EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 3779:3788, October, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 02-06-2024 • Accept Date : 10-07-2024 • Available online: 05-10-2024 • DOI : 10.21608/EDJ.2024.293493.3063

EFFECT OF SPRING MACHINING OF ROTARY NICKEL-TITANIUM PREPARATION SYSTEMS ON CANAL TRANSPORTATION IN CURVED ROOT CANALS USING CONE BEAM COMPUTED TOMOGRAPHY

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ABSTRACT

purpose: to evaluate canal transportation of three different rotary nickel titanium (Ni-Ti) preparation systems including Spring Endo, Spring H and ProTaper Next files using cone beam computed tomography (CBCT). ***Materials and Methods:*** 30 extracted humans mandibular first molars with the same range of mesiobuccal canal curvature (20-40°) were used. Selected teeth were randomly divided into three groups (n=10) according to the type of files used for preparation. Group 1: Spring Endo, Group 2: Spring H and Group 3: ProTaper Next. Pre-and post-instrumentation CBCT images were recorded at several root canal levels (3,5, 8 mm) from the apex following the same imaging technique then canal transportation was calculated in mesio-distal and bucco-lingual directions. ***Results***: concerning root canal transportation in both directions, Group1 (Spring Endo system) showed the highest mean canal transportation value while the lowest value was recorded for Group 2 (Spring H system). One-Way ANOVA showed a statistical significant difference between the three tested groups at the three tested levels. Statistical significant differences between groups 1 and 2 at all canal levels in both directions was detected using Tukey's pair-wise comparison test, while statistical significant differences between group 1 and 3 were found at all canal levels in mesio-distal direction and only at 5 mm in bucco-lingual direction. Comparing canal transportation at the selected three root canal levels regardless of the used preparation systems showed that the smallest canal transportation mean value was recorded at 8mm level and the highest root canal transportation mean value at 3mm level. ***Conclusion***: root canal transportation reduction depends on the type of used file system alloy and its heat treatment rather than its spring machining.

KEYWORDS: Canal transportation, Cone beam computed tomography, Spring Endo files, Spring H files, ProTaper Next

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INTRODUCTION

Creating a consistent conical shape that tapers from the apical to the coronal direction while preserving the original canal shape is the goal of root canal preparation. Both the instrument's design and the root canal anatomy have an impact on the instrument's ability to maintain the root canal's original route during shaping procedures. [1]

Advanced nickel titanium (Ni-Ti) instruments design with variable modifications in its alloy, flexibility, taper or method of fabrication provide significant improvement of the quality of root canal preparation with less iatrogenic mishaps, even in severely curved canals. [2]

ProTaper Next rotary files are made from M-wire. These instruments are fifth generation instruments which are characterized by an innovative off-centred rectangular cross section that provides these files a snake-like swaggering movement. The pitch length increases from the tip to the shaft which aids to decrease the screwing effect of the instrument within the root canal minimizing root canal transportation. [3]

ProTaper Next instruments are available in multiple sizes and tapers X1(17/0.04); X2 (25/ 0.06); X3 (30, 0.07); X4 (40/0.06); and X5 (50/ 0.06). However, it has to be taken into consideration that the given taper is not constant, but all files have a variable taper along their working shaft. [3]

Spring Endo file is another novel file which is rotary Ni-Ti instrument with an elastic spring on its shaft via laser cutting.[4] The elastic spring on its shaft can make its insertion within the root canals, especially of posterior teeth, easier with less risk of fracture compared to conventional Ni-Ti instruments. It was also suggested that the spring structure buffers the overload applied to the instrument, resulting in an improved resistance to cyclic fatigue, torsional resistance and increased flexibility. Additionally, it improves cutting ability by generating micro-vibration which reduces the screw-in phenomenon into the canal through the blade area. [4]

Spring Endo and Spring H files have identical designs; however, unlike Spring Endo, Spring H is manufactured from a heat-treated controlled-memory wire. It is assumed that the heat treatment of Ni-Ti alloy in addition to the spring design improves the flexibility of these instruments during root canal preparation compared to original Spring Endo files. [5]

