Evaluation of the Canal Transportation and Centering Ability of Different Rotary NiTi Systems in Simulated Curved Canals (A Comparative Study)

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Abstract

Background: Creating a continuous tapered shape while preserving the original root canal geometry particularly in the narrow and curved root canals represents a significant challenge for clinicians.New Niti instruments have been established with new metallurgical and heat treatment, these may play an important role in retaining the original shape of the canal with less mishaps.The study wasaimed to assess and compare the transportation of thecanal and centering ability of three Niti rotary instruments:, EdgeOne Fire,ProTaper Next and TruNatomy filesat different points of simulated curved canals.

Material and Method:60 simulated curved canals were randomly distributed into 3 groups of 20 canals for each group. 1st group was instrumented with ProTaper Next x2 file, 2ndgroup was instrumented with EdgeOne primary file, and 3rd group was instrumented with TruNatomy prime file.The quantity of the removed resin was calculated at 5 levels: 5 mm from the beginning of the canal; The Half-way from the beginning of the curve to the beginning of the canal; the point of deviation of the canal from the long axis of coronal portion which called the beginning of the curvature; the point of intersection of long axes of the coronal and apical portions of the canal which is named the apex of the curve; the end point of the canal. Pre and post-instrumentation images were taken in standardized method.Assessment of canal preparation was done using Photoshop and Digimizer software. The Data were analyzed utilizing Shapiro-Wilk test and Kolmogorov-Smirnov test then Kruskal Wallis test and Mann-Whitney U test were used by SPSS version 21 software.

Conclusion: TruNatomy group showed the best result regarding to the canal transportation as well as centering ability compared to the other file systems evaluated in this study.

Key words: *ProTaper Next, EdgeOne,TruNatomy, transportation, centering ability*

Introduction

The accurate cleaning and shaping is one of the most important goals to achieve success in endodontic treatment[1]. Both Cleaning as well as shaping procedures are separate concepts but are performed concurrently. The principles of canal preparation comprise developing a tapered funnel form of the canal, conserving the original geometry of the root canal, keeping the apical opening in its position without transportation and as small as possible, in addition to establish of glassy and smooth walls [2].

Any deviation from the curvature of the canal can lead to several mishaps like transportation, canal blockage, wall perforations, elbows, zips, ledges, as well as changing in working length and straightening of the canal [3]. In order to overcome these problems, significant technological innovations were establishedto simplify the root canal preparation [4]. Novel instruments withnew manufacturing ideas have been established using high flexible materials and there has been a remarkable Transformation from the conventional taper (0.02mm per mm) instruments to greater taper instruments [5].

Many of new endodontic NiTi systems have been developed with different characteristics, such as: variable cross sectional shapes, multiple tapers, number of helical angles, kinematics, in addition to changes in metallurgical properties in order to improve the properties of Nickel Titanium instruments [6].

ProTaper Next system (Dentsply Tulsa Dental Specialties, USA) made from M-wire was announced in 2013, incorporating a different taper design, novel rectangular cross-sectional design with offset center of rotation[7].

EdgeOne Fire (EdgeEndo, Albuquerque, New Mexico, USA) is new file possess similar cross section of the Wave one Gold system and it is manufactured to be used in reciprocating motion similar to WOG handpiece settings. EdgeOne Fire files are fabricated with a proprietary heat procedure named FireWire™ that it is claimed to increasing the flexibility and offer slight restoring force [8].

TruNatomy instruments (TRN) (Dentsply Sirona) was announced as a newbrand of heat-treated Nickel Titanium instrument with a distinct design. The manufacturer stated that the shaping instruments of TRN provide a slim shaping that aim to enhance the canal debridement as a result of more space existing by the unique design of the file[9].

