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Comparison of the Shaping Ability of M3 Pro Gold, M Pro and Pro Taper Universal Rotary Nickel Titanium Systems (An In Vitro Study)

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Aim: The aim of the study was to compare the changes in angle of curvature, transportation and centering ratio after instrumentation in M3 Pro Gold system and M Pro system Pro Taper Universal system was used as gold standard and reference for comparison.
Materials and Methods: Thirty human mandibular first molars were selected. Teeth were randomly allocated into three groups (n= 10): Group 1: M3 Pro Gold; Group 2: M Pro; Group 3: Pro Taper Universal. Cone Beam Computed Tomography (CBCT) were taken before and after preparation measurements were made using On Demand software. Evaluation of angle of curvature was done using Schneider's method. Transportation and centering ratio were evaluated using Gambill's method. Comparison between 3 groups was performed by using One Way ANOVA test followed by Tukey`s Post hoc test for multiple comparisons.
Results: After root canal preparation significant difference in the change of canal curvature values were found, Pro Taper Universal showed the least change and M Pro showed the highest change ($p = 0.0001$), while canal transportation results showed significant difference between all groups at all levels as M3 Pro Gold showed the least transportation and M Pro showed the highest transportation ($P = 0.0001$). Centering ratio results showed significant difference between all groups at all levels as M3 Pro Gold was better centralized in root canal in comparison to M Pro and Pro Taper Universal ($p = 0.0001$).
Conclusion: M3 Pro Gold better respected the original canal anatomy and better conserved root dentine structure as compared to M Pro and Pro Taper Universal.

Keywords: M3 Pro Gold, M Pro, Pro Taper Universal, Shaping ability, Canal Transportation

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Introduction

Root canal shaping is one of the most important factors affecting the outcome of endodontic treatment ideally the canal should be shaped in a way to preserve the original curvature without changing its original configuration over shaping and transportation of canals will lead to perforations, ledges and blockage of canals also will lead to weakening of roots.[1,2]

Recently manufacturers constantly produce rotary files with special concern about flexibility and conformation to canal anatomy in order to achieve the most accurate endodontic treatment with best prognosis. The aim of recent rotary files production is to make canal preparation simple and minimize instrumentation techniques errors to avoid further complications.[3,4,5]

Instruments have undergone several continuous modifications including alloy as well as the design of cutting blades, tapers, helical angles, numbers of flutes, cross-sectional shapes and tip designs. M 3 pro gold (United Dental) is a newly introduced Chinese file system. It's manufactured by a special heat treatment that enhances flexibility, also CM alloy provides high flexibility and advanced triple polishing technique increasing resistance to cyclic fatigue, it possesses noncutting tip design which allows the file to safely follow the canal anatomy and preventing transportation and ledge formation. M pro files(IMD) x wire material allows the file to be pre bendable, great flexibility and high resistance to cyclic fatigue, also the convex triangular cross section design aids in high cutting efficiency, it possesses an increasing pitch of the cutting edges, and less of a screwing effect.[6] Pro Taper Universal files (DENTSPLY) have variable taper along length of cutting blades and noncutting tip.[1,2] Differences in these characteristics have direct effect on mechanical properties, shaping ability and cutting efficiency of rotary files.

The present study was designed to evaluate change in canal curvature, canal transportation and centering ratio achieved by M 3 Pro Gold and M Pro and comparing them with Pro Taper Universal which is used as a gold standard file.[3,4,5,7,8,9] The null hypothesis test was that there are no significant differences among the used files systems.

Materials and Methods

Sample size calculation

Sample size calculated depending on a previous study as reference.[10] According to this study, the minimally accepted sample size was 7 per group, when mean ± standard deviation of group 1 was 0.06 ± 0.18 while estimated mean difference with group II was 0.3, when the power was 80 % & type I error probability was 0.05. Total sample size increased to 10 per group to compensate for the 25% drop out. The t test was performed by using P.S. power 3.1.6.

Sample preparation

This study was exempted from Ain Shams Faculty of Dentistry Ethical Committee (no. 19438) because the study was In Vitro (stored extracted teeth whose owners were not found) and not conducted on patients or experimental animals. Thirty human permanent mandibular molars (mesio-buccal canals) having mature apices and angle of curvature between 25- 35 degrees were included in this study. Teeth were cleaned from any soft or hard calcific deposits and then stored in saline solution till used.

