

A COMPARATIVE STUDY OF APICAL TRANSPORTATION AND STRAIGHTENING OF TWO ROTARY NICKEL-TITANIUM SYSTEMS WHEN USING FINAL APICAL BRUSHING

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ABSTRACT

INTRODUCTION: Apical transportation results in an inadequately clean apical area and makes apical seal more difficult thus affecting the final outcome and may lead to failure.

OBJECTIVES: The aim of this study was to compare between the effect of two rotary nickel titanium systems after using final apical strokes on canal transportation and apical straightening of the canal.

MATERIALS AND METHODS: Sixty mesiobuccal canals of extracted mandibular first molars with root canal curvature angle (25 to 45 degree) were selected. Canals were divided into two groups (n=30). In group I canals were prepared with OneShape file, while in group II, canals were prepared with Revo-S system. Each group was then sub-divided into two sub-groups according to the motion used (pecking or circumferential filing). Sub group Ia (OneShape file) and sub group Ib (Revo-S system) were prepared with pecking motion while sub group II an and sub group II b were prepared with circumferential filing motion. A radiographic platform was used to obtain accurate radiographs. All specimens were radiographed from proximal and mesiodistal views. To measure apical transportation, the pre and post-instrumentation radiographs were exported from the Kodak software into Photoshop program. Then a grading system was used to assess the amount of transportation. Based on apical curvature measured before and after instrumentation (using Image J program), canal straightening was determined as the difference between these two measurements.

RESULTS: Regarding apical transportation, no statistical significance was found between both groups and the sub groups. Apical straightening was evaluated, and no statistical significance was found between the groups. However, circumferential filing produced more straightening.

CONCLUSIONS: OneShape file and Revo-S system maintained the original canal curvature with no significant differences between the files. Circumferential filing motion with both systems resulted in higher values of straightening when compared to pecking motion.

KEYWORDS: Apical canal transportation, canal straightening, rotary nickel titanium, single file.

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INTRODUCTION

Root canal shaping is one of the most important procedures in endodontic treatment. The main goal is to debride the pulp cavity completely and enlarge the root canal system for ease of obturation, while maintaining the original canal configuration.

Apical transportation results in an inadequately clean apical area and makes apical seal more difficult thus affecting the final outcome and may lead to failure. This can occur during canal preparation due to tendency of the files to restore themselves to their original linear shape leading to removal of canal wall structure on the outside curve in the apical half of the canal⁽¹⁾.

Several techniques have been used for the assessment of canal instrumentation, such as scanning electron microscope, radiographic evaluation and photographic assessment. Double- digital radiographic techniques are currently used for assessment of canal transportation. These techniques are easy to use, inexpensive and potentially informative^(2,3).

Over the years, many nickel titanium rotary instruments have been developed to improve root canal preparation owing to their super-elastic properties. They are available in various designs that differ in tip and taper design, rake angles, helical angles, pitch and presence of radial lands. The use of NiTi instruments decreased the prevalence and

degree of root canal transportation compared with hand instruments⁽⁴⁾.

Older rotary systems adapted a crown down technique preparation that includes pre-flaring prior to apical preparation using a sequence of three to four instruments.

The Revo-S system is a novel rotary system intended for endodontic treatment by crown down technique with only three instruments. The asymmetrical cross section of the Revo-S facilitates penetration by snake-like movement and offers a root canal shaping adapted to the biological and ergonomic imperatives⁽⁵⁾.

Recently, single file endo concept was introduced. Single file requires a minimum or no glide path and only a single file for complete instrumentation for majority of root canals. The recommendation for single use has added the advantage of reducing instrument fatigue and lower cross contamination between the patients⁽⁶⁾.

One Shape is a single nickel titanium file used in continuous rotation for better quality of canal preparation. This file allows for better negotiation of curved canals with an instrumental and easy dynamic. The instrument with three different cross section zones is guided down the glide path by three cutting edges providing flexibility and assuring a perfect respect to the original canal path, thus decreasing the risk of apical transportation⁽⁷⁾.

In both systems (Revo-S and OneShape) slight pecking motion is recommended for use. The manufacturers claim

that upon reaching the apical portion with the last used instrument, brushing motion could be used for circumferential filing for further flaring of the canal.