Materials and Method

Sixty resinsimulated canals were used in this study. These curved canals were 16 mmin length and a taper of 0.02. The non-curved part being 11mm while the curved portion5 mm. The curvature wasmeasured mathematically with resulting in an angle of 40°[10]. All the resin blockshave been coded with a fixed marker. Then each blockwasmarked with four pointshighlighted with black pigmentin order to makea well defining block boundaries. These points served as a guide during the superimposition of pre and post instrumentation photos.The blocks Patency was testedby using K file #10 to the length of (15 mm). After thatblack ink was injected to all samples using an irrigation syringe to increase photographic documentation[11]. All blocks were placed over the base of the stereomicroscope in a standardized place with assistance of custom made holder prior to imaging.The printable ruler sheet have beenpositionedunder the blocks in a secure position. The ruler was used in the calibration procedure after images combination.Magnification power was set to 30X. The captured images were transferred from digital microscope, to a personal computer[12,13].The blocks secured in bench vise then the WaveOne endomotor was used with the all three NiTi systems for instrumentation[13]. Each file was lubricated with glycerin before the insertion into the canal. Irrigation protocol was achieved with distilled water after each instrument used as well as after each patency check.The sequences which were used in our study followed the instructions of manufacturer for all system. After instrumentation, red ink was introduced instead of the black ink then postoperative photo was taken for each sample in the same manner of preoperative method.The before and after images were overlapedby means of Adobe Photoshop software with the aid of orientation dots (Figure 1).

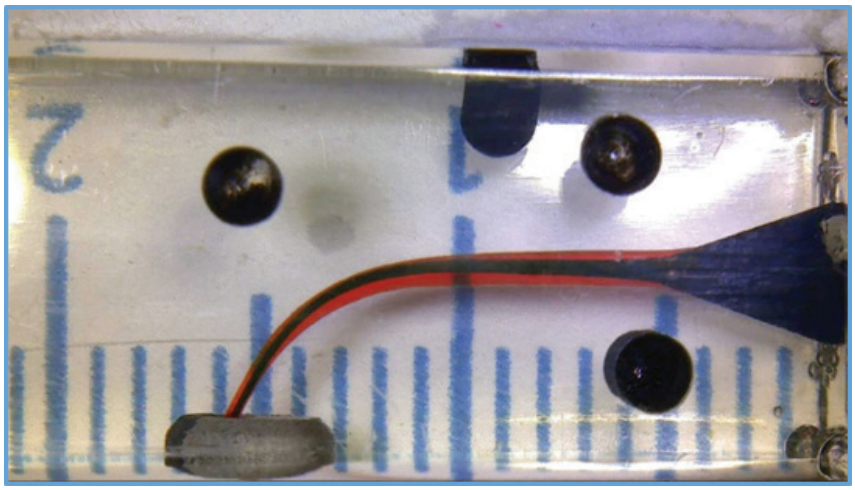

Figure (1): Pre and postoperative images being

superimposed using the Adobe Photoshop software.

Digimizer Image Analysis Software (MedCalc Software, Belgium) have beenutilized to measure of the eradicated resin material Under zoom of 300X to achieve digital measurements. The exact 1 mm gotten in scale image was measured in pixels. The number of pixels acquired was fixed as a reference unit [13,14]. Measurements were recorded at 5 points [15]:

- Level 1: 5 mm from the orifice
- Level 2: 7 mm from the orifice
- Level 3: at the beginning of the curve
- Level 4: at the apex of the curve
- Level 5: 15 mm from the orifice

The extent of deviation was calculated and the centering ratio was computed with the following forma: Do-Di/Dt × 100 (in mm) where; Do: represent the outer resin removed , Di: represent the inner resin removed, Dt: represent the total width of the canal after preparation(Figure 2).

