was established with #10 K-file, then the X-Smart Plus micro-motor was programmed with the recommended speed (350-500 rpm) and torque limit (1.5 N.cm). C1, an orifice opener was introduced into the canal with maximum depth of 5mm in a brushing motion, then the A1 #25 and 8% taper was introduced into the canal by in and out movement, pulled out for cleaning, irrigation and recapitulation. The previous steps were repeated until the A1 file has reached the full working length of the canal.

In Group B WaveOne; a glide path was established with a #10 K-file, then the pre-programmed setting on the X-Smart Plus micro-motor was selected and the Primary # 25 with 8% taper was introduced gently into 2-3 mm of the canal in a brushing motion, using glide (Dentsply Maillefer) as a lubricant, then removed, cleaned and introduced again into the canal after irrigation with 2.5% sodium hypochlorite and recapitulation with #10 K-file, till reaching the full working length.

Assessment of the root canal preparation

Canal transportation and centric ability in the mesiodistal and in the buccolingual directions were the evaluated parameters. Canal transportation corresponds to the deviation in the axis (in millimeters) after instrumentation, compared with the pre-operative. Evaluation of canal transportation was carried out according to the technique described by ***Gambill et al. 1996*** [26], using the following formula: [(M1-M2)-(D1-D2)] to record the mesiodistal canal transportation and the formula [(B1-B2)-(L1-L2)] to evaluate the buccolingual canal transportation. The amount of transportation in each canal was assessed at three different cross-sections of the canal. In the formulae above a positive value indicates (mesial/buccal) transportation, a negative value indicates (distal/lingual) canal transportation and a value "zero" means that there was no canal transportation.

The centering ability ratio which is the ability of the instrument to stay in a central position within the canal, was calculated for each cross-section using the ratio of (M1 - M2)/(D1 - D2) or (D1- D2)/(M1- M2) for the mesiodistal direction and (B1 - B2)/(L1 - L2) or (L1- L2)/(B1- B2) for buccolingual direction. The numerator for the ratio formula was the smaller of the two numbers. According to these formulae, a result of 1 indicated perfect centering ability and the closer the result to zero the worst the ability of the instrument to stay in the canal central axis.

All CBCT images were evaluated retrospectively by one dentomaxillofacial radiologist with 11 years of experience and measurements were taken twice by the same observer with an interval of 2 weeks. Data were analyzed using IBM SPSS advanced statistics (Statistical Package for Social Sciences), version 21 (SPSS Inc., Chicago, IL). Numerical data were described as mean and standard deviation and data were explored for normality using Kolmogrov-Smirnov test and Shapiro-Wilk test. Comparisons between the cross-sections for normally distributed numeric variables were done using the Oneway-ANOVA, while comparisons between the two instruments were done using the Student's t-test. Categorical data were described as numbers and percentages, where comparisons were done by chi square test or fisher exact as appropriate. All

