EGYPTIAN
DENTAL JOURNAL

Vol. 64, 3865:3872, October, 2018

I.S.S.N 0070-9484

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 170/1810

EFFECT OF DIFFERENT KINEMATICS OF ROTARY NITI INSTRUMENTS ON CANAL TRANSPORTATION IN CURVED ROOT CANALS

Amira Galal Ismail* *and* Manar Galal *

ABSTRACT

Objective: This study was aimed to assess and compare between the transportation of Protaper Next, WaveOne Gold and Twisted File Adaptive NiTi rotary systems on extracted curved molars.

Methodology: A total of ninety mesial root canals of human first and second molars were randomly divided into three experimental groups; ***Group I:*** Protaper Next/Continuous rotation (PTN/CR), ***Group II:*** WaveOne gold/Reciprocation (WG/R) and ***Group III***: Twisted file Adaptive/adaptive motion (TFA). Pre- and postoperative CBCT images were taken and fusion technique was applied to all specimens to ensure standardization. One-way ANOVA was used to compare between more than two groups in parametric data. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

Results: There was no statistically significant difference between all groups at the apical third. At the middle and coronal third group 3 revealed the highest transportation followed by groups 1 and 2, which showed a statistically significant difference between them.

INTRODUCTION

The goal of quality of endodontic therapy has remained the same since its inception. Root canal success is dependent upon cleaning and disinfection of a uniform and continuously tapered shaped canal maintaining an integral anatomical apex integrity for three dimensional filling. (1)

In spite of the fact that root canal preparations usually do experience deviations, but yet, enhanced endodontic outcome is always the result of maintaining the original canal anatomy.

Retaining shape and direction of root canal space during mechanical preparation is very challenging in curved canals (2). Improper instrumentation neglecting degree and direction of curvatures will result in canal straightening and dentin loss which may weaken the tooth structure (3)

In an ongoing quest to reduce complex problems of preparing curved narrow canals, endodontic breakthrough has progressed from exhausting a long series of stainless steel manual files to rotary nickel titanium files. Over the years, NiTi alloys

* Researcher of Endodontics, National Research Centre, Egypt

have invaded the endodontic field and became mandatory in endodontic treatment. Technological advancements in metallurgy allowed manufactures to produce instruments with improved mechanical and physical properties. [4,5]

Additionally, the advent of endodontic motors with adjustable kinematics in several directions attempted to tackle different anatomical complexities in the root canal system. [6]

In terms of continuous rotation, Protaper Next (PTN; DentsplySirona, Ballaigues, Switzerland) is made of M-wire heat treated alloy with an asymmetric cross section. It is run by a clockwise (CW) continuous rotation endodontic motor. PTN system consists of X1 (17/.04), X2 (25.06), X3 (30/.07), X4 (40.06) and X5 (50/.06) files. X1 and X2 both have an increasing and decreasing percentage taper over the active portion of the file while X3, X4 and X5 have fixed tapers from D1 to D3 then a decreasing percentage taper over the rest of the file length [7] A PTN file is made from M-wire alloy which is a thermomechanically treated Ni-Ti to produce alloy in a high flexibility form (martensite). M-wire technology has resulted in an increased resistance of the file to cyclic fatigue of up to 400% compared to other files. [8]

A single file working in a reciprocative mode is capable of preparing the root canal whilst maintaining its shape and direction in a shorter time in comparison to the multiple files conventional rotary systems [9]. WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland) has been recently introduced with a novel heat treatment of a special nickel titanium alloy to manufacture the Gold Wire. It is claimed to have an edge over the martensitic nickel titanium alloy of Wave one in terms of higher flexibility and cyclic fatigue resistance. The available sizes of Waveone Gold are: small (20.07), primary (25.07), medium (35.06), and large (45.05). They work in a reciprocating motion, with clockwise and counter clockwise angles set by the manufacturer. Counter-clockwise value is greater than that of the clockwise and allows the instrument to proceed apically, whilst the clockwise angle disengages the file eliminates its binding [10,11]

Twisted file Adaptive (TFA) developed by SybronEndo (Orange, CA, USA), is utilized in a combined motion; continuous rotation and reciprocation. Its main design features are; R phase heat treatment, twisting of the metal and special surface condition. The twisted file design and the adaptive technology are claimed to improve centering ability and flexibility of the file and reduce its risk of fracture.

