An evaluation of canal transportation and centering ability at different levels of root canals prepared by self-adjusting file using computed tomography (A comparative study)

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ABSTRACT

Background: The new concepts and technologies continue to change the dynamics of endodontic practices in the world. Rapid and significant changes in techniques, instrument design, and the type of metals used to manufacture endodontic instruments which have been made during the last few years in an attempt to overcome canal preparation errors. The purpose of this study is to measure and compare canal transportation and centering ability of Self Adjusting File with two rotary nickel-titanium (Ni-Ti) systems, ProTaper and BioRaCe at different levels.
Material and Methods: Forty five distal roots of mandibular first molars with moderate curvature were selected using Schneider method. Roots were divided randomly into 3 groups of 15 each and were scanned using Computed Tomography (Initial scan). After canal preparation with ProTaper (group A), BioRaCe (group B), and Self Adjusting File (group C) the roots were rescanned (Final scan), the degree of canal transportation and centering ability were assessed at apical (4 mm), middle (6 mm), coronal (9 mm) sections using computed tomography. The collected data were statistically analyzed using ANOVA and Least Significant Difference tests.
Results: There were no statistically significant differences among the groups at level 4 mm and level 9 mm ($P > 0.05$). However, at level 6 mm there was a highly significant difference between (A) and (B) groups ($P < 0.01$) and there was a significant difference between (A) and (C) groups ($P < 0.05$). There were no statistically significant differences among different levels of (A) and (C) groups ($P > 0.05$), while (B) group showed a highly significant difference between 4 mm and 9 mm levels and between 6 mm and 9 mm levels ($P < 0.01$). Regarding canal centering ability, there was no statistically significant difference among the three groups at different levels ($P > 0.05$)., while (B) group showed a significant difference between 4 mm and 9 mm levels ($P < 0.05$), and a very highly significant difference between 6 mm and 9 mm levels ($P < 0.001$).
Conclusion: The study demonstrated that canal preparation with the three designs of Ni-Ti instruments produced canal transportation. Self Adjusting File group showed less canal transportation than ProTaper group. There was a comparable value of canal centering ability among different levels in each group except in BioRaCe group.
Keywords: Canal transportation, Self Adjusting File System, Computed tomography. **(J Bagh Coll Dentistry 2014; 26(1):16-23).**

INTRODUCTION

The primary aim of any preparation of root canal system is to enlarge the root canal space to facilitate either disinfection by antibacterial agents or to prevent re- infection through the placement of a fluid-tight root canal filling in combination with a sufficient coronal restoration. Despite recent advances in the field of endodontic instruments and devices, the mechanical preparation of a curved root canal is still a challenge even for very skilled and experienced clinicians [(1)].

Different, well-described preparation errors may result during the shaping of these curved root canals, such as canal transportation, straightening, or deviation [(2)]. As most root canals are curved [(3)], a high prevalence of preparation errors or canal aberrations has been reported [(4)]. The new concept and technologies continues to change the dynamics of endodontic practices in the world.

Rapid and significant changes in techniques, instrument design, and the type of metals used to manufacture endodontic instruments have been made during the last few years in an attempt to overcome canal preparation errors [(5)].

The convex triangular cross section of ProTaper instruments reduces the contact areas between the file and the dentin. The greater cutting efficiency inherent in this design has been safely improved by balancing the pitch and helix angle, preventing the instruments from inadvertently screwing into the canal [(6)].

The major goal of BioRaCe is to achieve apical preparation sizes efficiently and safely that with the addition of antimicrobial irrigation will effectively disinfect the canal. The unique aspect of this sequence is that the apical sizes of most of the teeth can be achieved with only five to seven instruments depending on the root canal anatomy [(7)]. File shows flutes and reverse flutes alternating with straight areas; this design reduces the tendency to thread the file into the root canal [(8)].

The Self Adjusting File (SAF) which is a new concept in cleaning and shaping was developed to overcome the inherent remaining problems of the nickel-titanium instruments. The SAF has no

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blades and no rigid predetermined form; therefore, it does not impose its shape on the canal but rather complies with the canal's original shape. This is true both circumferentially and longitudinally [9].

Different methodologies have been used to assess the effects of different endodontic instruments on canal transportation. Classical in vitro methods of studying the morphologic characteristics of root canal systems either produce an irreversible change in the specimen or provide only a 2-dimensional projected image [10,11].