All groups were prepared using high speed contra angle hand piece with small round bur and finished with endo z bur. Sodium hypochlorite with 2.5% concentration was used to irrigate the canals during preparation. Working length was obtained by using manual k-file size ISO 10 to ensure canal patency, followed by file size

ISO 15 until its tip is visible from apex and flushed to apex. The working length was calculated 1mm shorter from tooth length.

Each group consisted of 3 straight line addition silicone blocks; this arrangement took into consideration the maximum field of view of cone beam CT (CBCT) machine to include all teeth with high resolution. Each addition silicone blocks were labeled as (1,2,3) for group 1, (4,5,6) for group 2, (7,8,9) for group 3. The mold was designed as a straight line to fit perfectly in CBCT machine specimen holder without compromising the image and avoiding sample cut –off.

Pre instrumentation CBCT scanning

The mesiobuccal canals were randomly assigned to 3 groups according to instruments used: Group A (n= 10 teeth): prepared using M3Pro gold files. Group B (n=10 teeth): prepared using M Pro files. Group C (n=10 teeth): prepared using Pro Taper Universal file.

The CBCT machine used for scanning GENDEX GXDP-700. The machine was operating with parameters (90 KVP, 63mAs, exposure time 8.7 seconds and a voxel size of 0.085mm). Reconstruction of images in axial direction was done using On Demand software. Schneider method (Figure 1) was used to determine change in canal curvature. Schneider`s method[11] involves making appoint at level of canal orifice extending straight line from point A to point B, and third point C was made at apical foramen, and aline was drawn from C to point B. The angle formed by intersection of lines connecting B and C was measured as the canal curvature.

For measuring dentin thickness, three cross sectional planes at levels 3,5 and 8 mm extended from apex to coronal direction. The amount of transportation, (Figure 2) was measured by comparing the distance from edge of the canal to the periphery of the root in a mesiodistal direction in un-instrumented to instrumented canals using Gambill[12] formula: (M1 –M2) – (D1-D2). According to this formula any value other than 0 indicates that transportation has occurred.

For measuring centering ratio, the mesial and distal dentin thicknesses of the mesiobuccal root canal were measured in each section. A comparison of pre and post operative measures was made and calculated according to Gambill formula[12] for each section according to the following ratio (M1 – M2) / (D1- D2). A value of 1 indicates perfect centering.

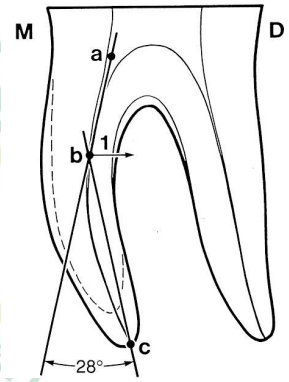

Figure 1: angle of curvature measurement according to Schneider's technique

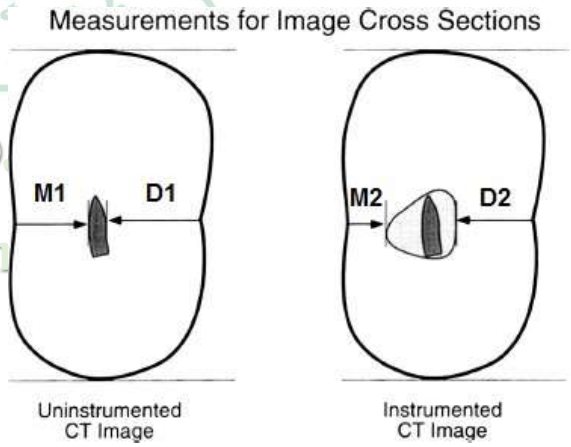

Figure 2: Cross- sectional measurement (M1, D1) in pre instrumentation scans (M2,D2) in post instrumentation scans

Root canal instrumentation

Instrumentation was done with torque and speed according to each file system manufacturer's instructions. E-connect

endomotor (Eighteeth, China) with torque control was used, after access cavity preparation and after initial file preparation by using k- files #10 and #15. Irrigation was done with (2.5%) sodium hypochlorite using side vented needles 30-gauge. Total volume used for each file system is 5 ml. After each stroke, the file was removed and cleaned with gauze and alcohol and inspected for any defects or fractures.