It is a two set of three-file system designed to treat the different variety of cases encountered in clinically. Files are available as SM1; 20/0.04, SM2: 25/0.06, SM3: 30/0.04 for small canals and ML1: (25/0.08), ML2: (35/0.06), ML3: (50/0.04) for larger canals. [12-14].

Hence it is mandatory to perform a detailed investigation of the shaping effect of instruments with different kinematics to understand how these modifications affect their performance in terms of conserving the original canal curvature.

MATERIALS AND METHODS

Samples Selection

A total of ninety mesial root canals of human first and second molars of completely formed roots were randomly divided into three experimental groups. Pre- and postoperative CBCT images were taken and fusion technique was applied to all specimens to ensure standardization. Canal curvature in mesiodistal direction ranged between (30- 45°) according to Schneider. Crowns were then removed at the level of the cervical line and distal roots amputated. The working length of each canal was determined by subtracting 1 mm short of the length of the patency file flushed with the apex.

Teeth embedding in acrylic resin

Three standardized custom made acrylic resin housing containers were made (10cm x 12cm) to fit 30 roots per block (2cm x2cm) making 5 columns and 6 rows. Transparent acrylic resin was mixed according to manufacturer's instructions and poured into the container and the roots immersed cervically outwards prior to setting. In order to prevent the resin from entering and polymerizing into the apical foramen, the apices of the roots were sealed with wax. Each sample was inserted into the unset acrylic resin so that its long axis was parallel to the long axis of the container with the buccal surface of all samples facing the same direction to ensure standardization of the specimens for the tomography images before and after root canal instrumentation. Each sample was marked to confirm the standard position for the post-operative imaging on the stage of the CBCT machine.

Grouping and instrumentation of samples

The three resin blocks were divided into three groups (n=30), according to the type of instrument used:

Group I: Thirty canals were instrumented using Protaper Next (PN) (X1, X2)

Group II: Thirty canals were instrumented using WaveOne Gold (WOG) (primary)

Group III: Thirty canals were instrumented using Twisted File Adaptive (TFA) (SM1, SM2)

The X-Smart™ Plus micro-motor (Dentsply, Maillefer) was used to drive the files and adjusted according to the manufacturer's instructions, for groups 1 and 2. The program was set at "Protaper Next" mode when PN was used and "WaveOne" mode when WO was used. The TFA instruments were coupled to the Elements Motor (Axis, SybronEndo, Texas, USA) at the TFA setting suggested by the manufacturer.

Each system was used according to the manufacturer's instructions creating a glide path with proglider for group A and B and M4 reciprocating handpiece for Twisted file Adaptive. Each instrument was used to enlarge four canals only. After each instrument, root canal was flushed with 3 ml of 1.3% NaOCl solution [15, 16].

Postoperative Imaging using CBCT

Post-operative images were captured the same way with the same position as preoperative ones. Image acquiring was performed using the Scanora software and reconstruction by On Demand. The CBCT fusion steps started by superimposing the primary (preoperative) and secondary (postoperative) images manually and by automatic registration of the Scanora software. First measurements were recorded on the primary image. Then the measurement on the primary image was left & the primary image itself was cancelled leaving the secondary image. A new measurement was recorded on the secondary image on the same plane direction & cut of the primary image ensuring standardization [17].

Methods of Assessment

Three cross-sectional planes of CBCT images before and after instrumentation at 3, 6, and 9mm from the apical end of the root were analyzed for transportation. Transportation values were determined according to the formula by Gambill et al [18] (M1-M2)- (D1-D2) in which (M1) is the shortest line from the edge of the canal to the periphery of the root before preparation in the mesial wall of the root, while (M2) is the same line but after the preparation. The number (D1) represents the shortest line from the edge of the canal to the periphery of the root before preparation in the distal wall of the root, while the (D2) is the same line after preparation. If the result is equal to 0 (zero), this means lack of transportation.

Statistical Analysis

One-way ANOVA was used to compare between more than two groups in parametric data. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

Transportation results of each group at different sections

A) Apical section (3 mm from the apical end)

There was no statistically significant difference between the three groups where (p=0.900). The highest transportation mean value was found in group 3 (TFA) (0.23 ± 0.19) followed by group 1 (PTN) (0.22 ± 0.19) while the least mean value of transportation was found in group 2 (WOG) (0.20 ± 0.14).

B) Middle section (6mm from the apical end)

There was a statistically significant difference between the three groups where (p=0.027).

