Original Study

A COMPARISON OF TRANSPORTATION OF THREE NICKEL-TITANIUM ENDODONTICS ROTARY SYSTEMS IN SEVERELY CURVED ROOT CANALS

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ABSTRACT

Aim: Root canal shaping with maintaining the curvature is one of the main parameters in analyzing the methods and instruments for root canal preparation thus, in this study the straightening of canal curvature was investigated using three nickel-titanium endodontics rotary systems in severely curved root canals.

Materials & Method: Seventy Five curved root canals having curvature angles ranging between 40° to 60° and radius ranged between 4 to 9 mm were divided into 3 groups (OneShape, RaCe, and ProTaper) in each 25 canals. Based on standardized radiographs, before and after instrumentation, transposition of canal curvature was obtained using Auto CAD software. Data was analyzed using variance of ANOVA.

Results: All the files maintained the original curvature of canal well and there was no significant difference among three systems (P>0.05).

Conclusion: Under the condition of this study, all the files maintained the original curvature of canal and did not lead to apical foramen movement thus, they are safe to use. Transportation caused by novel rotary single-file system type OneShape ranged in studied full-sequence files (RaCe and ProTaper).

Key words: : Endodontics, Nickel-titanium alloy, Root canal.

Introduction

Root canal preparation before filing the teeth is the most important procedure in the root canal treatment,[1] thus root canal shaping[1] has a main importance in root canal treatment[2] and has effect on the next procedures such as chemical disinfection and root canal instrumentation.[3] Complexity of root canal anatomy and limitations of the instruments may cause some challenges that may affect on the treatment results.[4] Root canal debridement, continous convergence, and maimtaining the original anatomy and position of apical foramen are the goals in instrumentation.[2] Although, ledge formation, apical foramen transportation, and root canal preparation like an hourglass are some problems following instrumentation of curved root canals.[5] These problems are so important that in the study by Cimis *et al*, 46% of curved canals showed different degrees of apical transportation after instrumentation.[6] Root canal shaping while maintaining the curvature is one of the important parameters in analyzing the techniques and instruments for root canal preparation.[7]

During enlargement of curved root canal, invasive application of the larger files may decrease the treatment prognosis.[8,9] There are many investigations in order to improve and facilitate root canal preparation mechanicaly so, the variaties of Nickel Titanium (Ni-Ti) alloy rotary systems have been developed.[2,3,10] On the other hand, the improvement of roatry Ni-Ti instrument technique caused novel designs and faster and more convenient techniques that maintain the original shape of root canal with the minimum iatrogenic errors.[2,11] Ni-Ti alloy has a lower modulus of elasticity in comparision with stainless steel[12] and because of this, Ni-Ti files can be placed in root canal walls with tless lateral force.[13] In spite of this advantage, NiTi files are more likely to have a straightening tendecy, specially with instruments having greater taper and tip.[14] Some factors such as file design, rotational speed, sequences of instrumentation, surface conditioning of the instruments, and applicable inhibition are important factors in an effective instrumentation.[15] The effect of file design on apical transportation or shaping ability has been studied.[16,17] Recent investigations have shown that under torsional and bending stress, cross- sectional design has more influence on shaping ability compared with taper[6] or size of instrument.[18]

There are different Ni-Ti systems with different features: (Dentsply Maillifer, Ballagigues, Switzerland) with variable taper over the length of their cutting blades and a convex triangular cross-section, variable helical angle and pitch over the length of their cutting blades and non cutting modified tip.[19] RaCe System (FKG Dentaire, Switzerland) having constant taper with a triangle cross-section, two alternative cutting edges which is efficient and avoids screwing-in effect of instrument in root canal.[20] The novel OneShape system (MicroMega, Besancon, France) incorporates different and variaty of cross-sections over the length of active file that provides optimal cutting action in three zones of root canal. In this system, in order to increase the cutting action the surface of instrument is electropolished. Felexibility of OneShape and the special downwad movement provides the efficient apical progression. Minimal fatigue over the length of file diminishes the risk of istrument fracture. OneShape system is designed to maintain the original canal curvature during root canal preparation.[21]

Materials & Method

Teeth selection

One hundred and twenty extracted human first molar teeth with at least one curved root were used in this study. The crown of each tooth was removed at the level of cementum enamel junction(CEJ) using diamond fissure bur then, the access cavity was prepared. In order to make sure that the

pathway is patent, the root canals were checked with K-file # 10. Only teeth with healthy roots and intact apices and whose root canal width near the terminus was approximately compatible with size 15 (not more that size 20) were selected in the first step of sampling. After taking radiographs, 75 teeth whose the radii of canal curvature ranged between 4 and 9 mm and the angles of canal curvature ranged between 40^{o} and 60^{o} (based on Prutte technique) were included.