Spring Endo and Spring H files are available in 10/0.02, 15/0.04, 20/0.04, 25/0.06 and 30/0.06. Similar to ProTaper Next, the files have a variable taper along their working shaft, and the provided taper is not constant. [5]

Despite the various adjustments made to the rotary file systems that are currently on the market, whether through innovative designs or heat treatments of their alloy, no one system has the ability to retain the original canal path without iatrogenic transportation. [1]

Several techniques, including serial sectioning, comparison of superimposed pre- and post-instrumentation digitalized radiographs or pictures, micro-computed tomography (μ-CT), and CBCT, have been employed to assess the canal transportation following root canal preparation. [6] CBCT imaging is a non-invasive technique for analysis of root canal geometry and evaluation of the ability of different shaping instruments and techniques in preservation of original root canal geometry by comparative evaluation of pre- and post-instrumentation images.[7]

Until now, few studies have evaluated the different properties of the introduced spring Ni-Ti rotary systems and its effect on canal transportation. Thus, this study's goal was to assess, using CBCT, how spring machining of rotary Ni-Ti preparation systems affected canal transportation in curved root canals. In contrast to ProTaper Next, it was hypothesised that spring machined files (Spring Endo and Spring H) result in less canal transportation.

MATERIALS AND METHODS

For this clinical trial, a minimum sample size of 27 teeth was required. The sample size was determined in accordance with an earlier investigation carried out by Elkhodary et al., [8] For this investigation, the power sample size was greater than 80%, the significance threshold was 0.05, the confidence interval was 95%, and the actual power was 96.7%. G Power version 3 was the computer program used to determine the sample size.

The formula of sample size

Sample size = Z2 P (1-P)/ C2

Where:

Z = Z value (1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal

c = confidence interval, expressed as decimal.

The sample size was increased to 30 in order to increase the validity of the results.

Tanta University, Faculty of Dentistry's Research Ethics Committee granted approval for this study. In accordance with the standards on human research issued by the Research Ethics Committee at Tanta University's Faculty of Dentistry, patients were told about the aim and details of the current investigation and their informed consent was acquired to use their extracted teeth in the study.

Human adult permanent mandibular first molars that had been recently extracted were gathered for this study. If there was any calculus or remnant soft tissue still attached to the extracted teeth, it was removed using sharp hand scalers. Then they were washed with distilled water and immersed in sterilized normal saline solution at temperature of 4°C until they were needed. The selected teeth were used within two to three months following extraction. [9]

The inclusion criteria of this study included mandibular first molars which were extracted due to any reasons unrelated to this study as periodontitis for example. They have two distinct mesial canals and fully developed roots with closed apices. All selected mandibular first molars had similar range of mesio-buccal canal curvature (20°-40°) as each tooth was digitally radiographed using digital intraoral sensor *then Schneider's approach was used to measure the mesial canal's degree of curvature. [10]

Based on the instrumentation equipment used for root canal preparation, ten randomly selected teeth were assigned to one of three treatment groups: Group 1: The Spring Endo rotary system**, was used to prepare the root canals. Group 2: Spring H rotary system[2] and Group 3: ProTaper Next rotary system***.

An independent trained investigator not involved in the study handled the randomization and concealment process. Random sequence generation was achieved using a computer random allocation program and concealed from the operator using the sequentially numbered opaque sealed envelope (SNOSE) technique. Then a closed envelope containing the instructions to use either Spring Endo[2], Spring H[2] or ProTaper Next[3] rotary preparation systems was selected.

Each group's teeth samples were arranged in a custom-made silicone putty impression material**** to the level of the cementoenamel junction in an impression tray (two or three teeth per tray) can

* Dr.Suni plus Digital Intraoral Sensor, Suni Medical Imaging, Inc.,Sanjose, USA

** DenFlex, Seoul, Korea

*** Dentsply/Maillefer, Ballaigues, Switzerland

**** Silaxil,Lascod, Sesto, Italy

serve as a specimen holder in order to streamline the imaging procedure and preserve the CBCT pictures' repeatability (Fig I). Using a Cranex 3D device* with an 8.6 field of view and a 4.9 second exposure period, running at 90kV and 10mA, pre-operative CBCT pictures were produced. In order to examine the root canal morphology at the 3 mm, 5 mm, and 8 mm level from the root apex, axial pictures with a 0.5 mm layer thickness were obtained. Magnetic optical discs containing the pre-instrumentation photos were used to save them for subsequent comparison with the matching post-instrumentation photographs.