No statistically significant difference was found between group 1 (PTN) on one hand and each of group 3 (TFA) and group 2 (WOG) files on the other hand where (p=0.057) and (p=0.995) respectively.

While a statistically significant difference was found between group 3(TFA) and group 2 (WOG) where (p=0.045).

The highest transportation mean value was found in group 3 (TFA) (0.30 ± 0.23) followed by group 1 (PTN) (0.16 ± 0.12) while the least mean value of transportation was found in group 2 (WOG) (0.15 ± 0.10).

C) Coronal section (9mm from the apical end)

There was a statistically significant difference between the three groups where (p=0.032).

No statistically significant difference was found between group 1(PTN) on one hand and each of group 2(WOG) and group 3 (TF Adaptive) files on the other hand where (p=0.795) and (p=0.130) respectively.

While a statistically significant difference was found between group 2 (WOG) and group 3 (TFA) files where (p=0.032).

The highest transportation mean value was found in group 3 (TFA) (0.41 ± 0.24) followed by group 1 (PTN) (0.27 ± 0.18) while the least mean value of transportation was found in group 2 (WOG) (0.22 ± 0.15).

TABLE (1): The mean, standard deviation (SD) values of Transportation of different groups. (One-way ANOVA)

Files	Section 3	Section 6	Section 9
	Mean ± SD	Mean ± SD	Mean ± SD
Potaper next	0.22 ± 0.19 [a]	0.16 ± 0.12 [ab]	0.27 ± 0.18 ab
TF Adaptive	0.23 ± 0.19 [a]	0.30 ± 0.23 [a]	0.41 ± 0.24 [a]
WaveOne Gold	0.20 ± 0.14 [a]	0.15 ± 0.10 [b]	0.22 ± 0.15 b
P-value	**0.900ns**	**0.027***	**0.032***

Mean with different letters in the same column indicate statistically significance difference ****; significant (p<0.05)***
ns; non-significant (p>0.05)

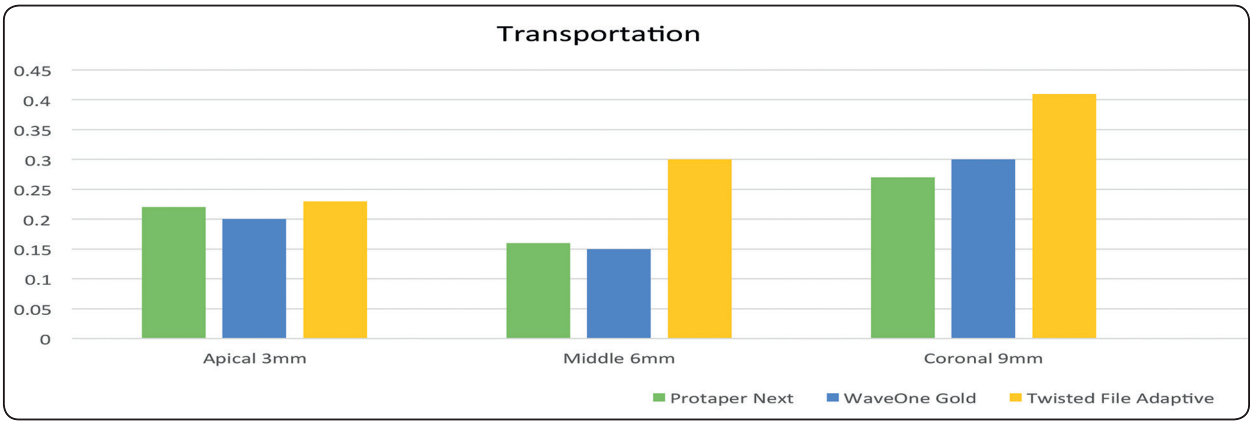

Fig. (1): Bar chart representing means of Transportation of different groups.

DISCUSSION

During root canal preparation, original canal curvature should be preserved with a flared shape apico-coronally irrespective of the instrument type, kinematics or instrumentation technique (19). This is mandatory so that chances of canal transportation and curvature straightening would be less liable to occur. (20)

Different kinematics of Nickel titanium systems have been introduced to try and maintain the original canal shape and direction by keeping the file centered (21).

Hence, the purpose of this study was to compare and evaluate the transportation of three different rotary file systems namely; Protaper Next, WaveOne Gold and Twisted file Adaptive These systems have different kinematics, designs, alloys and manufacturing methods.