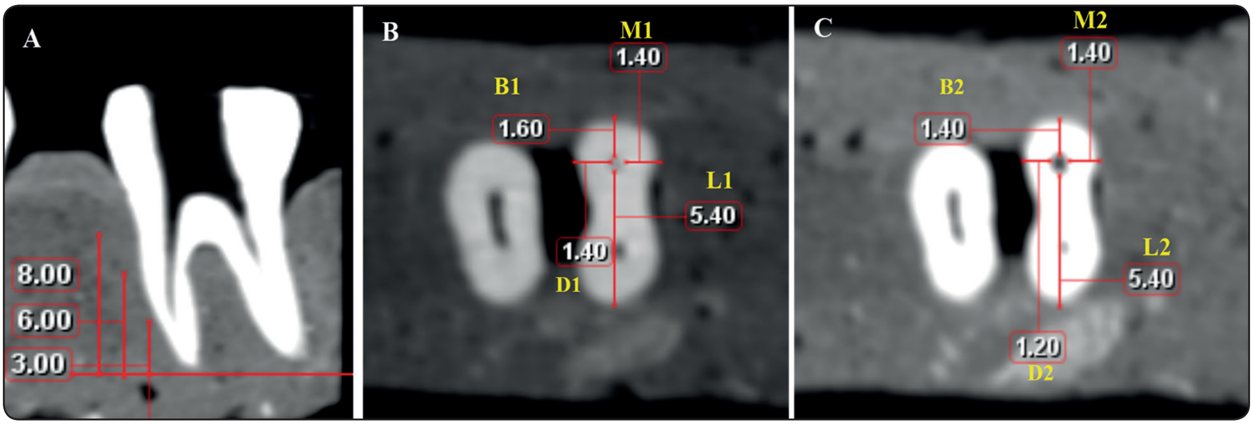

Fig. (1) A) The three cross sections selected for each specimen (3, 6 and 8 mm from the apex). B) Pre-instrumentation measurements of the dentin thickness at 8mm level. C) Post- instrumentation measurements of the dentin thickness at the same level.

analyses were repeated by non-parametric methods to ensure robustness of results but presentation of data were parametric only, significant level set at $p \leq 0.05$.

RESULTS

All groups showed transportation in all directions with all cross-sections with no statistically significant difference ($p \geq 0.05$). Mesiodistally, Neoniti showed the least incidence of transportation with all the cross-sections with no statistically significant difference between the two files ($p \geq 0.05$). Bucco-lingually, WaveOne showed least incidence of transportation at the apical and middle cross-sections with no statistically significant difference between the cross-sections and no statistically significant difference ($p \geq 0.05$) between the two files (Table 1 and Figure 2).

TABLE (1) The mean and standard deviation values of the Mesiodistal and Buccolingual canal transportation for comparison between the cross-sections and the two systems (Neoniti and WaveOne).

	Mesiodistal Canal Transportation						***p*-value1**
	Apical		**Middle**		**Coronal**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Neoniti	0.171	0.233	0.129	0.149	0.186	0.166	0.690
WaveOne	0.186	0.183	0.171	0.22	0.229	0.233	0.725
***p*-value2**	0.859		0.551		0.580		
	Buccolingual Canal Transportation						***p*-value1**
	Apical		**Middle**		**Coronal**		
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Neoniti	0.192	0.131	0.385	0.325	0.242	0.178	0.145
WaveOne	0.178	0.125	0.342	0.287	0.242	0.210	0.146
***p*-value2**	1.000		0.713		0.777		

: Significant at p ≤ 0.05. SD= standard deviation. p-value 1 for comparison between the two systems and p-value 2 for comparison between the cross-sections.