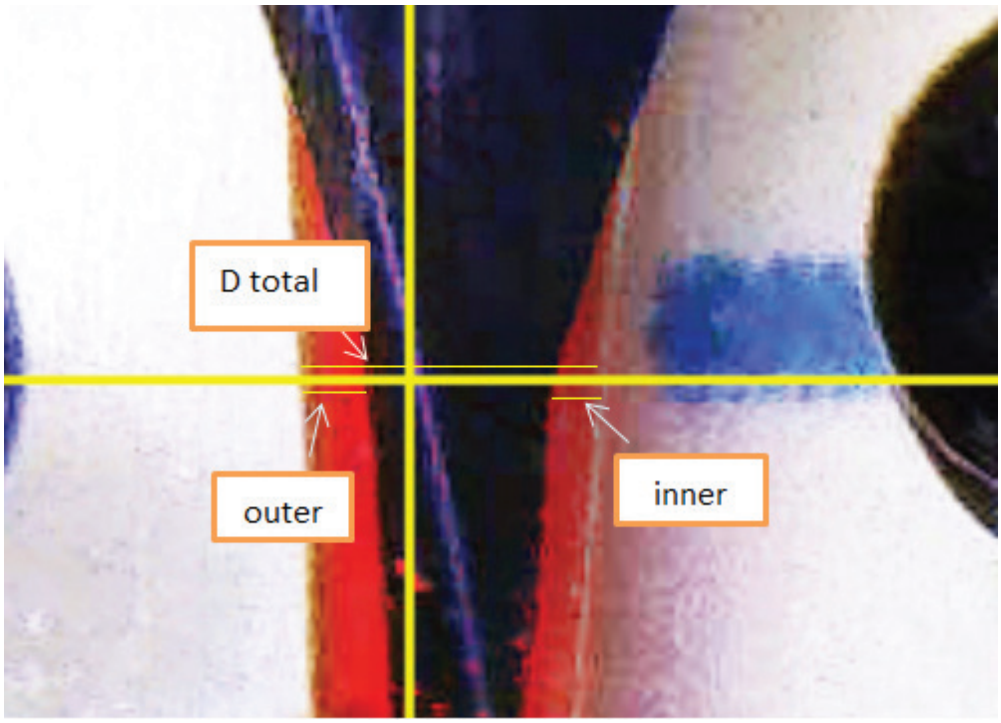

Figure (2): (Di) represents the amount of inner transportation. (Do): Represents the amount of outer transportation. (Dt): represents the total diameter of the final canal preparation.

Results

1. Canal transportation

Testing the normality of data distribution was carried out by using Shapiro-Wilk test and Kolmogorov-Smirnov. Statistical analysis was performed with Kruskal Wallis Test foridentification of the occurrence of any statistically significant difference betweenregarding to the mean values of canal transportation for all groups, as shown in Table (1).

The results of Kruskal test revealed that no significant difference obtainedin level 1 and 2 among the groups, while there were a significant differences among the groups in the last three levels. Mann-Whitney U test was performed in order to explain the source of significance in the last three levels. as shown in Tables (2). The results of Mann-Whitney testrevealed a significant differences between the three groups ($P \leq 0.05$). TruNatomy showed a significant difference with EdgeOne and ProTaper next ($P \leq 0.05$) at level (3,4,5). Also there was a significant difference between EdgeOne and ProTaper next ($P \leq 0.05$) at level (3,4,5).

Table (1): Kruskal Wallis test for canal transportation among 3 files along 5 levels.

	Null Hypothesis	Test	Kruskal-Wallis H	df	Sig.	Decision
1	The distribution of Level1 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	1.083	2	0.582	Retain the null hypothesis.
2	The distribution of Level2 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	1.552	2	0.460	Retain the null hypothesis.
3	The distribution of Level3 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	31.726	2	0.000	Reject the null hypothesis.
4	The distribution of Level4 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	42.196	2	0.000	Reject the null hypothesis.
5	The distribution of Level5 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	52.264	2	0.000	Reject the null hypothesis

Table (2): Canal transportation Mann-Whitney Test.

Levels	Files	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Sig.
Level 3	TruNatomy	20	27.90	558.00	52.000	0.000
	EdgeOne	20	13.10	262.00		
	Total	40				
	TruNatomy	20	30.00	600.00	10.000	0.000
	Protaper Next	20	11.00	220.00		
	Total	40				
	EdgeOne	20	24.70	494.00	116.000	0. 023
	Protaper Next	20	16.30	326.00		
	Total	40				

Cont... **Table (2): Canal transportation Mann-Whitney Test.**

	TruNatomy	20	10.60	212.00	2.000	0.000
	EdgeOne	20	30.40	608.00		
	Total	40				
	TruNatomy	20	10.50	210.00	0.000	0.000
Level 4	Protaper Next	20	30.50	610.00		
	Total	40				
	EdgeOne	20	25.25	505.00	105.000	0.010
	Protaper Next	20	15.75	315.00		
	Total	40				
	TruNatomy	20	10.50	210.00	0.000	0.000
	EdgeOne	20	30.50	610.00		
	Total	40	27.90	558.00		
	TruNatomy	20	10.50	210.00	0.000	0.000
Level 5	Protaper Next	20	30.50	610.00		
	Total	40				
	EdgeOne	20	11.00	220.00	10.000	0.000
	Protaper Next	20	30.00	600.00		
	Total	40				

2. Centering ratio

In order to assess existence of statistical significance among the data sets of the canal centering ability obtained after instrumentation, Kruskal-Wallis Test was performed. as shown in Tables (3). Corresponding to results of Kruskal-Wallis test, nosignificant difference was found regarding centering ability among the levels 1 and 2 but regarding to the remaining three levels there were a significant differences.Mann-Whitney U test was performed.as shown in Table (4). The results showed that there was a significant difference between the three groups ($P \leq 0.05$). TruNatomy showed a significant difference with EdgeOne and ProTaper next ($P \leq 0.05$). Furthermore EdgeOne showed a significant difference with ProTaper next.