Group 1(M3 Pro Gold files)

Starting with orifice opener file (# 17/08) the file was introduced in canal using an endo motor having continuous rotation motion and torque maintained at 2 N.cm at a speed of 300 rpm as per manufacturer's instructions. Canals were shaped using files (#20/04) and (#25/06) until reaching working length with same torque and speed as the orifice opener, following the same irrigation protocol mentioned above. Each file in the sequence was not used for more than four canals before discarding.

Group 2 (M Pro files)

Shaping started using the orifice opener with size ISO18 taper 4 (torque 3N.cm and speed 450 rpm) with light brushing motion until reaching working length then. Subsequently shaping was continued with files ISO 20 taper 4 and ISO25 taper 6 with applying the same irrigation protocol between each file. Each file was used for four canals before discarding to avoid file fracture.

Group 3 (Pro Taper files)

The SX (# 19/ 0.035) file was introduced in canal after setting its length to correct working length, at a speed of 300 rpm and torque 3N.cm using endo motor in continuous rotation motion. minimal pressure was applied to avoid file breakage. S1 (#17/ 0.02) (300 rpm, 2.5 N.cm), S2 (#20/ 0.04) (300rpm, 1.5 N.cm), F1 (#20/ 0.07) (300rpm,1.5N.cm), F2 (#25/ 0.08) (300rpm, 2N.cm) were used in sequence. Each file was used for only four canals and then discarded.

Post instrumentation CBCT evaluation

Comparison between pre and post operative CBCT images was made using image analysis software to determine the change in angle of curvature pre and post instrumentation according to Schneider`s method.[11]

The equation used to determine percentage of change of angle of curvature used was:

$$C = A1 - A2 / A1 \ \%$$

C is percent of change of angle of curvature
A1= angle of curvature before canal preparation
A2= angle of curvature after canal preparation

Canal transportation was measured in a mesio–distal direction using Gambill formula[12]: (M1 –M2) – (D1-D2). According to this formula any value other than 0 indicates that transportation has occurred (+ve towards mesial and –ve towards distal).

Centering ratio was measured according to Gambill formula[12] for each section according to the following ratio (M1 – M2) / (D1- D2). A value of 1 indicates perfect centering (value above 1 indicates file deviation towards mesial wall and value below 1 indicates file deviation towards distal wall).

Statistical evaluation

Statistical analysis was performed with SPSS 20®1, Graph Pad Prism®1, and Microsoft Excel 2016. All data were presented as mean & standard deviation. All data explored for normality by using Shapiro Wilk and Kolmogorov-Smirnov normality test which revealed that all data normal data (P-value > 0.05). Accordingly, comparison between pre and post measurements was performed by using Paired t test, comparison between mesial and distal was performed by using Paired t test, while comparison between 3 groups was performed by using One Way ANOVA test followed by Tukey`s Post hoc test for multiple comparisons.

Results

Regarding change in angle of curvature, Group 1(M3 Pro Gold) and group 2 (M Pro) showed significantly higher change in the angle of curvature in comparison to group 3 (Pro Taper Universal). PTU showed significantly the lowest change in the angle of curvature with no significant difference between group 1 (M3 Pro Gold) and group 2 (M Pro) (p value= 0.0001), (table 1), (Figure 3).

Table (1): Mean and standard deviation of angle of curvature in all groups, intergroup comparison using One Way ANOVA test followed by Tukey`s Post Hoc test

	Mean ±standard deviation	P value
Group 1 (M3 Pro Gold)	7.773 ^{a} ± 1.56	0.0001*
Group 2 (M Pro)	7.815 ^{a}± 1.56	
Group 3 (PTU)	4.514 ^{b}± 1.49	

*Significant difference as P<0.05.
Mean with the same superscript letters were insignificantly different as P>0.05. Mean with different superscript letters were significantly different as P<0.05.