Teeth Preparation

The working length (WL) was determined as 1mm short of the length where a K-file #10 was visible from the terminus of canal. Before instrumentation, K-file #15 was placed in the root canals and the primary digital radiographs were taken. In order to achieve a constant position, teeth were mounted in resin acrylic prior to radiography, so maximum of the canal curvature was visible in radiography. The long axis of root canal was paralleled and very close to the surface of the film. The X-ray tube, and therefore, the X-ray beam were aligned perpendicular to the root canal (0^{o} vertical and horizontal). The exposure time (0.25 s; 70 kv, 7 mA) was the same for all radiographs. The distance between source and film was 50 cm and the distance between tooth and film was 5mm constantly.

The angles and radii of canal carvuture before and after shaping were measured using Auto CAD 2014 software then, only teeth whose the radii of canal curvature ranged between 4 and 9 mm and the angles of canal curvature ranged between 40^{o} and 60^{o} (based on Prutte technique) were included. After balancing the teeth respecting to these three parameters (radii and angles of canal curvature and the distance from JEC to apex), they were divided into 25 groups randomly.

At the next step, in each group the teeth were prepared using one of these systems:OneShape, ProTaper and RaCe. After canal preparation, radiograph of each sample was taken with the final file under the condition of the primary radiographs then the amount of angles and radius of the canal curvature were determined to compare with the amount of angles and radius of the canal curvature before preparation. Then the balance among groups with respect to transportation was determined using analysis of variance (ANOVA) and Post-hoc Student-Newman-Keuls test.

After preparation of the access cavity, working length was determined by inserting #10 K-file into the root canal ,until its tip was visible in the terminus of apex, and subscribing 1 mm from its length when the file was first observed. Each file was used for preparation of only four root canals. After each file, the root canals were irrigated with *2 ml of a 2.5%* sodium *hypochlorite solution* and after instrumentation they were irrigated with 5 ml of a sodium *hypochlorite solution* using plastic syringe. The tip of syringe was inserted into the root canal as deep as possible without binding. All files were used with electromotor regarding to the preparation sequence which is explained later.

Group 1: OneShape System

A classic OneShape file with a size 25 and a convergence of 0.06 was applied in a slow in-and-out motion, rotational speed of 400 rpm, and torque of 4 Ncm. This file can be used with handpieces of airmotor.

Group 2: RaCe System

In RaCe file, the root canal was checked by K-file #15 patency then, the following steps were applied:

a) A PRE-RaCe #35/0.08 with foure gentle in-and-out motions was uesd.
b) A PRE-RaCe #30/0.06 progressed near the canal curvature.
c) A RaCe #25/0.04 was used with light stroke until the working length.
d) Each of RaCe # 25, 30/ 0.02 files, reached to the working length with light strok.

In order to use RaCe files optimally, the following issues should be noticed:

a) The rotational speed should be 600-1000 rpm and the torque should be 0.5- 1.5 Ncm.
b) The in-and-out motion should be applied without pressure.
c) The time working should be 3-4 seconds and after using file, the root canals should be cleaned and flushed.

Group 3: ProTaper system

In ProTaper files, after hand preparation of the root canal , these steps were followed until size #15:

a) S1 file was used gently, until resistance was encountered.
b) SX file was used for root canal preparation until resistance was encountered.

After following the above steps, the coronal of the canal would be prepared.

c) For preparation the apical of canal, S1 was used apically.
d) After using S1, S2, F1 and F2 were used sequentially until the working length.

According to manufacture protocol for most of the root canals, after using F1 the preparation is completed and F2 and F3 are used for the large and direct root canals.[19] In this study, F2 file was used to balance the size of the apical area. All the ProTaper files were used with a reduction handpiece attached to an electromotor.

The rotational speed and torque were adjusted to 200-300 rpm and 520 g.cm respectively. All of the preparation procedures were done by a single evaluator, while measuring the root canal curvature (after and before instrumentation) was done by a second evaluator who was blind respecting to all the experimental groups.

According to the measurement of canal curvature(before and after instrumentation), the canal straightening was

applied as the difference before and after measurement. One way ANOVA was used to compare the difference among the groups.

