Evaluation of Cross-Sectional Designs Impact of Different NiTi Files on Distortion Resistance Using SEM (An-in Vitro Study)

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***Abstract*—Background and aims: The aim of this study was to compare the effect of cross-sectional designs of four rotary systems (One Curve, 2Shape, K3-i File, E3 Azure), on distortion resistance of the metal surfaces of these files in simulated resin blocks under controlled conditions with five repeated usages, using scanning electron microscope (SEM).**

Materials & Methods: Four rotary file systems: (1) One Curve, (2) 2Shape, (3) K3-i File, and (4) E3 Azure, were tested in simulated J-shaped root canal resin blocks with a 45° angle of curvature. Ten files from each system, each one of the 10 files were used to prepare 5 resin blocks, named R1-R2-R3-R4-R5. All the used files from the 4 systems had tip size 25 diameter, taper (6%), and length (25 mm). Following the manufactural recommendation of each system. All the resin blocks were prepared for Glide Path with manual reamers size 10, and 15, with a fixed working length 16 mm, then all the samples were prepared with a Proglider rotary file from Dentsply (size 16 taper 3%), then finally were prepared with Edge Files (USA), with size 20 and taper 6%, reaching to the step of master preparation with the selected files of the 4 systems. Using a customized device for preparation to ensure fixed vertical force and to exclude any lateral force, preparation was done with EDTA solution as irrigation, with a fixed no. of 5 strokes, the time was controlled by using a Metronome, each stroke duration was 6 seconds. Five parameters were suggested to be evaluated by two observers. These parameters or criteria includes: 1) Apical deformation, 2) Cutting edge deformation, 3) Crack presence, 4) Full spiral deformation, 5) Apical spiral deformation. The data were collected and registered in the Excel sheet for all 44 files (4 instruments as control) and comparison was done between the 4 systems. Visual observation for all the images has been done, and the data registered as a scale from 1 to 4 for the first two criteria, and as present or not for the other three criteria.

Results: For the apical deformation parameter, there was a non-significant difference ($P > 0.05$) (P value = 0.625) among all experimental groups by using the KWT. For the cutting-edge deformation parameter, there was a significant difference at ($P < 0.05$). For the crack parameter, there was a non-significant difference at $P > 0.05$ (P value = 1) among all experimental groups by using Fisher's Exact test.

Conclusion: The Ni Ti alloys with heat treated technologies showed a high resistance to cutting edge deformation, cracks formation, and instrument fracture, with five repetitions of use.

***Index Terms*— Cross-sectional design, SEM, Nickle Titanium rotary files.**

I. INTRODUCTION

This Since the introduction of the new alloy of Nickel Titanium endodontic rotary instruments there have been countless number of gradual growths in file cross-sectional designs which could be confusing and sometimes inconsistent to the endodontist. Ultimately, this aids the clinician to employ the instruments more confidently and having much information about choosing the most appropriate file design for his routine endodontic cases. Selecting the best design should facilitate the work and improve the cleaning and shaping of each canal (1). Many factors have been identified that exert an effect on the shaping ability of the files, such as the design features or characteristics of the instruments that had been used for canal preparation (Cutting angle, Tip design, Pitch, Radial Land, Rake Angle, Helical Angle, Core Diameter, Taper, Chip Space, Configuration of the cutting edges of the instruments) (2). Many innovations have been made during the last years to enhance the performance of endodontic rotary instruments with respect to their shaping ability, and modification of the cross-sectional design was an important issue (3). The main aim of this study was to analyze and assess the effect of different cross-sectional designs on the on-distortion resistance of the metal surfaces of these files in simulated resin blocks under controlled conditions with five repeated usages, using scanning electron microscope (SEM).

One Curve endodontic instruments: Manufacturer (Micro Mega) France, File size 25 taper 6%. One Curve rotary file system made from C-Wire heat-treated Ni-Ti alloy in 2017. It is a single-file system that depends on continuous rotation movement during work. This system comes with tip diameters (0.25, 0.35, and 0.45) and with two tapers (4% and 6%). The alloy that is used for this system (C-Wire) has two stages of manufacturing: an initial electro-polishing and a subsequent heat-treatment which provide its advanced properties (4). It is a hyper-flexible instrument through its control memory technology. One Curve is a smart, efficient and conservative instrument. The file has a variable cross-section all along the blade for a centering ability in the apical third and excellent debris removal up to the medium and coronal parts (5).