Access cavity for each tooth in each group was prepared using a rose head diamond bur. The Next step was determination of the mesio buccal canals' working length by inserting a stainless steel K-hand file[3] #10 into the estimated working length found on the previously taken CBCT, which was subsequently verified by a second digital radiograph. A stainless steel K-hand file #15 was used to create a glide path.

Fig. (I) Teeth placed within custom-made silicone putty impression material

Group 1: To prepare root canals, the Spring Endo rotary file system was used in the following sequence 10/0.02, 15/0.04, 20/0.04 till master apical file (25/0.06) using a 20:1 gear reduction hand piece driven by a torque-limited endodontic motor**. Crown-down manner was used throughout the sequential preparation at 200 rpm and torque 0.8 NCM in accordance with the manufacturer's specifications.

Glyde™ [3] lubricant was applied to each file, then each file was inserted slowly and without any pressure. Following each canal preparation, each file was examined, and once any defects were detected within the file, it was discarded immediately. However, the maximum number of root canals to be prepared with the same file is three canals and then the file was discarded even with absence of any deformity within it. Before and after applying each instrument, 3 ml of immediately prepared 2.5% sodium hypochlorite*** (NaOCl) solution was used to irrigate each root canal using a plastic disposable syringe with a 30-gauge closed-end needle. Finally, after completion of the preparation, the canals were flushed with 3 ml of normal saline solution as a final irrigation. All groups followed the same irrigation technique.

Group 2: Root canals were prepared with the Spring H rotary system till master apical file (25/0.06) following the same irrigation protocol and using the same motor and hand piece devices as in group 1.

Group 3: ProTaper Next files were used up to master apical file X2 (25 / 0.06), at 300 rpm rotational speed and 2 NCM torque values. Using the same hand piece and endodontic motor as in group 1. Each file was utilized in a circumferential brushing motion inside the root canal.

The pre-operative and post-operative CBCT pictures were acquired using identical parameters. Using Adobe Photoshop software****, pre-operative and post-operative axial portions of CBCT images

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**** Adobe Systems, Mountain View, CA, USA for the three selected root canal levels of the three groups were superimposed, then the superimposed images were transferred to Auto-CAD software* to calculate canal transportation.

Canal transportation in mesio-distal direction was calculated using the formula below:

Canal transportation= $[(a_1 - a_2) - (b_1 - b_2)]$

Where (a_1): the shortest path between the uninstrumented canal's mesial edge and the root's mesial edge. (a_2): the shortest path between the instrumented canal's mesial edge and the root's mesial edge. (b_1): the shortest path between the uninstrumented canal's distal edge and the root's distal edge. (b_2): the shortest path between the instrumented canal's distal edge and the root's distal edge (Fig. 2).

While canal transportation in bucco- lingual direction was calculated according to the following formula =

Canal transportation= $[(X_1 - X_2) - (Y_1 - Y_2)]$

Where (X_1): the shortest path between the buccal edge of the root and the buccal edge of the uninstrumented canal. (X_2): the shortest path between the buccal edge of the root and the buccal edge of the instrumented canal. (Y_1): the shortest path between the lingual edge of the root and the lingual edge of the uninstrumented canal. (Y_2): the shortest path between the lingual edge of the root and the lingual edge of the instrumented canal (Fig 5).

The previous formula stated that when the obtained result was zero, it meant that no canal transportation had been detected; However, any other registered values rather positive or negative indicated that canal transportation had occurred within the root canal.