Results

One way ANOVA was used to compare the mean angle and radius in three groups (inter-group comparison) before and after instrumentation. For intra-group comparison (before and after instrumentation) paired t-test was applied. The significance *level* was $\alpha = 0.05$ in all the tests. Kolmogorov–Smirnov test was used to evaluate *normality* and the results indicated that distribution of the radius and angle data was normal in three groups.

Instrumentation Results

According to experimental observations during the curved canals preparation, none of the instrument fractured, all the root canals were patent after instrumentation and none of them were blocked with dentine. There was no preparation longer than working length also, there was not any loss of working length in all instruments.

The results of comparision of the degree of curved canals among three groups and the mean straightening of the curved canals following preparation in RaCe, ProTaper, and OneShape systems are presented in Table 1.

Device Type	Number	ANOVA						Paired t-test	
		Angle of the channel before intervention (°)			Angle of the channel after intervention (°)			Diff (°)	p-value
		Min	Max	Mean ± SD	Min	Max	Mean ± SD		
One Shape	25	40	60	46.12 ± 8.70	30	60	42.04 ± 8.22	4.08	0.001
ProTaper	25	40	58	44.92 ± 7.94	27	64	41.60 ± 10.31	3.32	0.015
RaCe	25	40	58	47.16 ± 7.61	30	52	43.40 ± 8.65	3.76	0.005
		p-value: 0.622			p-value: - 0.768				

Table 1: Statistical analysis of mean and standard deviation of curvature of the canal.

In inter-group comparision, the range of curved canal straightening was between 3.32 degrees (for ProTaper) and 4.08 degrees (for OneShape). Compared with the other instruments, ProTaper system showed less straightening of the curved canals, but this difference was not statistically meaningful ($p > 0.05$). The result of one-way analysis of variance indicated that there is no meaningful statistical difference in the mean of angle of curved canal(before and after insrumentation) in all three systems ($p > 0.05$).

In inter-group study, OneShape group showed the highest mean of changes in the angle of canal that was 4.08 and statistically meaningful ($p < 0.05$). The mean of difference of changes in the angles of root canal obtained 3.76 degrees that is statistically meaningful ($p < 0.05$). The lowest mean of difference of changes in the angles of root canal was in ProTaper group (3.32 degrees), that is statically meaningful ($p < 0.05$). The result of paired t-test showed that the difference in the mean of angle of canal before and after instrumentation is meaningful in each group.

In Figure 1, the comparison of the mean of canal curvature before and after root canal shaping in presented for three groups.

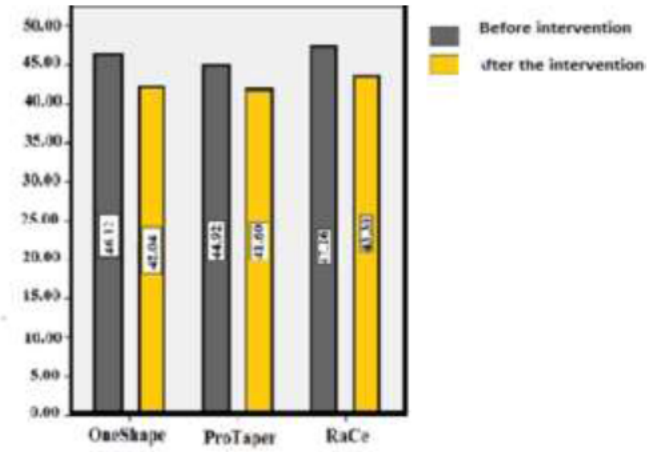

Figure 1: Comparison of the angles of curvature of canals in all three groups before and after the channed forming process.

The statistical analysis of changes in the radius of canal curvature is presented in Table 2. In the inter-group study, the canal straightening ranged between 0.17 mm (ProTaper) to 1.24 mm (OneShape). The mean of changes in radius of the canal curvature following instrumentation was negative in RaCe and ProTaper systems that means the radius of canal curvature increased following the instrumentation.

Device Type	Number	ANOVA						Paired t-test	
		Radius of Curvature before intervention (mm)			Radius of Curvature after intervention (mm)			Diff (mm)	p-value
		Min	Max	Mean ± SD	Min	Max	Mean ± SD		
One Shape	25	4.20	9.00	8.70 ± 1.84	2.17	14.13	7.45 ± 2.44	1.24	0.001
ProTaper	25	4.1	8.99	8.11 ± 2.36	3.97	14.8	8.28 ± 3.00	-0.17	0.750
RaCe	25	5.20	8.99	8.97 ± 2.09	4.15	12.80	9.23 ± 2.81	-0.27	0.458
		p-value: 0.080			p-value: - 0.351				

Table 2: Statistical analysis of mean and standard deviation of curvature channel radius.