2Shape endodontic instruments: Manufacturer (Micro Mega) France, TS2 File size 25 taper 6%. 2Shape endodontic instrument made from Ni-Ti alloy which has been heat treated with T-Wire technology. The T-Wire technology used in the production of files is claimed to increase the cyclic fatigue resistance of files by 40% in comparison to One Shape (MicroMega) files. 2Shape has a latest generation of a cross-section of the asymmetrical cross-section with a triple helix with 2 main cutting edges for cutting efficiency and one

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secondary edge for improved removal of debris (6). The 2Shape system is composed of TS1 (25/.04), TS2 (25/.06), F35 (36/.06), and F40 (40/.04) files. This system works with continuous rotation movement. The flexibility of the instruments brings comfort to use and excellent negotiation of the curvatures of the canals. The instruments return to their original shape after each use (7). This system has 2 post-treatments, electro-polishing and heat treatment, just like the previous system (One Curve).

K3-i File endodontic instruments, Manufacturer (K3 DENT) London UK, File size 25 taper 6%. Dental Britain K3-i File Thermal Activity Endodontic Root Canal Files Nickel Titanium Rotary system, this system has the following files: KV file, size 20 taper 10% length 17 mm. K1 size 20 taper 4% length (21/25/28/31mm). F2 file, size 25 taper 4% length (21/25/28/31mm). K2 file, size 25 taper 6% length (21/25/28/31mm). K3 file, size 35 taper 4% length (21/25/28/31mm). K3-I File has a square cross-sectional design.

E3 Azure HT Technology endodontic instruments, Manufacturer (Endostar-Poldent) Poland, file size 25 taper 6%. This system has been fabricated from a high-quality Nickel-Titanium alloy, which was passed through a special heat treatment process called AZURE HT technology by Poldent, this technology produced a very high flexible and durable files. The modified shape of the NiTi S file with two cutting edges provides the efficient cutting ability, transport of debris up the canal and decreases preparation time. The files of this system are with a non-cutting tips or could be described as inactive tips(8). The file of E3 AZURE can also be pre-bent before insertion into the canal. This system contains the following files: size 20 taper 4/6, size 25 taper 4/6, size 30 taper 4/6/8, size 40 taper 4, size 45 taper 4 (9).

II. MATERIALS AND METHODS

Two hundred high hardness clear resin blocks of J-shaped canal (Endo Training-Bloc, 0.02 taper) were selected to do this study. An apical foramen size of #10 was confirmed, and each canal had a curvature of 45° and a mean canal length of 16 mm. High-hardness resin blocks show similar apical canal transportation when compared with extracted teeth (10). All the samples were labeled, and they were divided into four groups, named; group (A) prepared by One Curve, (B) 2Shape, (C) K3 i-File, and finally (D) E3 Azure. So, there are four rotary systems, 10 files were used from each one, named file-1 to 10, and each one of these files has been used to prepare 5 resin blocks, named R1-R5 representing the five repeats. The selected files for the study were of size 25, taper 6%, and 25mm length. The speed was fixed at 350 rpm, and the torque was 3 Ncm. The preparation of the samples started with the preparation of the glide path with manual and rotary instruments (11). All 200 samples were prepared with manual file size #10 and then #15, after that a 100 ProGlider files from Dentsply with size 16 and taper 3% had been used to prepare the 200 samples, each file (Proglider) has been used to prepare 2 resin blocks. And then 200 Edge Files with size #20 and taper 4% had been used to prepare the 200 samples, each file was used to prepare one resin block to ensure accurate size and taper for all the samples before starting the master preparation. The preparation of the resin blocks with the rotary instruments had been done using a customized device for the preparation to avoid any lateral inclination during introducing the file into the simulated canal, a contra angled hand piece (X smart-plus from Dentsply) was fixed on the device to do the preparation and adjusting the desired speed and torque. Regarding the adjustment of the time a Mechanical metronome (Nikko prestissimo Japan) had been used to control the number of strokes and their time, for each stroke of preparation 6 seconds were used. 5 strokes had been used for the 4 systems. The working length was fixed at 16 mm for all the used files, the device was adjusted to be stopped at 16 mm by a metal blocker, and all the files were of 25 mm in length, therefore; there was no need to use the rubber stopper as a guide. During all steps of preparation, EDTA solution had been used as a lubricant to simulate the clinical situation. After the completion of the preparation of all the 200 samples till size #20 and taper 4% (before starting the master preparation), all the samples were irrigated, cleaned and dried with a paper point. After the master preparation with the selected files, each file was examined before and after use for any defects and was wiped regularly to remove resin debris. EDTA solution had been used as a lubricant with each file, by adding 2 drops of the solution prior to starting preparation. After the finishing of master preparation, again all the 200 samples were irrigated with Sodium hypochlorite solution NaOCl 2%, cleaned and dried with paper points and they were all kept in a room temperature for 48 hours to be completely dried. After the completion of the master preparation of all the resin blocks, each file was cleaned from resin debris with alcohol and gauze, labeled with a coded sticker, and kept in a laboratory glass tube and closed with a rubber cup. The 44 files were ready for the SEM study (10 files + 1 control file from each system).