For each tested group and selected root canal

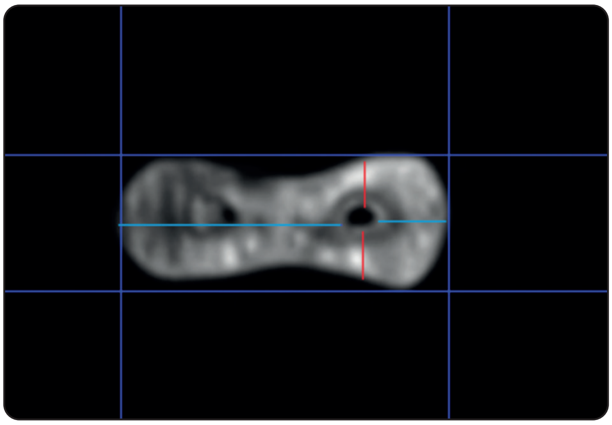

Fig. (2) Pre-instrumentation and post-instrumentation CBCT images of MB root canal at 5mm level with coincidence between them.

level, the data of canal transportation values in the bucco-lingual and mesio-distal directions were tabulated, and their means and standard deviations (SD) were calculated. To ascertain whether there were statistically significant differences between the groups, One-Way Analysis of Variance (One-Way ANOVA) was used with SPSS** software version 21. Tukey's test was applied to make pairwise comparisons between each of the two tested groups or selected root canal levels at a 95% confidence level if a statistically significant difference was recorded in the calculated data.

RESULTS

Table 1 presented the comparison of the tested groups for root canal transportation in the mesio-distal direction at each root canal level. Similar outcomes were seen at the three tested levels (3, 5, and 8 mm), with Group 1 (Spring Endo system) exhibiting the highest mean canal transportation value and Group 2 (Spring H system) displaying the lowest value. A statistically significant difference was recorded between the tested groups at the selected three levels ($P \leq .001$, 0.003, and 0.002) according to a one-way ANOVA. There were statistically significant differences between groups

* Autodesk Inc., SanRafael, CA, USA

** SPSS Inc. Chicago, USA

1 and 2 as well as between groups 1 and 3, according to Tukey's pairwise comparison test.

Concerning Spring Endo (group 1), The apical level (3 mm) had the highest mean transportation value, while the coronal level (8 mm) had the lowest value among the three selected levels with a statistically significant difference between them (P≤0.001). Tukey's test detected statistically significant differences between level 3 and both 5 mm and 8 mm levels.

When Spring H and ProTaper Next groups were considered, 8mm level showed the lowest mean value of transportation without any statistical significant differences among tested root levels in both groups.

The comparison of mean values of canal transportation in the bucco-lingual direction for the three selected root canal levels across the tested groups are presented in Table 2. Similar findings were seen at the three tested levels where Group 2 (Spring H system) exhibiting the lowest mean canal transportation value and Group 1 (Spring Endo

TABLE (1) Recorded values of canal transportation of the three tested groups (Spring Endo, Spring H and proTaper Next) at the three tested root canal levels (3, 5 and 8 mm) in mesio-distal direction and their statistical analysis

M-D		Groups			ANOVA		TUKEY'S Test		
		Group 1	**Group 2**	**Group 3**	**F**	**P-value**	**1&2**	**1&3**	**2&3**
3 mm	**Range**	0.03 - 0.05	0 - 0.02	0.01 - 0.02	29.832	<0.001*	<0.001*	<0.001*	0.516
	Mean ±SD	0.040 ± 0.006	0.013 ± 0.008	0.018 ± 0.004					
5 mm	**Range**	0.02 - 0.035	0.01 - 0.022	0.013 - 0.023	8.847	0.003*	0.006*	0.007*	0.998
	Mean ±SD	0.028 ± 0.006	0.017 ± 0.005	0.018 ± 0.004					
8 mm	**Range**	0.015 - 0.03	0.01 - 0.013	0.011 - 0.02	10.286	0.002*	0.001*	0.025*	0.314
	Mean ±SD	0.023 ± 0.005	0.012 ± 0.001	0.016 ± 0.004					
ANOVA	**F**	13.720	1.420	0.360					
	P-value	<0.001*	0.272	0.704					
TUKEY'S Test	**3&5**	0.010*							
	3&8	<0.001*							
	5&8	0.232							