Table (3): Kruskal Wallis test for centering ratio among 3 files along 5 levels.

No	Null Hypothesis	Test	Kruskal-Wallis H	df	Sig.	Decision
1	The distribution of Level1 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	3.082	2	0.214	Retain the null hypothesis.
2	The distribution of Level2 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	4.609	2	0.100	Retain the null hypothesis.
3	The distribution of Level3 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	31.948	2	0.000	Reject the null hypothesis.
4	The distribution of Level4 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	41.558	2	0.000	Reject the null hypothesis.
5	The distribution of Level5 is the same across categories of files.	Independent-Samples Kruskal-Wallis Test	51.521	2	0.000	Reject the null hypothesis.

Table(4): Mann-Whitney for Centering ratio.

Levels	Files	N	Mean Rank	Sum of Ranks	Mann-Whitney U	Sig.
Level 3	True Anatomy	20	27.35	547.00	63.000	0.001
	EdgeOne	20	13.65	273.00		
	Total	40				
	TruNatomy	20	29.95	599.00	11.000	0.000
	ProTaper Next	20	11.05	221.00		
	Total	40				
	EdgeOne	20	25.85	517.00	93.000	0.004
	ProTaper Next	20	15.15	303.00		
	Total	40				
Level 4	True Anatomy	20	10.70	214.00	4.000	0.000
	EdgeOne	20	30.30	606.00		
	Total	40				
	TruNatomy	20	10.50	210.00	0.000	0.000
	ProTaper Next	20	30.50	610.00		
	Total	40				
	EdgeOne	20	25.10	502.00	108.000	0.012
	ProTaper Next	20	15.90	318.00		
	Total	40				

Cont... **Table(4): Mann-Whitney for Centering ratio.**

Level 5	True Anatomy	20	10.50	210.00	0.000	0.000
	EdgeOne	20	30.50	610.00		
	Total	40				
	TruNatomy	20	10.50	210.00	0.000	0.000
	ProTaper Next	20	30.50	610.00		
	Total	40				
	EdgeOne	20	11.00	220.00	10.000	0.000
	ProTaper Next	20	30.00	600.00		
	Total	40				

Discussion

One of the most essential and fundamental aspects of endodontic medicines is cleaning and forming the root canal region and the best endodontic results are achieved When the original canal morphology is retained with less invasive methods [16]. The aim of our study was to assess and compare the transportation of the canal and centering ability of three different Niti rotary systems; ProTaper Next, EdgeOne Fire and TruNatomy instruments in simulated curved canals made of resin having a curvature of 40° at different levels. The Simulated curved canals have been usedsince it is adopted to be reproducible as well as the experiment achievement could be consistent [17,18]. The simulated canals authorize standardization for the extent, diameter and location of canal curvature in addition to the tissue stiffness [18].

A variety of techniques have been used to test the transportation and centering capabilities of NiTi files such as sectioning technique, radiograph, micro-computed tomography as well as digital imaging technology. Each one of mentionedmethods hasa desirable features and shortcomings. For example, sectioning regarded as an invasive, hard, in addition the teeth sectioning prior to preparation may lead to bias caused from damage of tissue, furthermore it is restricted to predestined levels [19]. The computed tomography imaging method is another reliable mean for the study of centering ability and degree of transportation but it is not economical [20]. Another technique which is noninvasive and employed only to trace two-dimensional alteration is the radiographic method [21]. Digital photographic technique by superimposition of pre and postoperative imagesshowing the canal spacepre and postpreparation so can be done with relative ease to resin canals and this assist the determination process of transportation and subsequent centering ability at anysite of the canals by the mean of digital calculations. So, this technique giving a high level of standardization in the resultsobtained of the experiment [22,23,24].

In this study Digital stereomicroscope was used to improve the precision and the standardization in order to achieve and examine the images by the available software of the device. Furthermore, it reduced the number of sophisticated equipment needed for conduction of the graphical portion of the study. Digital stereomicroscope used in several studies performed previously in the field of crown and bridge as well as endodontic field in order to obtain the pre and post instrumentation images [25].