However, the effect of repeatedly using this circumferential filing motion on apical transportation is still under investigation. The null hypothesis of this study was that circumferential filing after reaching the apical limit might increase apical transportation.

MATERIALS AND METHODS

This study was conducted following the requirements of the Institutional Review Board (IRB) of the faculty of dentistry, Alexandria University regarding research involving human tissues.

This study was conducted on sixty curved mesiobuccal root canals of extracted human mandibular molars that were extracted due to impactions or periodontal disease.

Preparation of the specimens

The distal roots were removed using a high speed tapered diamond bur at the furcation level, for ease of introduction into the plastic cubes and superimposition of the radiographs.

Endodontic access cavities were prepared in all molars using a #4 round-end diamond bur (Komet, gebr, Brasseler GmbH & co.) for the initial entry followed by Endo-Z (Dentsply Maillefer, Ballaigues, Switzerland) bur for lateral extension and finishing of the cavity walls. Access cavities were then irrigated with 2.5% sodium hypochlorite to flush away debris and coronal pulp tissue. An endodontic explorer was used to explore the canal orifices and to evaluate a straight line access. The cusp tips were ground flat to achieve a stable reference point for the files. A # 10 K file was introduced into the mesiobuccal canals until just visible at the apical foramen to ensure apical patency, and one mm was subtracted from this measurement to establish the working length. The apical foramen of each root was sealed with wax to prevent resin penetration while embedding the tooth in the resin. The resin blocks were prepared using 60 identical plastic cubes. These plastic cubes were prepared to receive the tooth and resin, and each has a protrusion to fit into the plastic base of a radiographic platform.

Digital evaluation of apical transportation

A radiographic platform was fabricated to allow accurate pre- and post-instrumentation radiographs to be taken in the same position.

Pre-instrumentation radiographs

Standardized digital pre-instrumentation radiographs were taken for each tooth in a bucco-lingual and proximal direction with the initial file inserted up to the exact working length using the radiographic platform and Kodak RVG digital radiography system. Kodak dental imaging software was used to display and save the radiographs in a specific file for each tooth.

Measuring canal curvature using Schneider's technique

⁽⁸⁾ The pre-instrumentation radiograph of each tooth was exported from Kodak software to Image J (Image-J v1.44; Us national Institutes of Health, Bethesda, MD, USA). A line was scribed parallel to the long axis of the canal. A second line was drawn from the apical foramen to intersect the first line at the point where the canal began to leave the long axis of the root. The acute angle thus formed was measured using the angle tool feature of the Image J

program. Only canals whose angle of curvature ranged between 25 degrees and 45 degrees were included.

Guidelines for instrumentation of the canals Manual preflaring of all the canals with stainless steel K-files # 15 and # 20 was done to the full working length to create a glide path before using Ni-Ti rotary instrumentation. Copious irrigation was performed between the use of each file during the instrumentation procedure with freshly prepared 2.5% NaOCl using a 27-gauge needle placed into the canal without binding after each successive enlargement of the canal for both techniques. A # 10 K file was inserted after each file to check apical patency. File-Eze (Ultradent, USA) was used as a lubricating and chelating agent before and during the use of each instrument to facilitate preparation. Endoflare rotary file (Micro-Mega Besancon cedex, France) was inserted inside the canal 3mm below the pulp chamber floor to remove all coronal constrictions.

Mesiobuccal canals of all teeth in group I were instrumented using OneShape files (Micro-Mega Besancon cedex, France). The OneShape file was operated with 350 rpm speed of rotation and 4 N.cm torque. The file was placed down to the two-thirds of the working length using in and out movement without pressure with an amplitude of three mm. The file was then withdrawn from the root canal, cleaned and the canal was irrigated and canal patency checked with # 10 K file. The file was introduced again into the root canal and placed down to 3 mm from the working length, then withdrawn and cleaned again. In sub group Ia the file was then re-introduced into the root canal and taken down to the working length with supplemental slight pecking motion. In sub group Ib, upward circumferential filing motion was performed to the full working length. In group I, the file was discarded after the preparation of each root canal.