TABLE (2) Recorded values of canal transportation of the three tested groups (Spring Endo, Spring H and proTaper Next) at the three tested root levels (3, 5 and 8 mm) in bucco-lingual direction and their statistical analysis

B-L		Groups			ANOVA		TUKEY'S Test		
		Group 1	**Group 2**	**Group 3**	**F**	**P-value**	**1&2**	**1&3**	**2&3**
3 mm	**Range**	0.02 - 0.03	0.01 - 0.02	0.01 - 0.02	5.708	0.014*	0.014*	0.066	0.712
	Mean ±SD	0.025 ± 0.005	0.016 ± 0.004	0.018 ± 0.004					
5 mm	**Range**	0.01 - 0.02	0.01 - 0.012	0.01 - 0.012	4.170	0.036*	0.050*	0.050*	1.000
	Mean ±SD	0.015 ± 0.005	0.010 ± 0.001	0.010 ± 0.001					
8 mm	**Range**	0.01 - 0.02	0 - 0.01	0 - 0.01	7.368	0.006*	0.005*	0.059	0.440
	Mean ±SD	0.012 ± 0.004	0.002 ± 0.004	0.005 ± 0.005					
ANOVA	**F**	11.304	25.551	17.127					
	P-value	0.001*	<0.001*	<0.001*					
TUKEY'S Test	**3&5**	0.010*	0.030*	0.009*					
	3&8	0.001*	<0.001*	<0.001*					
	5&8	0.504	0.002*	0.083					

system) recording the greatest value. At each of the three levels, statistically significant differences were found between the tested groups according to One-Way ANOVA (P ≤ 0.014, 0.036, and 0.006). A statistically significant difference was found between groups 1 and 2 at every tested level, in addition, at the 5mm level there were a statistically significant difference between groups 1 and 3, according to Tukey's pairwise comparison test.

Concerning tested groups, for all tested group (Spring Endo, Spring H and ProTaper Next groups), the level of 3mm showed the largest recorded mean value of canal transportation while the 8 mm level showed the least recorded value. There was a statistical significant difference among the three selected root sections (3,5 and 8mm) where P= 0.001, <0.001, <0.001 respectively. Tukey's pair-wise comparison test revealed a statistical significant difference between 3 vs 5mm and 3 vs 8mm in all groups. In addition, there was a statistical significant difference between the levels 5 vs 8mm in group 2 (Spring H system) only.

Without regard to the three tested levels, Spring Endo group registered the highest canal transportation value while Spring H group recorded the lowest canal transportation value. Statistically significant differences among the three groups in mesio-distal and bucco-lingual directions were recorded (P≤0.001 and 0.005 respectively) (Fig.3,4). When Tukey's pair-wise comparison test was performed, it revealed a statistical significant difference only between group1 and group 2 (P≤0.001, 0.005) and between group 1 and 3 (P≤0.001, 0.037) in both mesio-distal and bucco-lingual directions respectively.

Furthermore, a comparison of the selected levels across all groups showed that the highest value was recorded at 3mm and the least amount of canal transportation mean values were recorded at 8mm level with a statistically significant difference in the bucco-lingual direction (p≤0.001), and without any statistical significant differences in mesio-distal direction (P=0.100) (Fig. V, VI). Tukey's pair-wise comparison test revealed a statistical significant difference in bucco-lingual direction among 3 and 5, 3 and 8, 5 and 8 levels (<0.001, <0.001, 0.006).