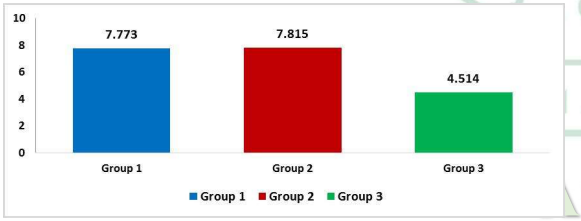

Figure 3: bar chart showing percentage of change in angle of curvature in each group

Regarding canal transportation, at the 3 mm level, there was a significant difference between them as group 1 (M3 Pro Gold) demonstrated significantly lower canal transportation, then group 3 (Pro Taper Universal), while group 2 (M Pro) demonstrated significantly higher canal transportation. At the 5 mm level, there was a significant difference between them as group 1 demonstrated significantly lower canal transportation, while group 2 and group 3 demonstrated significantly higher canal transportation with insignificant difference between them. At the 8 mm level, there was a significant difference between them as group 1 demonstrated significantly lower canal transportation, while group 2 and group 3 demonstrated significantly higher canal transportation with insignificant difference between them (p value = 0.0001), (table 2), (Figure 4).

Table (2): Mean and standard deviation of pre and post canal transportation in all groups at 3-, 5- and 8-mm distances from the apex, intergroup comparison using One Way ANOVA test (comparison between different groups)

	Canal transportation			
	Group 1 (M 3 Pro Gold)	Group 2 (M Pro)	Group 3 (PTU)	P value
	Mean ± Standard Deviation	Mean ± Standard Deviation	Mean ± Standard Deviation	
3 mm	0.066 ^{a} ± 0.05	0.269 ^{b} ± 0.08	0.15 ^{c} ± 0.05	0.0001*
5 mm	0.034 ^{a} ± 0.05	0.216 ^{b} ± 0.05	0.18 ^{b} ± 0.001	0.0001*
8 mm	0.066 ^{a} ± 0.05	0.25 ^{b} ± 0.001	0.225 ^{b} ± 0.09	0.0001*

*Significant difference as P<0.05.
Mean with the same superscript letters were insignificantly different as P>0.05. Mean with different superscript letters were significantly different as P<0.05.

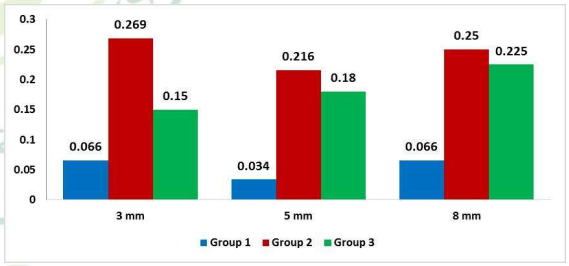

Figure 4: bar chart showing intergroup comparison of canal transportation at all levels

Regarding centering ratio, At 3 mm level there was a significant difference between them as group 3 demonstrated significantly lower centering ratio than group 1, while group 2 demonstrated significantly higher centering ratio. At 5 mm level there was a significant difference between them as group 1 demonstrated significantly lower centering ratio than group 3, while group 2 demonstrated significantly higher centering ratio. At 8 mm level there was a significant difference between them as group 1 demonstrated significantly lower centering

ratio than group 3 while group 2 demonstrated significantly higher centering ratio (p value = 0.0001), (table 3), (Figure 5).

Table (3): Mean and standard deviation of remaining dentin thickness (centering ratio) in 3 groups at 3-, 5- and 8-mm distances from the apex, intergroup comparison using One Way ANOVA test (comparison between different groups)

Distance from apex	Remaining dentin thickness (centering ratio)			
	Group 1 (M 3 Pro Gold)	Group 2 (M Pro)	Group 3 (PTU)	P value
	Mean±Standard Deviation	Mean±Standard Deviation	Mean±Standard Deviation	
3 mm	1.331 ^{a} ± 0.24	6.24 ^{b} ± 1.80	0.067 ^{c} ± 0.02	0.0001 *
5 mm	1.169 ^{a} ± 0.24	5.325 ^{b} ± 0.94	1.735 ^{a} ± 0.19	0.0001 *
8 mm	0.566 ^{a} ± 0.05	2.4 ^{b} ± 0.01	1.705 ^{c} ± 0.37	0.0001 *

*Significant difference as P<0.05.
Mean with the same superscript letters were insignificantly different as P>0.05. Mean with different superscript letters were significantly different as P<0.05.