All the used files from the four selected rotary systems, with a control file for each system group, were preserved in a laboratory tube and labeled. For the examination of the surface texture of the metal of the used files in the present study, SEM (scanning electron microscope) was used to get a detailed image for the 40 files after 5 repeats (including a new file from each system as a control file). All the files were photographed by a professional camera (Nikon D610 DSLR with Nikkor lens 105mm) before sending them for SEM study. Two images were documented for each file with the label and code fixed on it. Then at three different magnifications: 100X, 200X, and 300X. Two points of each file were scanned (the D3 apical part and the D6 middle part). That means six images were taken for each file. After the completion of gathering the pictures from the SEM study, five parameters were suggested to be evaluated by two different observers. These parameters or criteria include: 1) apical deformation; 2) cutting edge deformation; 3) crack presence; 4) full spiral deformation; and 5) apical spiral deformation. The data were collected and registered in the Excel sheet for all 44 files, and a comparison was done between the four systems. A visual observation of all the images has been done, and the data has been registered as a scale from 1 to 4 for the first two criteria and as present or not for the other three criteria. Statistical analysis was performed by the SPSS statistical software Ver. 25 for windows (SPSS, Chicago, Il, USA), and the significance level was set at $p \leq 0.05$.

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III. RESULTS

A total number of 44 rotary instruments (4 instruments as control) from the four experimental groups were examined by SEM. The examination has been done after the completion of the five repetitions of use in the simulated resin blocks. There was no fractured file after all repeats in all experimental groups. For each system, one new instrument (unused file was examined and considered as control file for the evaluators). For each file, the point D3 (considered as the apical third part image), and the point D6 (considered as the middle third part image). Three magnification powers had been used: X100, X200, and X300.

For the apical deformation parameter, the number of defects for each group is presented in (Table 1). Statistically, there was a non-significant difference ($P > 0.05$) (P value = 0.625) among all experimental groups by using the KWT. For the cutting-edge deformation parameter, the number of defects for each group is presented in (Table 1). Statistically, there was a significant difference at ($P < 0.05$) among all experimental groups by using the KWT. The deformation in the margin of the cutting edge of the active part of the instrument (in the examined section) after five repetitions of use is shown in (Fig. 1). The highest values observed in group C and D, followed by group B. Meanwhile in group A there was no any deformation observed. For the crack parameter, the number of defects for each group is presented in (Table 1). Statistically, there was a non-significant difference at $P > 0.05$ (P value = 1) among all experimental groups by using Fisher's Exact test. After finishing the fifth repetition of preparation, only two instruments were subjected to cracks (one instrument in group B and one in group C), one of which is shown in (Fig. 2).

For the full spiral deformation parameter, the number of defects for each group is presented in (Table 1). Statistically, there was a non-significant difference ($P > 0.001$) among all experimental groups when using Fisher's Exact test. This parameter was retrieved from the examination of the high-quality images of the instruments after five repetitions. For the apical spiral deformation parameter, the number of defects for each group is presented in (Table 1). Statistically, there was a highly significant difference ($P < 0.001$) among all experimental groups when using Fisher's Exact test. Samples of the distorted instruments from the experimental groups can be seen in (Fig. 3).

TABLE 1: VALUES OF EACH PARAMETER BY SEM

No. of defects recorded					
Parameter	OneCurve	2Shape	K3-i File	E3 Azure	Control
Apical deformation	5	5	1	2	0
Cutting edge deformation	0	2	10	9	0
Crack	0	1	1	0	0
Full spiral deformation	0	0	0	0	0
Apical spiral deformation	8	2	0	10	0

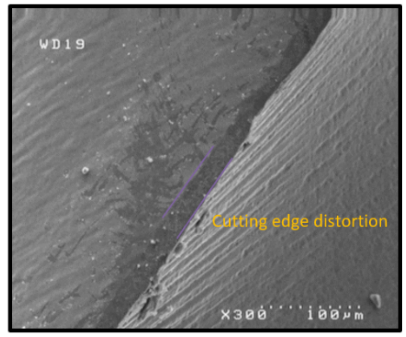

Fig. (1): Surface topography SEM image showing the cutting-edge deformation of File number 1 from group B (2Shape). Magnification power: X300

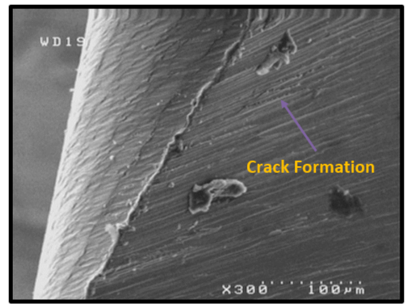

Fig. (2): Surface topography SEM image showing the crack in the apical third of file number 10 in group B (2Shape)

Fig. 3: Apical Spiral Deformation of: (A) File 2 From Group A, (B) File 5 From Group B and (C) File 1 From Group D.