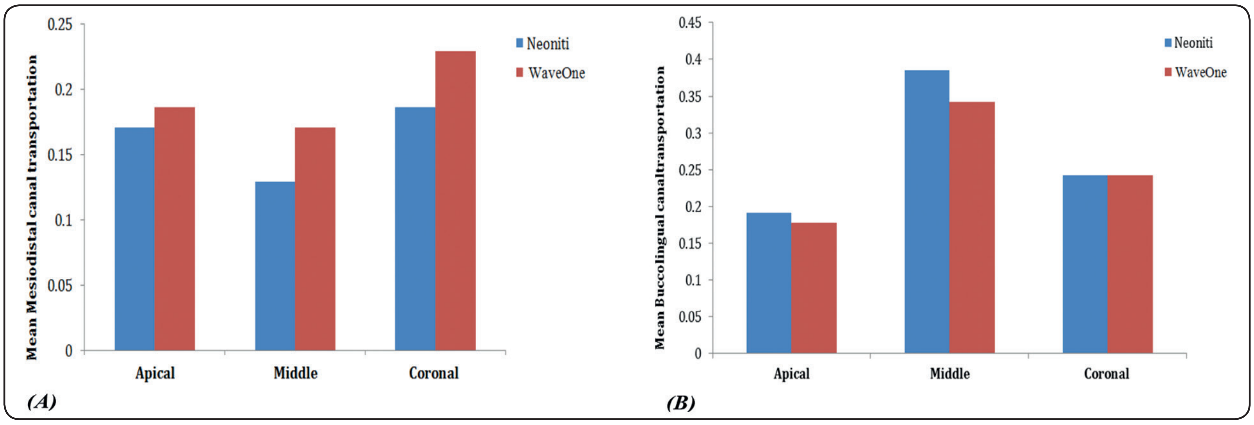

Fig. (2) Column chart showing the mean Mesiodistal (A) and Buccolingual canal transportation (B) of the two systems (Neoniti and WaveOne) at the different cross-sections.

Results showed that Neoniti had more tendency for mesial transportation in the apical and middle cross-section and had more tendency for distal transportation in the coronal cross-section, while the WaveOne had more tendency for distal transportation in the all cross-section, with no statistically significant difference between the two files ($p \geq 0.05$), while in the buccolingual direction the Neoniti showed more tendency for lingual transportation in the apical cross-section and more tendency for buccal transportation in the middle and coronal, and WaveOne showed more tendency for lingual transportation in the all cross-sections, with no statistically significant difference between the two files ($p \geq 0.05$). Regarding the incidence of perfect centering; there was no statistically significant difference between the two files ($p > 0.05$) except in the buccolingual direction at the middle cross-section ($p \leq 0.05$) (Table 2 and 3).

TABLE (2) The frequency (n) and percentage (%) of Mesiodistaly incidence of perfect centering for comparison between the cross-sections and the two systems (Neoniti and WaveOne).

		Neoniti		WaveOne		*p*-value
		No	%	No	%	
Apical	None	12	85.7	12	85.7	1.000
	Perfect	2	14.3	2	14.3	
Middle	None	12	85.7	8	57.1	0.209
	Perfect	2	14.3	6	42.9	
Coronal	None	10	71.4	8	57.1	0.430
	Perfect	4	28.6	6	42.9	

: Significant at *p* ≤ 0.05. SD= standard deviation.

TABLE (3) The frequency (n) and percentage (%) of Buccolingual incidence of perfect centering for comparison between the cross-sections and the two systems (Neoniti and WaveOne).

		Neoniti		WaveOne		*P*-value
		n	%	n	%	
Apical	None	11	78.6	10	71.4	1.000
	Perfect	3	21.4	4	28.6	
Middle	None	13	92.9	8	57.1	0.029*
	Perfect	1	7.1	6	42.9	
Coronal	None	11	78.6	10	71.4	1.000
	Perfect	3	21.4	4	28.6	

: Significant at *p* ≤ 0.05. SD= standard deviation.

DISCUSSION

The success of endodontic therapy depends on proper root canal preparation, the main objectives of mechanical instrumentation are to remove infected tissue debris, microorganism and provide adequate access for irrigating solutions and adequate canal taper for obturation [27]. Procedural errors may occur, including canal transportation, ledge and/or perforation [28, 29], which compromise the integrity of the root, resulting in fracture of the root. Several factors are contributing to these procedural errors, such as the presence of curvature, the instrument designs and motion. ***Wu et al. 2000*** [30] reported that apical transportation of more than 0.3 mm; negatively affect the sealing ability of the obturating materials.

NiTi alloy with its superior elasticity allowed the manufacturing of several instruments capable to prepare curved canals with the ability to maintain the original canal shape with little tendency for decentralization and root canal transportation, with reduced tendency of transportation of the apical foremen [31]. Recently, single-file rotary systems are used as they reduce the time required for root canal preparation and reduce the instrumentation failures [32]. Different systems were introduced using reciprocating motion, reducing the cyclic fatigue, flexural stresses and improving the ability to maintain centralized in the canal in comparison with the continuous rotating motion [33, 34].