Mesiobuccal canals of all teeth in group II were instrumented using Revo-S nickel-titanium rotary files (Micro-Mega Besancon cedex, France). The Revo-S file was operated with 350 rpm speed of rotation and 0.8 N.cm torque. File SC1 (tip size 25 and taper 6%) was inserted to two-thirds the working length to prepare the middle third. The canal was irrigated and patency checked with # 10 K file. File SC2 (tip size 25 and taper 4%) was used to full working length. Again, the canal was irrigated and patency checked with file # 10 K file. File SU (tip size 25 and taper 6%) was used to full working length with supplemental slight pecking motion for group II a. For sub group II b, upward circumferential movement was performed to the full working length. In group II, the files were discarded after the preparation of four root canals according to the manufacturer's instructions.

Post-instrumentation radiographs

Standardized digital post-instrumentation radiographs were taken in a bucco-lingual and proximal direction with the aid of the radiographic platform and with the master file inside the canal up to the exact working length using Kodak RVG digital radiography system. The post-instrumentation radiograph was displayed then stored in the specific file of each tooth with its pre-instrumentation one.

Grading of apical transportation

⁽⁹⁾ The pre- and post-instrumentation radiographs for each tooth were exported from the Kodak software into Photoshop program (Adobe systems, San Jose, CA, USA). The apical portions of the initial and master apical files were selected and colored each with a different color using the

Photoshop tools, the pre- and post-instrumentation radiographs were superimposed, the metallic L-shaped wire reference object and the root outline were used to achieve superimposition of the radiographs.

No transportation (0): Complete superimposition in the apical 2mm of the master apical file so that the initial file falls within the confines of the master apical file.

Mild transportation (1): Slight shift of the superimposed files.

Moderate transportation (2): There is still contact in the apical 2mm of the divergent files.

Severe transportation (3): No superimposition in the apical 2mm of the superimposed files.

Apical transportation was recorded from buccal and proximal views.

Measuring the degree of apical canal straightening

Based on apical canal curvature measured before and after instrumentation, apical canal straightening was determined as the difference between these two measurements according to Hulsmann and Styrge technique⁽¹⁰⁾ as follows:

Measuring pre-instrumentation apical canal curvature

Pre-instrumentation radiograph of each tooth was exported from Kodak software into Image J program. An axis was drawn along the main part of the root canal as proposed by Schneider. (This main axis was used as a reference for the following post-instrumentation measurement). A second axis was drawn along the apical two mm of the initial file to the main axis (which is a slight modification of the Schneider's technique). The angle thus formed was measured by the angle tool feature of the Image J to determine the pre-instrumentation apical curvature.

Measuring post-instrumentation apical canal curvature

Post-instrumentation radiograph of each tooth was exported from Kodak software to Image J and superimposed over its pre-instrumentation one guided by the L shaped orthodontic reference wire and the root outline.

An axis was drawn along the apical two mm of the master apical file to the reference axis and the angle thus formed was measured using the angle tool feature of the Image J to determine the post-instrumentation apical canal curvature. Apical canal straightening for each tooth was determined as the difference between the pre- and post-instrumentation apical canal curvatures. Apical canal straightening was calculated from buccal and proximal views.

STATISTICAL ANALYSIS

After data were collected it was revised, coded and fed to statistical software SPSS IBM version 20. The given graphs were constructed using Microsoft excel software. All statistical analysis was done using two tailed tests and alpha error of 0.05. Descriptive statistics in the form of frequencies and percent were used to describe the categorical data while mean and standard deviation for numeric data which follow normal distribution, non-parametric statistics were used. To test for association between groups at different phases, Mont Carlo exact test was the preferred. Non parametric Mann-Whitney test was used to compare means between the two groups at different views.

RESULTS

Grading of apical transportation (figure 1) In this study there was no statistical significant differences between sub group I am (ONESHape pecking) and sub group I b

(ONESHape circumferential filing) in buccal view at $P < 0.05$ ($P = 0.078$).

Sub group I am (OneShape with pecking motion) showed equal distribution of apical transportation between the scores of no, mild and moderate, but severe transportation was not observed (Table 1). In sub group I b (OneShape) with circumferential filing, the highest percentage was seen with mild apical transportation in (53.30%) of the cases, while severe transportation has been observed in (6.70%) of the cases.