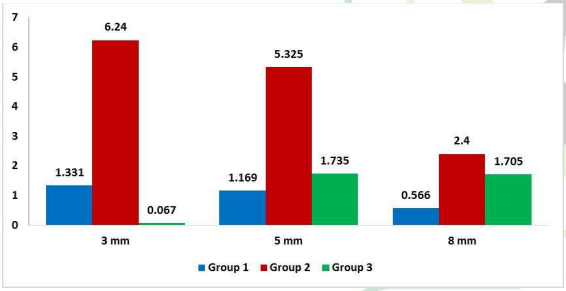

Figure 5: bar chart showing intergroup comparison regarding centering ratio at all levels

Discussion

Shaping is one of the most important factors affecting the outcome of endodontic treatment. The canal should be instrumented in a way to preserve the original curvature without changing the original configuration. Over preparation and transportation will lead to iatrogenic mishaps as perforations, ledges and blockage also will lead to weakening of roots. This procedure was carried out previously by stainless steel files, but the main disadvantage was liability to breakage, tarnish and corrosion and was associated with transportation and straightening of root canal.[1,13]

The advent of Ni –Ti rotary files have reformed root canal instrumentation, which was developed by Buehler et al.[14] in 1963. These files possessed elastic memory enabling the file to return to its original configuration without deformation and have better ability to avoid canal transportation as compared to stainless steel instruments.[7,15] Given that the use of Ni-Ti rotary files, with their higher flexibility and resistance to cyclic fatigue has become of great importance M3 pro gold files were selected due to the advanced metallurgy which improved instrument flexibility. M Pro files are made from X-wire that has pre-curving ability, increased flexibility and cyclic fatigue resistance. Pro taper universal was selected as it has been used for years (conventional Ni –Ti alloy) as a gold standard. it has convex triangular U-shaped cross-section shaping files have multiple tapers that provides flexibility.

In this study human mandibular molars were used to reproduce the anatomic differences, and mesial roots were selected because they have two planes curvature so it can be used as ideal model to compare mechanical differences.[8,12,16,17,18,19,20] The mesiobuccal canals were selected for the purpose of homogenization and possessing their curvature.[21]

In most studies the samples used were made from epoxy resin.[2,22,23,24] When files used in canals in this type of material, they generate sticky flakes interfering with the progression of file along the sample. [20,25]

M3 Pro Gold files are series of multiple sequence instruments applied with most advanced metallurgy technology. The gold heat treatment improves flexibility and resistance to

cyclic fatigue and the convex triangular cross section enhances cutting efficiency. The kit consists of orifice opener file #17/08 and #20/04 file and #25/06 file.

M pro files convex triangular cross section improves cutting efficiency and fracture resistance, and the cutting edges allow instrument to progress easily in the canal. The x wire material allows the instrument to be pre-curved to conform to different configurations of root canals. It has rounded noncutting tip to avoid over instrumentation.[26] The kit consists of orifice opener file #17/04 and #20/04 file and #25/06 file. The manufacturer assumes that this file composition, along with the special manufacture material, allows the files to tightly preserve different canal curvatures without causing any transportation, ledge formation or perforations.

Pro Taper Universal files feature a convex triangular cross-section which is assumed to cut dentin more efficiently. The shaping files have a progressive taper sequence increasing from tip to coronal, where the finishing files show a decreasing taper profile. It is claimed that progressive taper should enhance flexibility of files at the middle and the tip region and decreasing taper should enhance the strength of the files.[1] The Mesiobuccal canals were prepared till F2 in Pro Taper Universal group. The F2 prepared the apical third and enlarged the middle third of root canals. F3 was not used to avoid over preparation in Mesiobuccal narrow canals.

CBCT was used to evaluate the shaping parameters. It can provide cross-sectional 3D images that are highly precise with high resolution, fully quantifiable and provides repeatable results.[20,27,28] In the past, ways of assessment of canal transportation and dentin thickness included radiographic techniques[16,17,29], serial sectioning method[30] ,scanning electron microscopy[31] these techniques were invasive in nature and presented difficulty in gaining accuracy of pre and post prepared samples where radiographic method provides 2D images of 3D objects.

Teeth were put in addition silicone mold[20,32] to ensure the same teeth position during scanning for pre and post instrumentation records. Additionally, Radio density of addition silicone would not hide the details of root canals.[33] By mounting them in that way, teeth of each group can be removed and returned back in exact same position after preparation for post preparation imaging.