On the other hand, the mean of changes in radius of canal curvature was positive in OneShape system indicating the reduction of the radius of canal curvature after instrumentation. The result of one-way analysis of variance showed that there is no statistical difference among three groups respecting to the mean of radius of canal curvature (before and after instrumentation), $p > 0.05$. But, in Intra-group study the change in radius was 1.24 mm in OneShape group that is statistically meaningful($p > 0.05$),

but it was not statistically meaningful in RaCe and ProTaper groups($p > 0.05$).

In Figure 2, the mean of radius of canal curvature in three groups, before and after root canal shaping is presented.

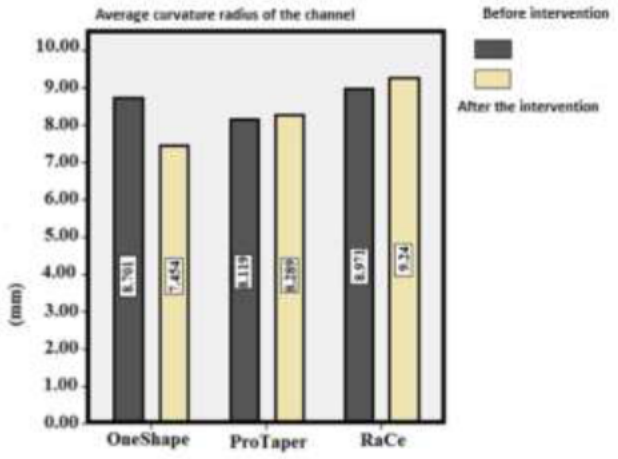

Figure 2: Comparison of the radius of curvature of canals in all three groups before and after the channel forming process.

Discussion

The aim of the current study was to compare the shaping ability of the novel OneShape Ni-Ti rotary file with two conventional, common, and old systems: Race and ProTaper. One of the important factors in choosing an efficient system is the amount of apical transportation or the amount of canal straightening. This is of great importance and Cimis at al. reported that in curved root canals there were different amount of apical transportation following instrumentation.[6] Therefore, apical transportation was chosen as a criteria in evaluation of the efficiency of the novel OneShape system in comparison with common RaCe and ProTaper systems. In the previous studies, RaCe and ProTaper systems showed the lowest and highest transportation, respectively but, the obtained values were not statistically meaningful.[9,24,27] Although in this study the transportation of ProTaper system was lower than RaCe system, but this difference is not significant and statistically meaningful. Regarding that there are many investigations about the efficiency of RaCe and ProTaper systems,[9,22-24,27] we selected RaCe and ProTaper systems to compare them with OneShape system. RaCe and ProTaper are two conventional full-sequence systems compared to novel single-file OneShape system in Iran.

In spite of the variations in the morphology of selected natural teeth, all three groups were balanced anatomically respecting to the size of apical area and the canal length (the distance between apex to CEJ). The teeth were also balanced based on the primary radiographs respecting to the radius and the angle of canal curvature so, in all groups the radius and the angle of canal curvature were 4-9 mm and 40-60 degrees. The final diameter of the files for apical preparation was F2 in ProTaper group and #30.02 in RaCe group. There was only one size in OneShape file for all canals. Also the convergence of the files was different: in RaCe group, for the first 3 mm, the convergence was 0.08 that reduced to 0.04, in F2 it was 0.08, and in OneShape group the convergence was constantly 0.06. Our results showed that the mean straightening of root canal in ProTaper, RaCe, and OneShape systems were 3.32, 3.76, and 4.08 degrees respectively, indicating the highest canal transportation in OneShape file and the lowest canal transportation in ProTaper file, but the result of analysis of variance showed that the difference in canal transportation was not statistically meaningful at the level of 5 % ($p > 0.05$). There is no reported meaningful difference in the amount of transportation in the other studies using single-file and full-sequence systems,[4,10,28] may be due to the non-cutting tips in all files that caused the minimal apical pressure and worked only as a guide to allow to insertion of the file.[28]