Also, no statistically significant difference was found between sub group II a (Revo-S pecking) and sub group II b (Revo-S circumferential filing) in buccal view at $P < 0.05$ ($P = 0.826$). In sub group II a (Revo-S with pecking), 33.3% of

the cases showed no transportation and the same percentage has been observed for moderate transportation. Severe transportation was traced in 6.75% of the cases, while mild transportation was seen in 26.7% of the cases (Table 1). Meanwhile, in sub group II b (Revo-S with circumferential filing), the same percentage of 26.7% has been observed in both no and moderate transportation. Severe transportation has been seen in a percentage of 13.3% while mild transportation showed the highest occurrence of 33.3% (Table 1)

No statistical significant difference was found between subgroup I am (ONESHape pecking) and sub group I b (ONESHape circumferential filing) in proximal view at $P < 0.05$ ($P = 0.163$) (Table 2).

The percentage of cases having no transportation in sub group II a (Revo-S pecking) and II b (Revo-S circumferential filing) was 33.3% (five cases) and 20.0% (three cases) respectively, cases with mild transportation was 33.3% (five cases) and 33.3% (five cases) respectively, cases with moderate transportation was 26.7% (four cases) and 46.7% (seven cases) respectively and cases with severe transportation the percentage was 6.7% (one case) and 0.0% respectively (Table 2).

By using the Mont Carlo exact test, there was no statistical significant difference between sub group II a (Revo-S pecking) and II b (Revo-S circumferential filing) in the proximal view at $P < 0.05$ ($P = 0.549$). (Table 2)

By using the Mont Carlo exact test, there was no statistical significant difference between group I (ONESHape) and group II (Revo-S) in the proximal view (Table 2).

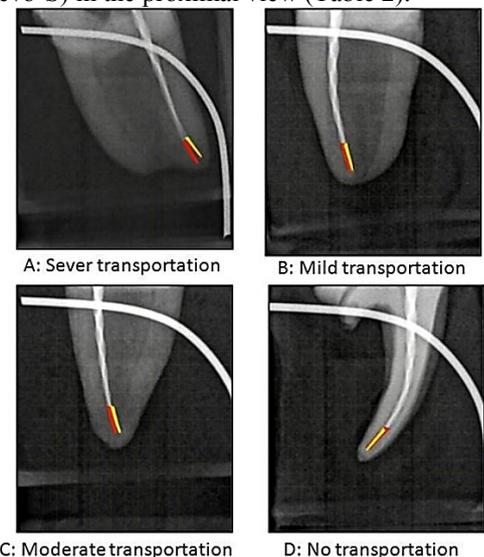


Figure 1: Grading of apical transportation.

Table (1): Grading of apical transportation in buccal view for both groups.

View	Group	Grade	File motion				MCP
			Pecking		Circumferential filing		
			No (n=15)	%	No (n=15)	%	
Buccal	Group I ONESHAPE	No (0)	5	33.30 %	3	20.00%	0.078
		Mild (1)	5	33.30 %	8	53.30%	
		Moderate (2)	5	33.30 %	3	20.00%	
		Severe (3)	0	0.00 %	1	6.70%	
	Group II Revo-S	No (0)	5	33.30 %	4	26.70%	0.826
		Mild (1)	4	26.70 %	5	33.30%	
		Moderate (2)	5	33.30 %	4	26.70%	
		Severe (3)	1	6.70 %	2	13.30%	
MCP			0.774		0.726		

Table (2): Grading of apical transportation in proximal view.

View	Group	Grade	File motion				MCP
			Pecking		Circumferential filing		
			No (n=15)	%	No (n=15)	%	
Proximal	Group I ONESHAPE	No (0)	7	46.7 %	4	26.7%	0.163
		Mild (1)	3	20.0 %	3	20.0%	
		Moderate (2)	5	33.3 %	6	40.0%	
		Severe (3)	0	0.0%	2	13.3%	
	Group II Revo-S	No (0)	5	33.3 %	3	20.0%	0.549
		Mild (1)	5	33.3 %	5	33.3%	
		Moderate (2)	4	26.7 %	7	46.7%	
		Severe (3)	1	6.7%	0	0.0 %	
MCP			0.584		0.437		

1.87±2.01 with no statistical significant difference at P<0.05 (P=0.443). (Table 3)

The results revealed a non-significant difference at P<0.05 between group I and group II at the proximal view by using the Mann Whitney test as shown in (Table 3).