The main methods for assessing shaping ability are using either simulated root canals or extracted human teeth. Simulated root canals inspite of having a high degree of standardization, but the resin does not mimic clinical situations due to differences in surface texture, hardening, and cross sectioning of dentine. Therefore using real canals in extracted teeth are required to mimic the clinical condition(22) Standardization parameters regarding canal curvature were set to ensure comparability of the experimental groups. Recently CBCT has been validated as a tool to explore root canal anatomy and assess the canal's shape before and after instrumentation (23, 31).

In the present study, fusion methodology was utilized to assess canal transportation by subtractive radiology. This methodology was proposed in our study to ensure standardizing specimen positioning for acquisition of CBCT images before and after preparation (17,24,). In order to enable comparisons between different instruments same apical enlargement was achieved with all tested instruments.

In the present study, apical preparation terminated at size 25. The final apical preparation diameter in the Protaper Next group was X2 size 25/0.06, WaveOne Gold group was Primary file size 25/0.07 and twisted File Adaptive group was SM2 file size 25/0.06. This size of final apical preparation came in accordance with other studies considering it a safe apical termination of preparation (25).

Excessive dentin removal in a single direction within the canal rather than in all directions equidistantly from the canal axis is known as transportation. This is due to the fact that files have the tendency to restore themselves to their original linear shape during root canal preparation (26-28).

Once transportation has occurred, it is impossible to get back to the original canal morphology [27,28]. Transportation is influenced by the design of the instrument (size, taper, flexibility, radial lands, and type of alloy) and the root canal anatomy [29].

Transportation was assessed at 3mm, 6mm and 9 mm from the apex in a mesiodistal plane. Canal transportation was evident at all tested levels, a result that came in consistence with other studies [30, 31, 32].

According to the results of the present study, magnitude of transportation of groups 1, 2 and 3 were considerably less than the critical transportation value of 0.3mm mm which was proposed by Wu et al [33] at both the apical and middle level. More transportation was seen at the coronal level in probably because of the elimination of coronal root interferences.

There was no statistically significant difference between canal transportation results among the three groups at the apical section of the canal. This can be justified in terms of:

i) The three systems worked in a crown down fashion, and terminated preparation with the same file tip apical diameter of size 25 that showed fixed taper over the first 3mm, with slight difference in the degree of taper (0.06, 0.07 &0.06) for PN WOG and TFA respectively.

ii) As for the cross-section,

PN file mass is offset (off centre). This feature was claimed to add some advantages to this file such as decreasing the engagement between the file and dentin, decreasing torque, and reducing the screw effect. Furthermore, it was thought to reduce the possibility of blocking the dentinal tubules by pushing debris laterally (7) and to enhance the ability to remove debris out of the root canal (9). Additionally, the offset centre of the PTN file gives it an ability to prepare a size of canal that would otherwise require larger and stiffer files with a centered axis of rotation [9]. The progressively decreasing percentage tapered design that can be found in any ProTaper file is claimed to increase the flexibility of PTN files, limit the preparation to the body of the canal and conserve the coronal root canal structure [6,7]

The cross sectional design of WOG is an alternating offset parallelogram. It has two cutting edges (85°) with only one cutting edge in contact with the canal wall. Hence, the contact between the file and dentin is reduced enhancing its centering and reducing taper-lock. [10,11, 34]

Owing to its triangular cross section and flexible alloy, TFA according to Tokka et al,[35] has been found to be more flexible than ProTaper® and M2, instruments with a design and mass very similar to WaveOne and Reciproc.

iii) Similar heat treatment utilized in the manufacture of these NITi files

PTN made of M-wire heat treated alloy file is claimed to increase the flexibility of PTN files, limit the preparation to the body of the canal and conserve the coronal root canal structure [34].

Whereas, gold wire of WOG is produced by applying proprietary thermal process (Ground NiTi files are heat-treated and slowly cooled) and post-machining procedure, thus increasing its flexibility [10]

The TFA file design features R-Phase technology to improve its flexibility [35, 36, 37]. This means that the file is twisted to shape to enhance durability.

All three groups have instruments of superior flexibilities due to their manufacturing process which led to similar canal transportation with different movement kinematics.

At 6mm and 9mm TFA showed the highest transportation value followed by PTN then WOG.