The angle of curvature of mesio buccal canals was measured by Schneider method.[11,20] This method showed reliability and accuracy. Apical transportation values that are more than 0.3 mm can endanger the outcome of treatment due to noticeable decrease of sealing ability of obturation material.[34,35]

The null hypothesis was rejected given that there was a significant difference between the three file systems regarding the shaping parameters.

M 3 Pro Gold showed significantly better preservation of root dentin as shown by the centering ratio and canal transportation values. This could be due to CM wire design of the files and the low speed used per manufacturer's instructions. This result agrees with Huang et al.[36] where HyFlex CM showed less transportation and better preservation of root dentin

than HyFlex EDM and Pro Taper Next. Likewise, Lin et al.[37] stated that HyFlex CM showed less transportation than T-Flex, Vortex blue, I Race and S5. This can be attributed to the high flexibility of HyFlex CM as it is manufactured by a unique thermal pre- treatment technology that controls the file's memory.

Conversely, Saber et al.[16] stated that HyFlex CM showed higher transportation value than iRace with no statistically significant difference.

Pro Taper Universal showed less transportation and more preservation of root dentin in comparison to M Pro this could be due to the Ni-Ti nature of instruments and the progressive taper which improves flexibility of files at the middle and tip regions. It could be also due to the low-speed settings used per manufacturer's instructions. This result agrees with Gasser et al.[20] where Pro Taper Universal showed less transportation than M Pro.

Conversely, Nagaraja et al.[38] study claimed that Pro Taper Universal should be used carefully, especially at severely curved canals, because it causes higher canal transportation and thinning of root dentine at middle and coronal thirds. M Pro files showed higher transportation values than other file systems this could be due to the higher speed and torque used for M Pro files than other files systems (speed 450 rpm and torque 3 N.cm) as per manufacturer's instructions. (M 3 Pro Gold speed 300 rpm and torque 2 N.cm) (Pro Taper Universal speed 300 rpm and torque 3 N.cm).

This was in conflict with Girgis et al.[39] who stated that M- Pro showed less transportation values than Revo –S and Pro Taper Next. This finding is due to M –Pro files are manufactured from heat treatment of Nickel Titanium alloys while Revo- S is made from conventional Nickel Titanium alloy.

Regarding change in angle of curvature, Pro Taper Universal showed less change than M 3 Pro Gold and M Pro this could be due to gradual change in instruments sequences (SX, S1, S2, F1, F2). Also, this could be due to the progressive taper of Pro Taper Universal files which improves instrument flexibility. M 3 Pro Gold and M Pro showed a higher change than Pro Taper Universal this could be due to rapid change in files sequences in comparison to the successive progression of instrument sizes of Pro Taper Universal (orifice opener files #17/08, #20/04, #25/06). This finding agrees with Gasser et al.[20] who showed that Pro Taper Universal made the least change in angle of curvature than M Pro and Endo Plus file systems.

Conversely, Asmaa et al.[40] showed that M Pro had the lowest percent of reduction of canal curvature in comparison to Revo – S and 2 Shape rotary systems. This finding was due to Revo –S file system is made of conventional Nickel – Titanium alloy increasing file tendency to straightening canal curve. While M- Pro and 2 Shape are manufactured from heat treated Nickel – Titanium alloy. Since heat – treatment improves file flexibility allowing better respect to original canal curve. Likewise, Saber et al.[16] stated that Pro Taper Next showed more canal straightening than iRace and HyFlex CM files. This can be attributed due to the difference of instrument taper (4% for iRace and HyFlex CM vs. 7% for Pro Taper Next).

Conclusions

1. M 3 Pro Gold better conserved root dentine structure as compared to M Pro and Pro Taper Universal.
2. CBCT is an accurate noninvasive tool for studying canal shaping, providing images of root canal anatomy with higher resolution than periapical radiographs.