The results revealed that circumferential filing in group I and group II caused more canal straightening than pecking motion

in the buccal and proximal views as shown in figure (Figure 3, 4).

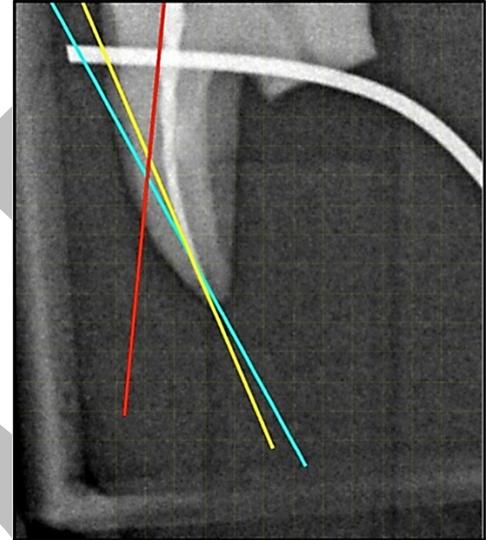


Figure 2: Measuring the degree of apical straightening.

DISCUSSION

A well-established fact stated that natural teeth show large variations in dentin hardness and root canal morphology, but their use seems to mimic the clinical condition and they are more valid when compared to simulated canals in clear resin block. Although resin blocks have the advantage of standardized root canal shape, size, taper, curvature, but their hardness is completely different from that present in normal dentin.

In the current study curved mesiobuccal root canals of mandibular first molars were chosen, as they are often narrow and have accentuated curves that make debridement and shaping more difficult (11,12). To minimize variables, curvature was standardized to 25-45 degree according to Schneider's technique (8).

Nevertheless, great care was taken to standardize the preparation and evaluation procedures. Aiming to standardize the size of canals before preparation, only canals that could be traversed by size 10 or 15 K-file but resisted passage of size 20 were selected. Also, attention was paid to standardize the tip size and file taper at 25 and 6% respectively, the Revo-S system was attained by SU file which matches the OneShape file regarding the tip size and taper. Standardization of the finishing file was important to standardize the final apical preparation size to ensure comparability between the groups (13).

It is also noteworthy that coronal pre-flaring with Endoflare file was done to overcome narrow mesiobuccal canal and to provide a straight-line radicular access. Moreover, coronal pre-flaring allowed more efficient cleaning and shaping, reduced instrumentation time and facilitated more thorough irrigation (14). Furthermore, crowns were maintained to simulate clinical conditions in

- a) Measuring the degree of apical straightening (figure 2) Buccal view: (Table 3)
In Group I (ONESHAPE), sub group I b (circumferential filing) showed higher mean percentage of canal straightening 1.84±1.93 than sub group I am (pecking) 1.82±1.71 with no statistical significant difference at P<0.05 (P=0.836) (Table 3). While in Group II, (Revo-S) sub group II b (circumferential filing) showed the highest mean percentage of canal straightening 2.13±2.05, while sub group II a (pecking) showed a lower mean percentage 1.91±1.99 with no statistical significant difference at P<0.05 (P=0.756).

By using the Mann Whitney test, the results revealed a non-significant difference at P <0.05 between group I and group II at the buccal view as shown in (Table 3).

Proximal view

In Group I (ONESHAPE), sub group I b (circumferential filing) showed higher mean percentage 2.62±2.25 of canal straightening than sub group I am (pecking) 1.42±1.32 with no statistical significant difference at P<0.05 (P=0.191) (Table 3). In Group II (Revo-s), sub group II b (circumferential filing) showed higher mean percentage of canal straightening 2.05±1.52 than sub group II a (pecking)

which the interference of cervical dentin projections would create tensions on the files during canal instrumentation ⁽¹⁵⁾.

In order to simulate the clinical situation, the working length was not standardized, although similar studies performed standardization of the working length by decoronation ⁽¹⁶⁻¹⁸⁾. To assure that variation in the working length did not affect the results, the mean working length of the two groups were compared and no statistical differences were found.

Table (3): Comparison of canal straightening between the test groups in buccal and proximal views (mean degree of apical canal straightening and SD).