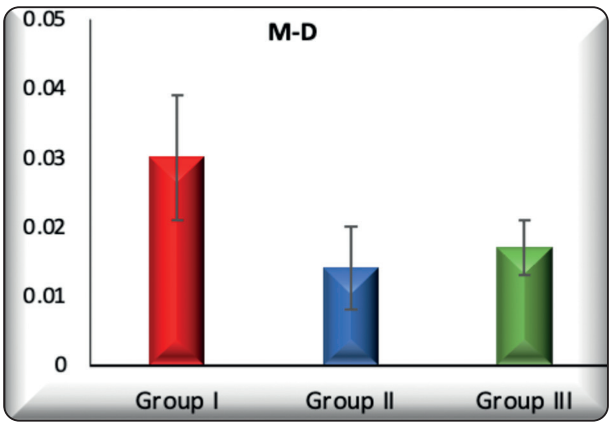

Fig. (3) Bar chart representing canal transportation of the three tested groups without regard to tested root canal levels in mesio-distal direction

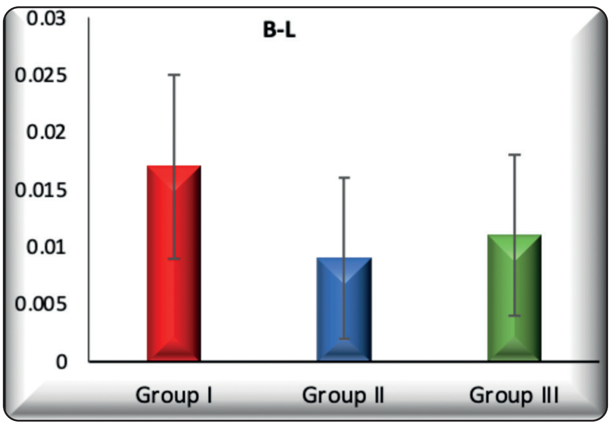

Fig. (4) Bar chart representing canal transportation of the three tested groups without regard to tested root canal levels in bucco-lingual direction

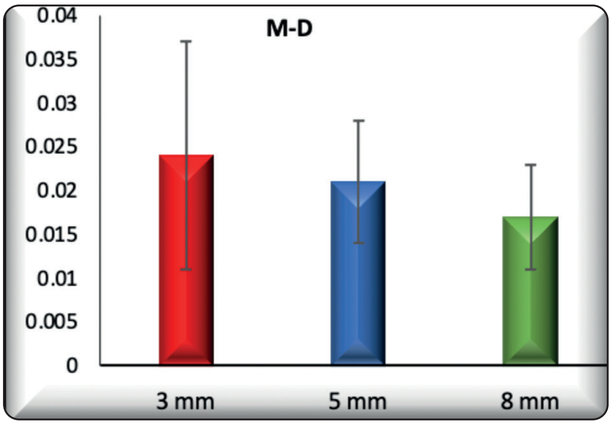

Fig. (5) Bar chart representing canal transportation at the three tested root canal levels without regard to the tested groups in mesio-distal direction

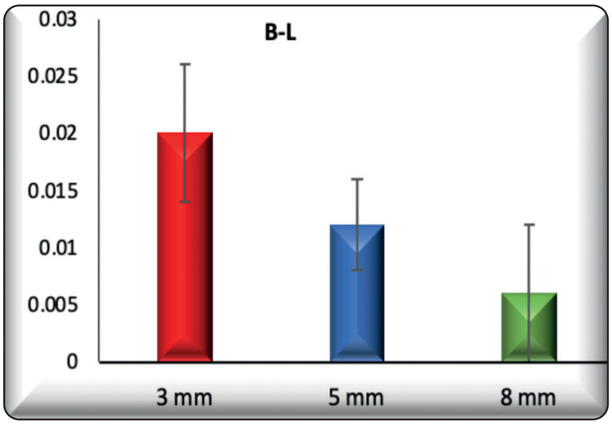

Fig. (6) Bar chart representing canal transportation at the three tested root canal levels without regard to the tested groups in bucco-lingual direction

DISCUSSION

None of the rotary devices that are currently on the market can completely prepare curved root canals biomechanically without iatrogenic alteration of the normal canal path.[11] Thus, continuous efforts are implemented to create new file systems which can conquer the shortcomings of the earlier applied systems. Consequently, this study was conducted to assess the canal transportation of three distinct rotary Ni-Ti preparation systems: Spring Endo files, Spring H files and ProTaper Next files which have different design features using CBCT.