Declarations

Competing interests

No conflict of interest

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References

1- Schafer E , Vlassis M. . Comparative investigation of two rotary nickel –titanium instruments ProTaper versus RaCe . Int Endod J2004; 37 :229-238
2- Calberson F L G, Deroose C A J G ,Hommez G M G ,De Moor R J G. Shaping ability of ProTaper nickel-titanium files in simulated resin root canals. Int Endod J2004; 37: 613–623
3- Veltri M, Mollo A, Pini P P, Ghelli L F, Balleri P. . In vitro comparison of shaping abilities of Pro Taper and GT rotary files . J Endod 2004 ; 30 : 163- 166
4- Yoshimine Y, Ono M , Akamine A. . The shaping effects of three nickel- titanium rotary instruments in simulated s- shaped canals. J endod 2005; 31 : 373-375
5- Schirrmeister J F, Strohl C , Altenburger M J , Wrbas K T , Hellwig E . Shaping ability and safety of five different rotary nickel- titanium instruments compared with stainless steel hand instrumentation in simulated curved root canals. Oral Surg , Oral Med , Oral Pathol , Oral Radiol Endod 2006; 101 : 807- 813
6- EL Feky H M, Ezzat K M, Bedier M M A. Cyclic fatigue resistance of M Pro and RaCe Ni- Ti rotary endodontic instruments in artificial curved canals: a comparative in vitro study. Restor Dent Endod. 2019; 44(4) : 1-11
7- Versiani M A, Pascon EA, De Sousa C J A ,Borges M A G, Neto M D S. Influence of shaft design on the shaping ability of 3 nickel titanium rotary systems by means of spiral computerized tomography.(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:807-811)
8- Bonaccorso A , Cantatore G , Condorelli G G , Schafer E, Tripi T R. Shaping ability of four nickel – titanium rotary instruments in simulated s-shaped canals. J endod 2009 ; 35 : 883- 886
9- Burklein S , Hinschitza K, Dammaschke T , Schafer E . Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper . Int Endod J 2012; 45: 449–461
10- EL Khodary SA , Roshdy N N , Comparative Assessment Of Apical Transportation And Centering Ability Of Three Novel Rotary NITI Files : A Cone Beam Computed Tomography Study. EDJ 2023 ; 69 (1) : 751-760
11- Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg ,Oral Med ,Oral Pathol 1971;32 (2) ;271-275
12- Druktinis S, Peciuliene V, Dummer P M H, Hupp J. Shaping ability of BioRace, ProTaper NEXT and Genius nickel-titanium instruments in curved canals of mandibular molars: a MicroCT study . Int Endod J, 2018;52, 86–93
13- Bryant ST, Dummer PMH , Pitoni C, BourbaM, Moghal S. Shaping ability of .04 and .06 taper ProFile rotary nickel – titanium instruments in simulated root canals . Int Endodontic J 1999; 32 : 155-164
14- Buehler WJ, Gilfrich JV, Wiley RC. . Effect of low temperature phase changes on the mechanical properties of alloys near composition. Tini Journal of applied physics 1963;34(5):1475-1482
15- Shalini Singh , Nitin Mirdha , PH Shilpa , Rahul VC Tiwari .Shaping ability of 2Shape and Wave One Gold files using cone – beam computed tomography . Journal of international society of preventive and community dentistry (2019) ;9 (3) : p245 – 249
16- Saber S E D M, Nagy M M, Schafer E. Comparative evaluation of the shaping ability of ProTaper Next, iRaCe and Hyflex CM rotary NiTi files in severely curved root canals. Int Endod J, 2015;48: 131–136
17- Burklein S , Mathey D, Schafer E . Shaping ability of Pro Taper NEXT and BT- RaCe nickel – titanium instruments in severely curved root canals . Int Endod J 2015; 48 :774-781
18- Ferrara G, Taschieri S , Corbella S , Ceci C ,Del Fabbro M , Machtou P . Comparative evaluation of the shaping ability of twodifferent nickel–titanium rotary files in curved root canals of extracted human molar teeth. J of Invest.and Clinical Dentistry (2017), 8, e12187