View	File motion	Group						up
		Group I			Group II			
		Degree of canal straightening						
		Minimum	Maximum	Mean (SD)	Minimum	Maximum	Mean (SD)	
Buccal	Pecking	0.10	5.12	1.82 (1.71)	0.02	6.27	1.91 (1.99)	0.917
	Circumferential filing	0.15	7.45	1.84 (1.93)	0.02	6.32	2.13 (2.05)	0.857
up		0.836			0.756			
View	Tool	Group						up
		Group I			Group II			
		Difference						
		Minimum	Maximum	Mean (SD)	Minimum	Maximum	Mean (SD)	
Proximal	Pecking	0.045	3.606	1.42 (1.32)	0.090	7.682	1.87 (2.01)	0.633
	Circumferential filing	0.020	8.000	2.62 (2.25)	0.219	4.812	2.05 (1.52)	0.604
		0.191			0.443			

It is also noteworthy that coronal pre-flaring with Endoflare file was done to overcome narrow mesiobuccal canal and to provide a straight-line radicular access. Moreover, coronal pre-flaring allowed more efficient cleaning and shaping, reduced instrumentation time and facilitated more thorough irrigation ⁽¹⁴⁾. Furthermore, crowns were maintained to simulate clinical conditions in which the interference of cervical dentin projections would create tensions on the files during canal instrumentation ⁽¹⁵⁾.

In order to simulate the clinical situation, the working length was not standardized, although similar studies performed standardization of the working length by decoronation ⁽¹⁶⁻¹⁸⁾. To assure that variation in the working length did not affect the results, the mean working length of the two groups were compared and no statistical differences were found.

Two rotary nickel-titanium systems were used in the present study: Revo-S system and OneShape file. The Revo-S system consists of three files. The asymmetrical cross-section of the Revo-S files provides a snake like movement to facilitate progression of the instrument toward the apical region of the canal and an upward removal of the generated dentin debris, preventing the obstruction of the grooves within the file for better debridement efficiency and preventing extrusion of debris beyond the instrument tip and apical foramen ⁽⁵⁾. While the OneShape system consists of only a single sterile instrument, which has a tip size of 25 and constant taper of 0.06, and is characterized by different cross-sectional designs over the entire length of its working part. Moreover, OneShape file has a variable pitch length along its working part, this design eliminates threading and binding of the instrument ^(7,13).

Although, the manufacturer recommends using the Revo-S system for the preparation of ten root canals, in the current

study it was used to prepare four canals to provide the same cutting efficiency as that of the OneShape file, which could be used to prepare a molar tooth with four root canals without the risk of file fracture ⁽¹³⁾.

It was noticed that the gradual canal preparation using multiple files in the Revo-S system provided a much easier progression of the files apically without constrain when compared with the single OneShape file system. On the other hand, OneShape files showed resistance to reach the apical third smoothly.

This study was conducted to evaluate the effect of two file systems with pecking or circumferential filing motions after reaching the apex on apical transportation and apical canal straightening. In the current study, the double radiographic superimposition method was used, for grading of apical transportation and measuring the degree of apical straightening.

To allow accurate reproducible pre and post instrumentation radiographs, the radiographic platform was specially fabricated. Exact superimposition was guided by the projected image of the L shaped wire that was glued facing the sensor ⁽¹⁹⁾.

It is important to note that transportation occurred toward the outer part of the curve with group I (OneShape) and group II (Revo-S). This was in accordance with several studies who stated that the direction of canal transportation at the end point of preparation was frequently toward the outer aspects of the curve ^(20,21).

Regarding canal transportation, the findings of this study showed no significant difference between both filing systems; this could be attributed to the same tip size and taper of the SU file of Revo-S system and OneShape file. This is in accordance with Hashem et al ⁽¹⁶⁾ who found that there was no significant difference in canal transportation and centering ratio in the apical one to three mm between Revo-S, Twisted files, ProFile GT series and ProTaper. They also stated that these results might be because the four systems have a non-cutting tip design that allows easy penetration with minimal apical pressure. On the other hand, some studies found statistical significant difference in shaping abilities when using different nickel-titanium instruments in simulated canals, except for the last two mm ^(22,23). Moreover, the fact that no significant difference was found in canal transportation might be attributed to the pre-flaring of the canals ⁽²⁴⁾.