In this clinical trial, in order to mimic clinical situations as possible, human teeth were utilized rather than resin blocks to assess iatrogenic transportation of root canals with moderate curvature.[12]

In order to achieve a consistent apical preparation diameter and uniform dentin removal in the apical region for every sample, teeth with comparable apical diameters (#15) were chosen and instrumented in a crown-down manner till master apical file #25/0.06.[13]

CBCT imaging is considered as a non-invasive technique with low radiation exposure compared to other medical CT scans that's why it was chosen as a method for evaluation of canal transportation in this study. In addition, it provided three-dimensional images which are more accurate with more diagnostic information compared to conventional radiographic methods.[14]

Using CBCT, comparative measurements were applied before and after instrumentation at the three selected levels (3, 5, and 8 mm) from the apex. These levels stand for the most apical section of the root canal, the curve's apex, and the starting point of the curve, which are representatives for the regions that are most vulnerable to iatrogenic accidents.[15]

Spring H files preserve the original canal path and reduce iatrogenic transportation in the curved root canals significantly better than Spring Endo. However, there was no significant difference in its performance with ProTaper Next files. This may be attributed to the modification of Ni-Ti alloy via heat treatment. The controlled memory (CM) wire exhibited a high austenitic transformation finishing temperature (Af), which in turn enhanced the cyclic fatigue resistance and provided higher flexibility compared to conventional Ni-Ti rotary instruments.[4,5]

In addition, ProTaper Next showed less canal transportation compared to Spring Endo files which can be also explained by the heat treatment of Ni-Ti alloy (M-wire technology) in addition to its significant design features which include progressive tapers on a single file and the off-set design which decreases the dangerous taper lock and file screwing effect by reducing the contact area between the file and the root canal surface. [16]

Zafar et al.,[17] concurred with the findings of this study as they compared the various heat treatments applied to conventional Ni-Ti alloy and stated that CM wires demonstrated higher flexibility and less iatrogenic errors as canal transportation compared to M-wire.

Furthermore, Almnea et al.,[18] sustained the obtained results because they claimed that the ProTaper Next produced less canal transportation when they compared this system to the original ProTaper system and attributed this to the M-wire modification of ProTaper Next compared to the conventional Ni-Ti alloy of the original ProTaper.

However, Deepak et.al., [3] analysed three different fifth generation rotary files including ProTaper Next and found that it produced more canal transportation than One Shape files and Revo S files and this could be explained by the added features to these systems over ProTaper Next either single file preparation technique or effective debris removal in upward direction leading to reduction of debris collection within the canal in addition to its inactive non- cutting tip which in turn allow easier guidance for the file throughout its movement within the canal providing more respect to canal anatomy.

Another study didn't support the achieved results as they compared root canal transportation in root canals with similar curvature range instrumented with Twisted file (TF), OneShape and ProTaper Next Ni-Ti systems, and found that TF and OneShape systems produced less canal transportation compared to ProTaper Next system which may be attributed to the different metallurgy of TF file (R-phase) which improved its flexibility and the single file preparation technique applied with OneShape system. [19]

On the other hand, the high canal transportation associated with Spring Endo files may refer to its fabrication from conventional Ni-Ti alloy without any heat treatment. Conventional Ni-Ti alloy is known by its tendency for straightening within the root canal compared to heat treated Ni-Ti alloy resulting in more canal transportation. [4,5]

The analysis of possibility of root canal transportation at the selected root canal sections, irrespective of the preparation systems employed, indicated that the 8mm level had the least value of canal transportation and the 3mm level had the highest value of transportation. This variation may be attributed to the different anatomical location of the both levels due to the fact that the 8mm level is located more coronally within the root canal, which is thought to be a nearly straight portion with less anatomical variety including presence of lateral canals, apparent curvature or even lateral apical foramen compared to apical portion of the root canal. In addition, the 8 mm level of the root canal would be less affected by lateral forces transferred from files used for canal instrumentation, in contrast to the most apical region of the root canal. [20]

CONCLUSIONS

Root canal transportation reduction depends on the type of used file system alloy and its heat treatment rather than its spring machining.

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