19- S Drukteinis , V Peciuliene , PMH Dummer , J Hupp . Shaping ability of BioRace, Pro Taper Next and Genius nickel –titanium instruments in curved canals of mandibular molars : a Micro CT study . Intrnational endodontic journal (2019) ; 52 (1) : p 86 -93
20- Shalaby G M W, Hassanien E E S and Nagy M M. Shaping Ability Of A Novel Rotary Nickel Titanium System Using Cone Beam Computed Tomography (An In Vitro Study) . E.D.J Vol. 69 ,No.4: P 3199- 3207
21- Hartmann MS , Fontanella VR, Vanni JR , Fornari VJ , Barletta FB. CT evaluation of apical canal transportation associated with stainless steel hand files , oscillatory technique and Pro Taper rotary system . Brazilian Dental Journal 2011 ; 22(4) : 288- 293
22- Thompson S.A , Dummer P.M.H Shaping ability of ProFile.04 taper series 29 rotary nickel- titanium instruments in simulated root canals . Int Endod J 1997; 30: 1-7
23- Bryant ST, Dummer PMH , Pitoni C, BourbaM, Moghal S. Shaping ability of .04 and .06 taper ProFile rotary nickel – titanium instruments in simulated root canals . Int Endodontic J 1999; 32 : 155-164
24- Kum K.Yon, Spangberg L, Cha B.Y, Young J, Jong LS, Young LC. Shaping Ability of Three ProFile Rotary Instrumentation Techniques in Simulated Resin Root Canals . J Endod 2000 ;26 :719-723
25- Arora A, Taneja S, Kumar M. Comparative evaluation of shaping ability of different rotary NiTi instruments in curved canals using CBCT . Journal of Conservative Dentistry 2014; 17(1) : 35
26- Luo HX, Huang DM , Jia LH, Luo SG, Gao XJ, Tan H, Zhou XD. Shaping ability of multi – taper nickel –titanium files in simulated resin curved root canal. China J of stmatol 2006; 24(4) 339-342
27- Ahmed J M M O , EL Gendy A A H , Mustafa T Shaping Ability of Three Different Rotary Nickel Titanium Systems An In Vitro Study. ASDJ 2024 ; 33 (1) : 156 - 163
28- Ibrahim M A , El Gendy A A H , El Sewfy T M , Comparative evaluation of shaping abilities of two different rotary files (an in vitro study). ASDJ 2021 ;22 (2) : 28- 38
29- El Batouty K M. , Elmallah W E. Comparison of canal transportation and changes in canal curvature of two nickel – titanium rotary instruments. Journal of Endodontics 2011 ; 37(9) :1290-1292
30- Vaudt J. , Bitter K, Neumann K, Kielbassa M. Ex vivo study on root canal instrumentation of two rotary nickel – titanium systems in comparison to stainless steel hand instruments. Int. Endod. J 2009 ;42:22-33
31- Lopez FU. , Travessas JA , Fachin E, Fontanella V , Grecca F. apical transportation : Two assessment methods . Aust . Endod. J 2009 ;35:85-88
32- Sauaia TS, Gomes BP, Pinheiro ET Thickness of dentin in mesial roots of mandibular molars with different lengths . International Endodontic Journal 2010;43(7):555-559
33- Generali L, Righi E, Todesca MV,Consolo U. Canal shaping with Wave One reciprocating files :Influence of operator experience on instrument breakage and canal preparation time . Odontology 2013; 102 (2) :217-222
34- Peters OA , Arias A, Paque F. A micro- computed tomographic assessment of root canal preparation with a novel instrument , TRUShape, in mesial root of mandibular molars. J Endod 2015 ;41:1545-1550
35- Zhou H, Ya Shen , Zheng W, Li L , Zheng Y, HaaPasalo M. Mechanical properties of controlled memory and super elastic Nickel – Titanium wires used in the manufacture of rotary endodontic instruments. J Endod. 2012 ; 38 : 1535-1540
36- Huang Z , Quan J , Liu J , Zhang W , Zhang X , Hu X . A microcomputed tomography evaluation of the shaping ability of three thermally – treated nickel – titanium rotary file systems in curved canals. Journal of international medical research (2019) ;47 (1) : p325 -334
37- Lin G S S, Singbal K P , Abdul Ghani N R N . A Comparative evaluation of the Shaping Ability , Canal straightening and Preparation time of five different NiTi rotary files in simulated canals . JCD 2021;24(1):67-71
38- Nagaraja S, Sreenivasa M . CT evaluation of canal preparation using rotary and hand Ni – Ti instruments . An in vitro study. J of cons. Dent. 2010 ;13(1) : 16
39- Girgis D Y, Sadek H S, Roshdy N N. Comparative Assessment of the Shaping and Cleaning Abilities of M-Pro and Revo-S versus Pro Taper Next Rotary Ni-Ti systems (An In Vitro Study) . ADJC 2020;2(4): 162-176
40- Hussien A A B , El Gendy A A H , Abdel Rahman T Y . Shaping Ability Of Different Rotary Nickel Titanium Systems (An In Vitro Study). ASDJ 2020 ; 19(3): 8-12