In 2014, Burklin *at el* reported that regarding to the size of the tips of the used files, during curved canal preparation, using less tapered instruments caused less straightening than more tapered instruments but, this report was not statistically meaningful at 0.05 level.[29] Based on our results, ProTaper system in which the final used file was F2 with size 25 and constant taper 0.08, the transportation and straightening was less that OneShape system with final file with size 25 and constant taper 0.06 although in ProTaper system the size of taper was higher than OneShape system. This inconsistency may be explained by the canals that were prepared using shaping files in ProTaper system: at first the coronal part of the canals was prepared using S_1 and S_x then, the remained part of working length (middle part and apical part of curved canal) were prepared using S_1 and S_2 with variable taper. The design of files with variable taper may lead to engagement of small part of file with crown. Also, the finishing files in ProTaper system (in contrast with shaping files) include D_4 to D_{14} reduction tapers that prevent the unnecessary enlargement in two-third of the coronal part in the root canal.

Although in contrast with the results of the current study, some previous studies suggested that in order to enlarge the apical of curved canals, NiTi files with tapers larger than 0.04 should not be used with old rotational files such as Profile and conventional ProTaper,[9] because it may lead to transportation. This controversy may be due to using novel Universal ProTaper system having a safe rounded tip in comparison with the older ProTaper system. The previous studies indicated that the mean canal straightening using non single-file systems in the same condition ranged between 1.24 to 3.32,[9,17] but, in this study the value of the mean canal straightening ranged between 3.32 to 3.37 in ProTaper and RaCe systems, respectively. In this study, the more straightening may be explained by higher canal curvature angle. The results of this study showed that the mean of changes in the angle of canal using OneShape file was 4.08 degrees that is higher than two other systems but this difference was not statistically meaningful. The result of the other studies indicated that the transportation of

OneShape system was not statistically meaningful in comparison with full-sequence systems[10,28] and the comparison of different single-file systems showed that the highest transposition occurred in OneShape system, although it was not statistically meaningful.[26] The results of the recent studies indicates that creating the glide path does not have any effects on the canal straightening.[29] Thus, in the current study, creating the glide path using K-file size 15 had no influence on canal straightening and transposition during root canal preparation. During canal preparation there were no blockage and perforation using all three systems thus, all the systems were efficient to removing debris from the root canals and maintaining the canal path. Assessment of the radius of canal curvature (before and after instrumentation), showed that the mean of changes in radius increased 0.17 mm in ProTaper group, and 0.27 mm in RaCe group after instrumentation. In intra-group comparison, there was no statistically meaningful difference in radius between ProTaper and RaCe groups after instrumentation ($p>0.05$). But in OneShape group the mean of changes in radius decreased 1.24 mm after instrumentation that is statistically meaningful in intra-group comparison ($p<0.001$), it may be explained that ProTaper and RaCe systems maintained the original anatomy of the root canal and the changes occurred along with straightening of the canal curvature and a and b points became far from each other that enlarged the canal radius. [Figure 3]

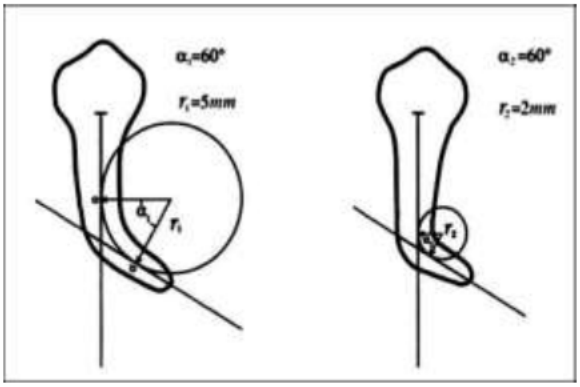

Figure 3: Pruett Technique

But OneShape file changed the original anatomy of root canal more than two other systems and disturbed the original anatomy of root canal thus, in spite of increasing the angle of canal curvature, a and b point got close to each other so the radius of root canal decreased. In previous studies on shaping ability of files only the radius of the canal curvature was investigated in order to balance the samples but, the radius changes following the instrumentation of systems were not studied.

The results of this study indicates that the amount of transportation made by novel rotary single-file system OneShape, is common using full-sequence that are in accordance with previous studies.[4] Therefore, it can be concluded that OneShape file was an efficient system regarding to the time needed for canal shaping and the times needed for changing files thus, it can be introduced as a novel efficient system.

Conclusion

Under the condition of this study, all the used files maintained the original curvature of canal well and did not caused foramen apical movement thus, they are safe to use.

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