Computerized tomography (CT) has been shown to be useful in endodontic evaluations, because it non- destructively measures the amount of dentin removed from root canal walls [12-14]. This study was designed to use CT to evaluate the canal transportation of SAF in comparison with ProTaper and BioRaCe.

MATERIAL AND METHODS

Sample

Forty five permanent freshly extracted human mandibular first molars were selected for this study. The gender, pulpal status and reason for extraction not considered, and criteria for teeth selection included the following [15]**:**

1. Age (18-35).
2. Roots with mature, centrally located apical foramen.
3. Roots devoid of any resorption, cracks, caries.
4. The distal roots have length of 11 mm from the apex up to furcation area.
5. Curvature at mesial-distal plane with (15) degrees.
6. Patent apical foramen.

Sample preparation

After extraction, The collected teeth were thoroughly washed and cleaned of all debris by immersion in sodium hypochlorite (NaOCL) for 30 minutes , calculus were removed by curette, then they were stored in distilled water with thymol crystals 0.1% at room temperature . The roots were examined for crack using the Halogen Light curing unit.

Teeth were radiographed in straight bucco-lingual direction (fixed on radiographic wood plate. The images so recorded were taken into vector drawing and edited using Coral Draw 9.0 software and an outline in vector form were drawn around the tooth and also the root canal.

The angle of canal curvature was calculated by the method described by **Schneider** in **1971**, and two straight lines were drawn, the first line from the canal orifice parallel to the axis of the canal and the second line passes through the apical foramen until its intersection with the first line where the curvature starts to occur **(Fig.1)**. Teeth with distal root that have curvature other than 15 degree of curvature and have multiple canals were excluded**.**

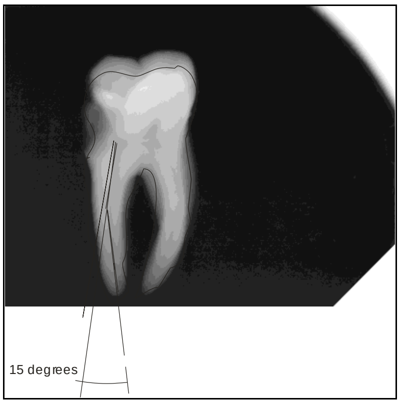

Fig.1: Soft ware (Corel Draw 9) used to measure the angle of root curvature.

Using a diamond disk with straight hand piece at a speed of 25000 rpm and water coolant, the distal roots of teeth were marked at 11.5 mm and sectioned perpendicular to the long axis of root at the furcation area to facilitate straight line access for canal instrumentation procedure**,** to get a flat reference point for measurement, and to eliminate the variables in the access opening, since if the crown is present each tooth would have its own access design [16].

Remnant of pulp tissue in each root was removed by barbed broach, then a size 20 K-file was placed into the canal until it was visible at the apical foramen to verify the location of apical foramen and patency of the canal, and the correct working length (WL) was established 1 mm short of the root length.

Mold construction

The roots were embedded in clear cold cure acrylic [13]. Ten ml disposable plastic syringe was used as a mold. The syringe was prepared by removing the barrel and cutting the plunger at the base to obtain a flat cutting surface. The barrel of syringe was cut off into 1.5 cm length with cutter. Then the coronal end of the sectioned root was fixed by heating the pink sheet wax on the flame and adapted to the flat surface of syringe plunger and the parallism of root (straight coronal part of the root) was checked with the aid of analyzing rod of dental surveyor.

The acrylic was prepared by mixing transparent cold cure acrylic powder and liquid according to the manufacturer's instructions in porcelain jar, and was left till the acrylic reached the dough stage, at this stage the mixture was ready for loading into the barrel of syringe, the plunger of syringe with root fixed on its flat cut surface were pushed into acrylic paste with gentle pressure to allow the complete embedding of the root into the acrylic.

The material was allowed to cure under cooled water which is necessary to compensate for the anticipated rise in the temperature of the samples subsequent to the exothermic curing reaction of the cold cure resin. The acrylic molds were allowed to cure completely for at least 30 min as recommended by the manufacturers. Then acrylic blocks were stored in a plastic containers filled with distilled water.

Sample Grouping

The roots were divided randomly into three groups of fifteen roots each.

Group A: 15 samples were prepared by Rotary ProTaper files.