It has been reported that when comparing the shaping ability of the instruments, the canals should be prepared to the same apical preparation diameter [35,36], in this study all the canals were prepared apically to size 25 [13,37,38], where using larger sizes would cause more deviations and sever transportation [39] increasing the apical preparation diameter in curved canals, wouldn't result in complete apical preparation but would lead to unnecessary dentin removal as reported by ***El Ayouti et al. 2011***[40].

Although simulated root canals have been used to allow the evaluation of the canal shaping and the instrument performance with high degree of standardization and reproducibility, but they don't reflect the clinical action of the instruments in the root canal due to the difference in the hardness and surface texture [41] with the generation of heat which may soften the resin. In this study natural teeth were used to simulate the clinical behavior of the instrument [13, 37, 38].

Mesiobuccal canals of mandibular molars have certain degree of curvature, the angle of curvature was measured by Schneider method [1] and canals with degree of curvature ranged from 25-45° were selected [13, 37] which was classified by Schneider as sever curvature.

In the present study canal transportation and centering ability were assessed at three cross-sections; 3, 6 and 8mm from the apical foramen [32, 42, 43], where the 3mm was selected to represent the apical third, at which elbows and zips develops as mentioned by ***Weine et al. 1975*** [44], while the 6 and 8mm were selected to represent the middle and cervical third where strip perforation occur [28].

Several studies evaluated the endodontic instrumentation by different methods such as the serial sectioning technique and optical microscopy, this technique leads to loss of the specimen structure, as they include sectioning of the tooth before and after instrumentation [26, 41]. The conventional radiographic technique has been used, where no physical intervention is needed, but it only provides a two-dimensional image [24]. CBCT have been used to calculate the amount of dentin before and after cleaning and shaping of the root canals and so to evaluate the different root canal preparation techniques. It provides three-dimensional precise reproduction of the tooth by a non-invasive technique [41].

Results of this study showed that both Neoniti and WaveOne had similar tendency for canal transportation, this was in agreement with ***Mandana***

et al. 2016 [37], who reported no significant difference in canal transportation and centering ability of WaveOne when used either in reciprocation or continuous rotation, which suggested that other factors than the motion pattern may affect the canal transportation and centering ability of the single-file system.

Supporting our results, ***You et al. 2011*** [45] reported no difference in canal transportation between the reciprocation motion or conventional continuous rotation motion with the ProTaper system and also ***Bürklein et al. 2013*** [46] found no difference between different single-file systems regarding canal straightening.

The results was in contrast with ***Berutti et al. 2012*** [47] who concluded that the primary file of WaveOne would better maintain the original canal anatomy, with less canal transportation compared with the ProTaper, this may be related to the use of training resin blocks. Also, ***Fariborz et al. 2016*** [48] showed that Reciproc with reciprocation motion caused higher transportation than Neoniti with full rotation motion.

Regarding the direction of canal transportation, although the direction of transportation in the apical area is mainly in the outside of the curvature [49], but several studies showed that canal transportation may present in all direction [50] these indicate that occurrence of deviations depend on factors other than curvature, such as instrument design, physical properties and technique of instrumentation [51,52]. In this study Neolix had more tendency to transport the canal in the mesial direction in the apical third while Waveone had more tendency for distal canal transportation.

Considering the incidence of perfect centering, the performance of both files in the apical cross-section was similar, this may be related to the thermal-treated M-wire of the WaveOne which leads to more flexibility, thus favoring the maintenance of the canal curvature during canal preparation[38], while the manufacturing of Neoniti file with a newly developed wire-cut electrical discharge machining (EDM) process and an appropriate heat treatment, explain its high flexibility and centering ability [48, 53, 54].

CONCLUSION

In conclusion, according to the results of this study, both Neoniti and WaveOne single-file system cause some degree of canal transportation in all cross-sections and are able to remain centered in the root canal with different degrees, thus can be used to prepare curved root canals with little deviation.

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