The results of this study demonstrated that all systems produced some degree of canal straightening and there was no file from the evaluated systems offered a perfect reproduction for the original anatomy of the canal.

Regarding to the direction of canals transportation in this study it was predominantly occurred toward the convexity of the canal (outer transportation) in the apical region for all systems. This could be linked to the shape memory properties of NiTi wire which always try to straighten itself inside the canal once it is bent in the curved portion of the canal. As a result it willproduce unbalanced forces laterally along the canal walls which lead to an increased in the risk to form ledge or excessive removal of root canal structure as well asnon-

efficient cleaning of the inner part of the apical canal [26]. At the terminal portion of the non-curved part of the canals and starting of the curved part the direction of transportation occurred in the direction of the concavity of the canal walls (inner transportation) predominantly. This possiblyrelated to the outward lateral brushing strokes together with the restoring forces initiated by the NiTi instrument[27].Thisresult show agreement with many researches being published which have reflected same findings of our study [11,13,28,29,30,31].

In this study the lowest means of transportation and best centering ratios founded with TruNatomy group followed by EdgeOne and ProTaper next respectively. but; unfortunately, the results regarding the TRN cannot be endorsed and compared due to the lack of related previous published studies. These results and favorable scores obtained by TruNatomy group could be attributed to the slim design features of the TRN file includes a special heat-treated wire, uses a 0.8mm NiTi wire replacing of 1.2mm NiTi wire of the most other instruments with variable tapers and regressive tapers. Also it could be related to the special NiTi heat-treatment that produce a file with super-elastic properties and highly flexible instruments which preserve the canal integrity aiding in less transportation.TruNatomy shaping file manufactured with an off-centered parallelogram cross-sectional design , it might be supposed that this design compared with PTN rectangular cross section and the EdgeOne parallelogram shaped cross section could contribute to these favorable results of the TRN files.

In this study the EdgeOne file revealedhigher transportation values and less favorable centering ratios when compared with the results of TruNatomy file, but still better than the values revealed by Protaper Next. These results could be related to the proprietary heat treatment process called FireWire™ which used by the manufacturer. This heat treatment process has created Firewire instruments with higher flexibility as result of the peculiar three-dimensional phase of the crystalline matrix of Fire-wire alloy which allows files to better follow the canal [8]. Other reason that could be attributed to this results may be related to the cross section since EdgeOne file has a parallelogram shaped cross section with a modified convex triangular cross-section and radial lands at the tip, and a convex triangular cross-section at the middle and coronal part of the file, similar to the Wave One Gold file according to the manufacturer. To date, there is no studies on the shaping ability of EdgeOne Fire instruments have been published yet.

The Protaper Next system recorded the least favorable centering ratios andthe maximum scores of transportation among the examined groups in this study. This system ismanufactured by using of M-Wire alloy. Grinded with different progressive tapers and an off-centered mass as well as a rectangular cross section [32].

In the two levels of the straight part there is no significance difference between the Protaper Next group and the other groups corresponding to canal transportation and centering ability. The last three levels which represent the curved part of the canal,Protaper Next file displayed means of transportation and reduced ability to remain in the center of the canal, resulting in more deviation than other systems assessed in this study. Similar findings were recorded by previous studies[13,29,31,32,33,34,35].These results could be credited to the following reasons:

1. The Protaper Next manufactured with progressive tapers and this increase the file stiffness at some areas leading to reduce its flexibility, since when the taper increased, the flexibility of the instrument will be reduced resulting in a risk for canal straightening [31,33,36].

2. The difference in cross section design of the file as the Protaper Next is made with off-centered rectangular cross section [37]. Rectangular cross section configuration has a highly ‘screw in’ force and this could increase the risk of transportation in curved canals [38].

Conclusions

Within the limitations of this study, it can be concluded that:

1. The study showed that all the tested systems in this study produced variable degrees of canal transportation of the artificial canals during the instrumentation.

2. TruNatomy groupshowed the least canal transportation and better centering ability compared to the other systems, followed by EdgeOne and Protaper Next systems respectively.

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Conflict of Interest: None to declare.

Ethical Clearance: All experimental protocols were approved under the College of Dentistryand all experiments were carried out in accordance with approved guidelines.

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