Group B: 15 samples were prepared by Rotary BioRaCe files.

Group C: 15 samples were prepared by SAF.

CT scanning the samples

A special radiographic wood plate was locally prepared for the purpose of this study with three halls at the same line and at an even distance from the boundary of the plate, and then six metal clips were used as a marker for the number of the specimen in the plate during computed tomography scanning procedure. The samples were mounted on the radiographic plate to allow reproducible results of the initial and final CT scan. Roots were fixed on a special wood plate and aligned so that the long axis of the roots were perpendicular to the beam (the beam passes from the mesial side of the root for each sample which determined by red line).They were scanned at 80 kV and 30 mA with an isotropic resolution of 0.22mm, to determine root canal cross section at 4 mm, 6 mm, 9 mm from root apex.

The images were displayed on Philips Personal computer screen from the option CT viewer. Then when selecting the slab mode cross hair lines appear to determine the specimen under the study and the axis that passes through the root canal, from the slab mode the images were viewed both in the axial and coronal views as shown in **(Fig.2).**

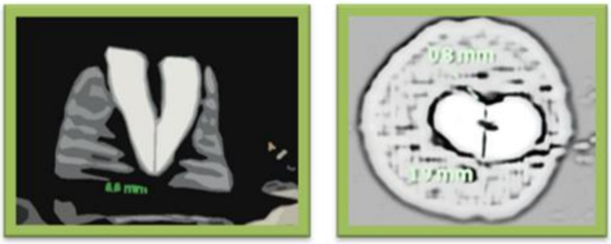

Fig. 2: Root canal shapes under the CT scanning unit (Initial scan)

First, from the axial view the canal was measured at 4 mm, 6mm, 9mm from the apex, to save the distance at specific location from the apex, the rotation center was selected. Then the coronal view was selected to view the canal cross section at the same location. After that, the distance from the edge of un-instrumented canal to the periphery of the root (mesial and distal) was measured at each level for each sample.

Root canal instrumentation

(Group A): Instrumentation was performed with a Crown Down technique using rotary ProTaper system (Dentsply, Maillefer, Switzerland), sequence used (Sx-F4) operated by X-Smart micromotor according to manufacturer instructions. The speed of the hand piece was fixed on 250 rpm, Torque 5 Ncm, gear ratio 16:1.

(Group B): Instrumentation was performed with a Crown Down technique using BioRaCe system (Chaux-de-fonds, Switzerland), sequence used (BR0-BR5) operated by X-Smart micromotor according to manufacturer instructions. The speed of the hand piece was adjusted to 500rpm, Torque 1Ncm gear ratio 16:1.

(Group C): Instrumentation was performed with Self Adjusting File system (Re Dent Nova) that is operated with transline (in and out) vibrating handpieces with 3,000 vibrations per minute and an amplitude of 0.4 mm, torque set to maximum, gear ratio 1:1. The (1.5 mm) SAF was inserted into the canal while vibrating and was delicately pushed in until it reaches the predetermined working length, then operated with in-and-out manual motion and with continuous irrigation using two cycles of 2 minutes each for a total of 4 minutes per canal.

For the three groups the canals were irrigated between each instrument and other with 3 ml of 3% (NaOCl) using a 27 gauge needle (insertion depth of needle one third of the canal), then 1 ml of 17 % EDTA were used after instrumentation and left in the canal for 1 minute to remove the smear layer then rinse with 3 ml of 3% NaOCL. Finally the canals were rinsed with 5 ml distilled water to avoid development of NaOCL crystals.

Rescanning

After instrumentation; the samples of each group were re-scanned to determine the distance from the edge of instrumented canal to the periphery of the root (mesial and distal) and then comparing this with the same measurements obtained from the un-instrumented images to be used in the determination of the canal transportation and the centering ability of the instruments.

The following formula was used for the calculation of transportation: **(a1 – a2) - (b1 – b2)** Where:a1: is the shortest distance from the mesial edge of the root to the mesialedge of the uninstrumented canal, b1: is the shortest distance from distal edge of the root to the distal edge ofthe uninstrumented canal, a2: is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal and b2: is the shortest distance from distaledge of the root to the distal edge of the instrumented canal.According to this formula, a result other than 0 indicates that transportation has occurred in the canal [17].