No significant difference was revealed between TFA and PTN. This may be due to similar kinematics of continuous rotation at the middle third of both systems. When the TFA instrument is not exposed to high stresses in the canal, it adapts itself to the continuous mode whilst on the contrary, upon contacting any impediments TFA file, adapts itself to the reciprocative mode. [36] The curvature in this study is in the apical third away from the middle third of the canal. So at the middle and coronal one third the TFA most probably rotated in a continuous mode

No significant difference was noted between PTN and WOG which may be due to the similar offset mass of the files cross section.

WOG revealed the least transportation value with a significant difference between TFA. This could be related to the reciprocation motion which allows a high centering ability of the file[6,10,33,37]

The adaptive motion of the system did not give it a credit over the two other systems where each rotated in a different kinematic, continuous rotation and reciprocation. Gambarini et al 2015 reported that adaptive motion and continuous rotation have similar cutting ability. [12]

Knowing that PTN is made from the same alloy as Reciproc (M-wire), Elsaka et al (2016) reported that WOG file had significantly greater flexibility compared to Reciproc and Twisted File Adaptive.[39]

CONCLUSION

Within the limitations of this study, it can be concluded that the difference in rotary motion does not solely affect root canal transportation. This indicates that other factors may play a role between different filing systems such as flexibility, the design of the file, instrument manufacturing alloy in addition to kinematics.

REFERENCES

1. Kandaswamy D, et al. Canal-centering ability: An endodontic challenge. J Conserv Dent 2009;12(1):3–9.
2. Ding-ming H, et al. Study of the progressive changes in canal shape after using different instruments by hand in simulated Sshaped canals. J Endod 2007;33:986–9.
3. Hulsmann M, et al. Mechanical preparation of root canals: shaping goals, techniques and means. Endod Top 2005;10:30–76
4. Krishna PP, et al. A comparison of root canal preparations using stainless steel, Ni-Ti hand, and Ni-Ti engine-driven endodontic instruments – an in vitro study. Bangladesh J Med Sci 2010;09(4):223–30
5. Varelo-Patino P, et al. Alternating versus continuous rotation: a comparative study of the effect on instrument life. J Endod 2010;36:157–9.
6. Capar ID, et al. A review of instrumentation kinematics of engine-driven nickel titanium instruments. Int Endod J 2016; 49(2): 119-35
7. Haapasalo, M., Shen, Y.A. (2013). Evolution of nickel–titanium instruments: from past to future. Endodontic Topics, 29(1), pp.3-17.
8. Johnson E, et al. Comparison between a novel nickel-titanium alloy and 508 nitinol on the cyclic fatigue life of Profile 25/.04 rotary Instruments. Journal of Endodontics 2008, 34(11), pp.1406-1409.
9. Saber SEDM, Nagy MM, Schäfer E. Comparative evaluation of the shaping ability of WaveOne, Reciproc and OneShape single-file systems in severely curved root canals of extracted teeth. Int Endod J 2015;48:109–14.
10. Webber J. Shapping cnal with confidence:WaveOne Gold single file,a system. Int DentAfrican Edition 2016;6(3):6–17.
11. Webber, J., Machtou, P., Pertot, W., Kuttler, S., Ruddle, C., and West, J. The WaveOne single-file reciprocating system. Roots 2011, 1(1), pp.28-33.
12. Gambarini G, et al. Cutting efficiency of nickel-titanium rotary and reciprocating instruments after prolonged use. Odontology. 2016;104:77-81.
13. Gergi R, Osta N, Bourbouze G, Zgheib C, Arbab-Chirani R, Naaman A. Effects of three nickel titanium instrument systems on root canal geometry assessed by micro-computed tomography. International endodontic journal. 2015;48:162-70.

14. Rodrigues RC, Antunes HS, Neves MA, Siqueira JF, Jr., Rocas IN. Infection Control in Retreatment Cases: In Vivo Antibacterial Effects of 2 Instrumentation Systems. Journal of endodontics. 2015;41(10):1600-5.D

15. Rosa et al, Influence Of The Rotary And/Or Oscillatory Reciprocating Systems In The Morphological Changes Of Narrow And Curved Molar Root Canals Anatomy. Rev Odontol UNESP. 2012 Oct; 41(5): 353-359.

16. Yoo YS, Cho YB. A Comparison of the shaping ability of reciprocating NiTi instruments in simulated curved canals. Restor Dent Endod 2012; 37: 220–227.