In the current study, no significant difference was found in canal transportation, yet circumferential filing resulted in more cases with severe transportation than pecking motion. These results were in accordance with other studies who reported that the use of pecking motion and circumferential filing motion resulted in small magnitude of transportation with no significant difference ^(18,25). It is important to note that increasing the number of brushing strokes resulted in more dentinal cutting in the direction of those strokes with no significant difference found between the groups at the apical level ⁽²⁶⁾.

On the contrary, Jeon et al ⁽²⁷⁾ reported that repetitive pecking motions at the working length might result in canal transportation because of the tendency of the file to restore its original linear shape and the reaction torque of the root canal wall especially in curved canals.

Regarding the canal straightening, there was no significant difference between OneShape and Revo-S files, when used with pecking or circumferential filing motions.

However, circumferential filing motion after reaching the full working length resulted in higher mean straightening values than pecking motions in both groups. These results were in accordance with several studies who reported that all instruments maintained the original canal curvature well with no significant differences between the instrument systems. Also the mean straightening values produced by the use of OneShape file with a slight pecking motion were close to those reported in the present study^(13,28).

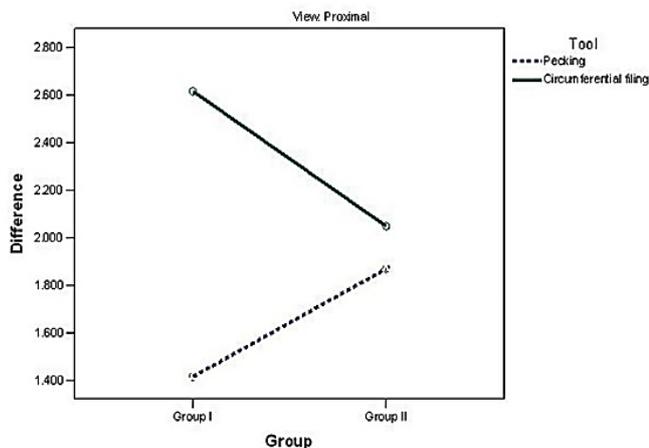


Figure 3: Comparison between group I and II in buccal view in canal straightening.

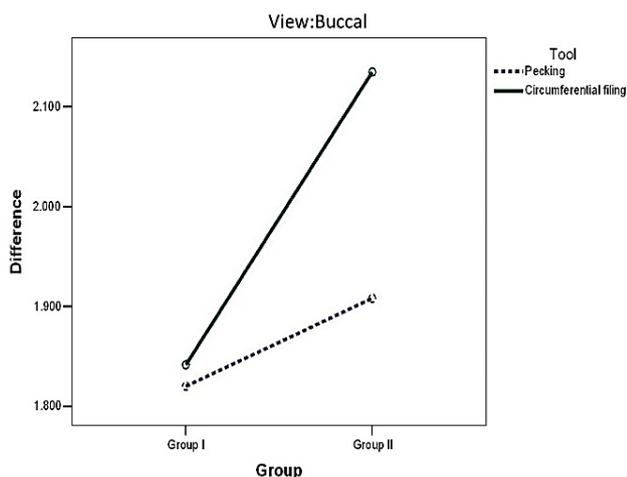


Figure 4: Comparison between group I and II in proximal view in canal straightening.

On the contrary, Burklein et al⁽²⁹⁾ reported that Revo-S system produced more pronounced canal straightening when compared with Mtwo and Hyflex CM. In addition, Saber et al⁽³⁰⁾ stated that the use of OneShape instruments with pecking motion resulted in significantly greater canal straightening and apical transportation than WaveOne and Reciproc systems.

It was noticed that as the degree of pre-operative canal curvature increases, as the degree of canal transportation and apical canal straightening increases. Moreover, the more severe the angle and the smaller the radius of the curvature, the more severe the canal transportation^(31,32).

CONCLUSIONS

The hypothesis of this study was found to be true as circumferential filing motion with both systems resulted in higher values of canal straightening when compared to pecking motion but this was not statistically significant.

Pecking motion after reaching the apical limit could be considered safe to finalize the apical preparation.

OneShape file and Revo-S system maintained the original canal curvature well with no significant differences between the different files.

Gradual canal preparation using multiple files in the Revo-S system provided a much easier progression of the files apically without constraint.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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