The mean centering ratio indicates the ability of the instrument to stay centered in the canal [17]. It was calculated for each section using the following ratio: **(a1 – a2)/ (b1 – b2)**. If these numbers are not equal, the lower figure is considered as the numerator of the ratio. According to this formula, a result of 1 indicates perfect centering, more than 1 canal deviation inward and less than 1 canal deviation outward [17].

RESULTS

The results of the descriptive statistics which include the minimum, maximum, mean and standard deviation of canal transportation for all groups at different levels are shown in **(Table 1)** and **(Fig. 3).** It has shown that ProTaper group has the highest mean values of canal transportation at all levels, while BioRaCe has the lowest mean values at the apical and middle levels.

Table 1: Descriptive statistics of canal transportation for all groups

Groups	Level of section	Mean	SD	Min.	Max.
A	4 mm	0.206	0.116	0	0.40
	6 mm	0.207	0.127	0	0.50
	9 mm	0.233	0.176	0	0.60
B	4 mm	0.113	0.064	0	0.20
	6 mm	0.113	0.064	0	0.20
	9 mm	0.220	0.152	0	0.50
C	4 mm	0.173	0.149	0	0.50
	6 mm	0.133	0.072	0	0.20
	9 mm	0.167	0.089	0	0.30

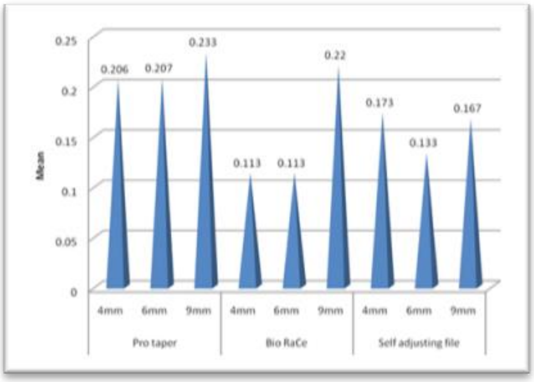

Fig. 3: Bar chart of mean canal transportation for all groups

Analysis of variance (ANOVA) test was performed to identify the presence of any statistically significant difference among the means of canal transportation of all groups, at each level **(Table 2)**

ANOVA test revealed that there were no statistically significant differences among the groups at level 4 mm and level 9 mm and there was a significant difference among the groups at 6mm level.

Table 2: ANOVA test for canal transportation among groups at each level

Cross section	A	B	C	Comparison	
	Mean	Mean	Mean	p-value	Sig.
4 mm	**0.206**	**0.113**	**0.173**	0.091	NS
6 mm	**0.207**	**0.113**	**0.133**	0.021	S
9 mm	**0.233**	**0.220**	**0.167**	0.414	NS

NS: Non Significant at level P > 0.05, S: Significant at level P ≤ 0.05.

Least significant difference test (LSD): was performed for multiple comparisons between groups, **(Table 3).** The results of (LSD) test showed that at level 6 mm there was a highly significant difference between (A) and (B) groups and there was a significant difference between (A) and (C) groups.

Table 3: LSD for mean transportation among the groups at level 6 mm.

Level of section	Groups		p- value	Sig.
6 mm	A	B	0.009	HS
		C	0.036	S
	B	C	0.557	NS

NS: Non Significant at level P > 0.05, S: Significant at level P ≤ 0.05, HS: Highly significant at level P ≤ 0.01.

One Way Analysis of Variance (ANOVA) test revealed that there were no statistically significant differences among different levels of (A) and (C) groups and there was a highly significant difference among the different levels of B group as shown in **(Table 4)**.

Table 4: ANOVA test for canal transportation among the different levels within each group

Groups	Level of section	Mean	p- value	Sig.
A	4 mm	0.206	0.840	NS
	6 mm	0.207		
	9 mm	0.233		
B	4 mm	0.113	0.008	HS
	6 mm	0.133		
	9 mm	0.220		
C	4 mm	0.173	0.562	NS
	6 mm	0.133		
	9 mm	0.167		

NS: Non Significant at level P > 0.05, HS: Highly significant at level P ≤ 0.01.

LSD test revealed that (B) group showed a highly significant difference between 4 mm and 9 mm levels and between 6 mm and 9 mm levels as shown in **(Table 5).**

Table 5: LSD for mean Transportation among levels of BioRaCe group

Group	Level of section		p-value	Sig.
B	4 mm	6 mm	1.000	NS
		9 mm	0.007	HS
	6 mm	9 mm	0.777	HS

NS: Non Significant at level P > 0.05, HS: Highly significant at level P ≤ 0.01.