IV. DISCUSSION

In this research, a comparison of the presence or absence of defects on the cutting edge of the new rotary endodontic instruments made of Ni Ti alloy from four different commercial brands has been done using a scanning electron microscope, as well as an examination of the surface defects in the instruments after five repeated uses in simulated resin blocks, considering the improvements in the type of the alloy of Ni Ti, the surface treatment, and the design of the rotary instruments. It is important to use the instruments correctly, taking into consideration sterilization, disinfection, and cleaning of these instruments during each stroke and before each use. Although

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improper use of the instruments produces deleterious effects such as deformations after their use. The need for instruments that stand up to more than one use is evident, even though manufacturers recommend they must be used only once. However, the better quality, greater flexibility, and durability of these instruments are a result of their current manufacturing processes, automatic auto-reverse motors, and control of torque and speed during work. High-tech instruments and motors have shown that it is possible to use these files rationally in multiple sessions (12)

In the SEM study for the experimental groups, all 40 files were examined microscopically with magnification powers of X 100, X 200, and X 300. After the examination of the resulting images by two different examiners, the most prominent and obvious signs are the cutting-edge deformation, apical deformation and cracks formation. The apical spiral deformation and the full spiral deformation were evaluated depending on photography, since all the files were photographed by the same customized device for photography with a macro lens and high-quality images, before sending them for the SEM study. The cutting-edge deformation was found mostly in group C (all the files), then group D (all the files), meanwhile, there was no deformation in group A and only two instruments in group B, which proves that the quality of the first two system's alloys and surface treatment were better. It was obvious that C-Wire followed by T-wire regarding the surface resistance, both of which are made from heat-treated Ni Ti alloy, which are highly resistant alloys for cutting edge deformation. This finding is in accordance with the findings of (13).

Since all the four groups were exposed to the same working condition and used for five times, the difference in their resistance to cutting edge deformation was related to the type and quality of their alloys and their surface treatment. Group C and D were the weakest systems from the cutting-edge resistance to deformation point of view. The apical spiral deformation was found in the following order: Group C: no presence of any spiral deformation in all the files, and this is related to the low cutting efficiency of the system and the high resistance of the square cross section to cyclic fatigue. (14). Group B was the second system in resistance for apical spiral deformation; only two files were subjected to distortion, also it is strongly related to the asymmetrical triangular design of the active shaft (15). In group A there were eight instruments showing deformations, this will give strong evidence that the asymmetrical triangular design (group B) is more resistant to distortion than the symmetrical triangular CS in (group A). while in group D which was the most system subjected to apical spiral deformation, all instruments were found with apical spiral distortion or deformation, revealing that the modified S shape CS is the least resistance to distortion. There was no file fracture in all the experimental instruments (40 files), this could be related to the amount of torque, the speed of the rotary engine, and both of them (torque and speed) were within the allowed limit of the manufacturer, proper lubrication of the canal during preparation, constant vertical path of movement, good cleaning of the flutes from resin debris during preparation between all strokes, Good glide path which is already accomplished for all resin blocks samples, and finally, it is related to the type of the alloy of the four system, all of them were made from heat treated alloys, except for the K3 (no available information about the alloy). No crack formation in all groups except one file in group B. Previous studies reported that the Af temperature for typhoon files was approximately 54°C and Vortex files were approximately 50°C, indicating that these files would be essentially in the martensitic phase at body temperature (16).

This can be attributed to reversible martensitic transformation, a process with excellent energy absorption characteristics that results in less damage per use and explains the improved results. The martensitic phase crystals make the alloy ductile, increasing both its deformation capacity and CF resistance, whereas the austenitic phase Ni Ti is strong, hard, and more resistant to deformation (17).

The instruments that did not receive any electrochemical polishing had a higher number of fabrication defects, such as grooves, cracks, and cavitation, and thus did not perform as well as those that did receive such electrochemical polishing (18).

The limitations of the study were; the instruments weren't subjected to Autoclaving between repeats, the use of the resin blocks instead of natural extracted teeth which differ in physical properties such as hardness and density, the use of EDTA solution solely as a lubricant during canal preparation, without the use of NaOCl, the SEM examination was done on a single side of the selected sections of the instruments, and the scoring of the parameters of the SEM study, although done by two observers, remain subjective.

CONCLUSION

The Ni Ti alloys with heat treated technologies showed a high resistance to cutting edge deformation, cracks formation, and instrument fracture, with five repetitions of use.

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