17. Ismail AG. Comparison of canal transportation and centering ability of protaper universal system, REVO S files and WaveOne single file. EDJ 2015; 61: 6 (1-8).

18. Gambill et al. Comparison of nickel titanium and stainless steel hand files instrumentation using computed tomography. J Endod 1996; 22: 369-375.

19. Zhou H, Peng B, Zheng Y. An overview of the mechanical properties of nickel titanium endodontic instruments. Endod Topics 2013; 29: 42-54

20. Schäfer E, Dammaschke T. Development and sequelae of canal transportation. Endod Top 2009; 15:75–90.

21. Sch€afer E, Florek H Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 1. Shaping ability in simulated curved canals. Int Endod J 2003; 36, 199–207.

22. Kum KY, Spängberg L, Cha BY, Il-Young J, Seung-Jong L, Chan-Young L. Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. J Endod 2000; 26:719–723

23. Michetti J, Maret D, Mallet J P, Diemer F. Validation of cone beam computed tomography as a tool to explore root canal anatomy. J Endod 2010; 36; 1187-1190.

24. Flores Claudia Bohrer, Machado patricia, Montagner Francisco, Gomes Brenda Paula Figuierdo de Almedia, Dotto Gustavo Nogara, Schmitz Marcia Da Silva. A methodology to standardize the evaluation of root canal instrumentation using cone beam computed tomography. Braz J Oral Sci 2012; 11: 84-87

25. Yoo YS, Cho YB. A Comparisonof the shaping ability of reciprocating NiTi instruments in simulated curved canals. Restor Dent Endod 2012; 37: 220–227

26. Moghadam K N, Shahab S, Rostami G. Canal transportation and centering ability of twisted file and reciproc: A cone beam computed tomography assessment. Iranian Dent J 2014; 9: 174-179.

27. Oliveira C A P, Meurer M I, Pascoalato C, Silva S R C. Cone beam computed tomography analysis of the apical third of curved roots after mechanical preparation with different automated systems. Braz Dent J 2009; 20: 376-381.

28. Silva E Souza P.A.R, Das Dores R.S.E, Tartari T, PinheiroT.P.S,Tuji F.M, Silva e Souza Jr M.H. Effects of sodium hypochlorite associated with EDTA and etidronate on apical root transportation. Int End J 2014; 47: 20-25

29. Peters OA. Current challenges and concepts in the preparartion of root canal systems: a review. J Endod2004; 30: 559-567.

30. Yang GB, Zhou XD , Zheng YL, Zhang H, Shu1 Y, Wu HK. Shaping ability of progressive versus constant taper instruments in curved root canals of extracted teeth. Int End J 2007; 40: 707-714.

31. Hashem AA, Ghoneim AG, LutfyRA,Foda MYA, Omar G. Geometric analysis of root canals prepared by four rotary NiTishaping systems. J Endod2012; 38: 996-1000.

32. Capar ID, Ertas H, OK E, Arslan H, Ertas ET. Comparative study of different novel nickel titanium rotary systems for root canal preparation in severely curved root canals. J Endod 2014; 40: 852-856.

33. You S Y, Kim H C, Bae K S,Baek S H, Kum K Y, Lee W. Shaping ability of reciprocating Motion in Curved Root Canals: A Comparative Study with Micro-Computed Tomography. J Endod 2011; 37: 1296-1300.

34. Ruddle, C. J. (2016). Single-File shaping technique achieving a gold medal result. Dentistry Today. http://www.dentistrytoday.com/articles/10143. Accessed September 2017

35. Tokka M et al, Centering ability and canal transportation of curved root canals after using different nickel–titanium preparation systems. Tanta Dental Journal 2018; 15 (1): 19-26

36. Karatas et al, Effect of movement kinematics on canal transportation: reciprocation with different angles, adaptive motion, and continuous rotation. Turk Endod J 2016; 1(1):13–18

37. Gambarini G, Gergi R, Naaman A, Osta N, Al Sudani D. Cyclic fatigue analysis of twisted file rotary NiTi instruments used in reciprocating motion. Int Endod J. 2012; 45(9):802-806

38. Elsaka, S.E., Elnaghy, A.M. and Badr, A.E. (2016). Torsional and bending resistance of WaveOne Gold, Reciproc and Twisted File Adaptive instruments. International Endodontic Journal, pp.1-7.