The results of the descriptive statistics which include the minimum, maximum, mean and standard deviation of canal centering ability for all groups at different levels are shown in **(Table 6)** and **(Fig. 4).** It has shown that ProTaper and Self Adjusting File have comparable values of canal centering ability at apical and coronal levels; also there were comparable values among levels in each group except in BioRaCe group.

Table 6: Descriptive statistics of canal centering ability for all groups

Groups	Level of section	Mean	SD	Min.	Max.
A	4 mm	1.025	0.681	0.33	3.0
	6 mm	1.194	0.641	0.40	2.66
	9 mm	1.056	0.535	0.25	2.0
B	4 mm	1.083	0.340	0.60	1.50
	6 mm	1.321	0.399	0.66	2.0
	9 mm	0.778	0.456	0.28	2.25
C	4 mm	0.925	0.375	0.33	1.66
	6 mm	1.167	0.422	0.60	2.0
	9 mm	0.915	0.321	0.50	1.70

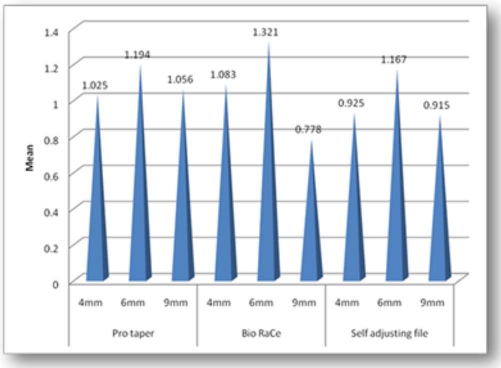

Fig. 4: Bar chart of mean canal centering ability for all groups

One Way Analysis of Variance test (ANOVA) revealed that there were no statistically significant differences among the groups at different levels as shown in **(Table 7).**

Table 7: ANOVA test for canal centering ability among the groups

Section	A	B	C	Comparison	
	Mean	Mean	Mean	P-value	S
4 mm	1.025	1.083	0.925	0.673	N
6 mm	1.194	1.321	1.167	0.666	N
9 mm	1.056	0.778	0.915	0.245	N

NS: Non Significant at level P > 0.05

One Way Analysis of Variance test (ANOVA) revealed that there were no statistically significant differences among different levels within each group as shown in **(Table 8).**

Table 8: ANOVA test for canal centering ability among different levels within each group

Groups	Level of section	Mean	P-value	Sig.
A	4 mm	1.025	0.733	NS
	6 mm	1.194		
	9 mm	1.056		
B	4 mm	1.083	0.003	HS
	6 mm	1.321		
	9 mm	0.778		
C	4 mm	0.925	0.128	NS
	6 mm	1.167		
	9 mm	0.915		

NS: Non Significant at level P > 0.05, HS: Highly significant at level P ≤ 0.01.

LSD test revealed that (B) group showed a significant difference between 4 mm and 9 mm levels and a very highly significant difference between 6 mm and 9 mm levels as shown in **(Table 9).**

Table 9: LSD for mean centering ability among different levels of BioRaCe group

Group	Level of section		P- value	Sig.
B	4 mm	6 mm	0,111	NS
		9 mm	0.044	S
	6 mm	9 mm	0.001	VHS

DISCUSSION

During instrumentation of the root canal, the development of a continuously tapered form and the maintenance of the original shape and position of the apical foramen are important objectives. The final results of the instrumentation of curved root canals may be influenced by several factors: flexibility and diameter of the endodontic instruments, instrumentation techniques, location of the foraminal opening, and the hardness of dentin [18].

In this study torque limited electric motor (X-smart motor) was used for instrumentation that can be programmed for different types of rotary instruments and is able to rotate the file in reverse direction when the file is locked in canal in order to prevent file separation.

An advantage of the present study was the fact that it did utilize roots of natural extracted teeth, as physical and chemical characteristics of the acrylic canals differ from natural tooth. In addition, a moderate root canal curvature of 15 degree was selected for the sample of this study to evaluate the ability of the instruments to preserve the canal with moderate degree of curvature and with the purpose of achieving precise measurements.

In this study CT imaging techniques have been evaluated as non invasive methods for the analysis of canal geometry and efficiency of shaping techniques. With this technique it is possible to compare the anatomic structure of root canal (cross section) before and after instrumentation which is not possible with conventional radiography [19].

The occurrence of up to 0.15 mm of canal transportation has been considered to be acceptable. Conversely, canal transportation reaching above 0.30 mm may have a negative impact on apical seal after obturations [1]. Under the condition of this study none of the specimens presented transportation levels > 0.23 mm.

The mean transportation at all levels was the greatest for ProTaper. This is probably because of the greater amount of dentin removal in all levels of the root canal prepared by ProTaper. This is due to the increased taper of ProTaper shaping files of up to 19%, whereas BioRaCe are available only with tapers of maximum 8% and SAF 4%.

There was no statistically significant difference among the groups at level 4 mm and level 9 mm. However there was a statistically significant difference among the groups at level 6 mm. Probably these differences could be detected because, at this point of the curvature there is a higher stress on the instrument owing to the critical changes on the relationship of diameter and flexibility.

The BioRaCe showed less canal transportation than ProTaper with a highly significant difference at level 6 mm, this is due probably to BioRaCe design with altering straight and twisted areas along the instrument shank and simple triangular cross section may eliminate screwing effect.

This is due probably to the design feature of ProTaper whose cutting edges do not have radial lands and at the same time display more positive rake angle this feature predisposes the canal to greater transportation.

The result of this study agreed with result of study done by **Schafer and Vlassis** [20] whose showed that RaCe created no canal aberration and maintained working length well in curved canals, and disagree with other authors whose showed more canal transportation with RaCe files, compared with Heroshaper and ProTaper.

The SAF showed less canal transportation than ProTaper with a significant difference at level 6 mm, this is due probably to the design difference of SAF whose metal meshwork and absence of metal core make the file compressible and does not impose its shape on the canal but rather complies with the canal's original shape. The result of this study agreed with the study of **Paque et al** [21] about the preparation of oval shaped root canals in mandibular molars using Ni-Ti instruments, they found that there was a significant difference between ProTaper and SAF.

The results of this study agreed with the study of **Paque and Peters** [22] whose found larger canal transportation for rotary ProTaper instruments than for the SAF in maxillary molar canals**.**

There was no statistically significant difference among different levels in ProTaper and SAF groups, while BioRaCe showed a highly significant difference between 4mm and 9 mm levels and between 6 mm and 9 mm levels this is due probably to the design of instruments BR 0, BR 1, BR 3 with tapers 0.08, 0.05, 0.06 respectively, in which tips do not touch the canal walls when the instrument are at full working length which allow larger transportation at coronal level. This study agreed with the study of **Al-Dameh** [23] in which she found that there was a significant difference between 4 mm and 9 mm levels and between 6 mm and 9 mm levels.

Regarding canal centering ability, there was no statistically significant difference among the three groups at different levels. The results of this study agreed with the study of **Narayanan et al** [(24)] in which they compared the centering ability of three rotary NiTi instruments Profile, RaCe and ProTaper, and they found that there was no statistically significant difference among three groups at different levels under computed tomography.

While BioRaCe showed a significant difference between 4 mm and 9 mm levels and a very highly significant difference between 6 mm and 9 mm levels, this is probably lie in preliminary enlargement of canals to size 20 K-file. The results of this study agreed with the study of **Al-Dameh** [(23)]**,** in which she found a significant difference between BioRaCe different levels.

The results of this study agreed with the study of **Javaheri and Javaheri** [(25)], in which they compared the three rotary NiTi systems Hero 642, ProTaper and RaCe, they found that RaCe showed less canal deviation than others.Also agreed with the study of **Bonaccorso et al** [(26)] in which they compared the centering ability of three rotary NiTi files ProTaper, BioRace and MTwo in resin blocks and they found that BioRaCe showed a superior centering ability.

As conclusions;

1. This study demonstrated that canal preparation with the three designs of Ni-Ti instruments produced canal transportation.
2. BioRaCe group showed less canal transportation than ProTaper and SAF groups.
3. SAF group showed less canal transportation than ProTaper group.
4. ProTaper and SAF groups have comparable values of canal centering ability at apical and coronal levels.
5. There were comparable values of canal centering ability among different levels in each group except in BioRaCe group.

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