Effect of Cross-Sectional Designs of Different Ni-Ti Files on Shaping Ability After Repeated Usage in Simulated Root Canals.

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Background and Objective: The study aimed was to compare the effect of cross-sectional designs of five rotary systems (One Curve, 2Shape, K3-i File, E3 Azure, Neolix), on the shaping ability of the files in simulated resin blocks under controlled conditions with five repeated use. The shaping ability of the files includes the following variables: (1) Longitudinal sectional area difference, (2) Canal wall surface area difference, (3) Canal volume difference, (4) SMI (structure material index) difference, (5) Cross-sectional area difference.

Methods: Five rotary file systems: (1) One Curve, (2) 2Shape, (3) K3-i File, (4) E3 Azure, (5) Neolix, were tested in simulated J-shaped root canal resin blocks with a 45˚angle of curvature. 10 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 5 systems had tip size 25 diameter, and taper (6%), and length (25 mm). The first 4 rotary systems were used with a fixed speed (350 rpm), and fixed torque (3 Ncm), except for the fifth system which was used with a speed of (500 rpm), and torque (4 Ncm), Following the manufactural recommendation of each system. All the 250 resin blocks were prepared for Glide Path with manual reamers size 10, and 15, with a fixed working length 16 mm, then all the 250 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 5 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 4 strokes for the first 5 systems and 9 strokes for the Neolix, the time was controlled by using a Metronome, each stroke duration was 6 seconds.

Results: In the first, second, third, and fourth variables a statistically non-significant difference ($P > 0.05$) was found between One curve and 2Shape, a statistically significant difference ($P < 0.05$) was found between One Curve, K3-i File, E3 Azure, and Neolix. About the fifth variable which is the Cross-sectional area difference: the study compared the difference between the cross-section area of the canal at the point D8, comparing the cross-section area before and after preparation using ANOVA test and Post hoc test, a statistically significant difference ($P < 0.05$) was found between the Neolix and (2shape, K3 i-File, and E3 Azure).

Conclusion: The cross-sectional design of the endodontic rotary instrument had an obvious effect on the shaping ability of the system.

Keywords: Cross-sectional design, Shaping ability, Nickle Titanium rotary files (One Curve, 2Shape, K3-i File, E3 Azure, Neolix).

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INTRODUCTION

Since the introduction of the new alloy of Nickel Titanium endodontic rotary instruments there have been a countless number of gradual growth in file cross-sectional designs which could be confusing and sometimes inconsistence 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, 4]. The main aim of this study was to analyze and assess the effect of different cross-sectional designs on the shaping ability of NiTi rotary instruments in simulated J-shaped canals. The shaping ability of the selected systems had been evaluated depending on the following variables: Longitudinal sectional area difference, Canal wall surface area difference, Canal volume difference, SMI (Structure Model Index) difference, Cross-sectional area difference.

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 electropolishing and a subsequent heat-treatment which provide its advanced properties. [5]

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. [6] 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 secondary edge for improved removal of debris. [7] 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.[8] This system has 2 post-treatments, electropolishing 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).

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. [9] 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.[10]

Neolix endodontic instruments, Neoniti A1 Manufacturer (Neolix) France. This system was presented for the first time in the market in 2014, it is manufactured from Nickel Titanium alloy with EDM (Electrical discharge machine). It is characterized by outstanding fatigue resistance. Neolix or (Neoniti) Chatres-La Foret, France, is considered as one of the third-generation rotary file systems. This system employs a single file used with continuous rotation to prepare and clean the root canal, they are characterized with ease of use and efficient. Neoniti contain the following sizes: 20/25/40 with both 6% and 8% taper. It contains one C1 file for coronal enlargement and three A1 files. [11]

The cross-sectional designs for these five systems which had been used in this study as follow: for the One Curve file it was a triangle at the apical third and S-shape at the middle and coronal thirds. For the 2Shape file it was modified triangle cross-section. For the K3 i-File it was a square cross section. For the E3 Azure file it was modified S-shape. And for the last system which is Neolix file, it was a rectangular cross-section.

METHODS

Two hundred fifty 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. [12] All the samples were labeled and they were divided into five groups, named; group (A) prepared by One Curve, (B) 2Shape, (C) K3 i-File, (D) E3 Azure, and finally (E) Neolix. So there are five 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. For the first four groups, the speed was fixed at 350 rpm, and the torque was 3 Ncm. While for the last group (Neolix) the speed was 500 rpm, and the torque was 4 Ncm. The preparation of the samples started with the preparation of the glide path with manual and rotary instruments. [13] All 250 samples were prepared with manual file size #10 and then #15, after that a 125 ProGlider files from Dentsply with size 16 and taper 3% had been used to prepare the 250 samples, each file has been used to prepare 2 resin blocks. And then 250 Edge Files with size #20 and taper 4% had been used to prepare the 250 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 by the use of 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 first 4 systems and 9 strokes were used for the last system. 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 250 samples till size #20 and taper 4% (before starting the master preparation), all the samples were irrigated, cleaned and dried with a paper point. The inner surface of the canals of all samples stained with a black ink to be photographed with a customized device for photography, Atav Ateş A.[14]250 photographic images were taken with a Nikon

D7100 DSLR camera and Nikkor 105 mm micro-lens. The images were taken with 1:1 ratio and the camera was permanently fixed to a metal holder on the photography customized device, the camera was triggered with a remote control bottom to avoid any tiny movement and to get a precise and sharp resolution images. The samples were held by a metal holder to produce an identical image. 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 3 drops of the solution prior to starting preparation. After the finishing of master preparation, again all the 250 samples were irrigated with Sodium hypochlorite solution NaOCl 2%, cleaned and dried with paper points, to remove any remnant black stain in the inner wall of the prepared canal, and they were all kept in a room temperature for 48 hours to be completely dried. Then all the 250 samples were stained with red ink. [14] All the samples were photographed again with the same customized device keeping all the settings of the camera fixed and unchanged just like the first step. The 500 images of the samples representing before and after preparation were superimposed by a specialized person using Photoshop application 2020 to produce a single image for each sample with the two color included and super-imposed on each other. These images were introduced into Auto Cad application 2021 to do the required analysis and extrude the data (Canal longitudinal cross sectional area difference, Canal wall surface area difference, Canal volume difference, and SMI (Structure Model Index). The first data was the longitudinal sectional area before and after preparation was calculated, then the radius of the canal, and all the other data depend on these tow variables. Regarding the fifth variable which is the canal cross-section area difference, from each group of five repeated use of each file, the first and the fifth resin blocks were taken (R1 and R5), and the total number of the chosen blocks were 100 blocks. Each block was sectioned at the point of D8 which was the midpoint at the middle third of the canal, to cut the canal at a point in which the canal still straight and before the curvature of the J shaped canal. Using a sharp electrical metal saw all the blocks were sectioned, the remaining part of the resin blocks were all with the same length. Then all the sectioned blocks were photographed with the customized device for photography, the quality and the resolution of each single image were inspected and then subdivided into groups representing each used system. With the use of AUTO CAD 2021 application all the 100 images were analyzed to draw the lines representing the border line of each canal and determining the radius of each canal cross section. The magnification value which is used in the AUTO CAD to draw the demarcating lines of the canal boundary and the radius was 50X. After that all the collected data about radius and area of the cross section were entered into an Excel sheet to be processed with SPSS application to compare the final result of the work on this part of the study.

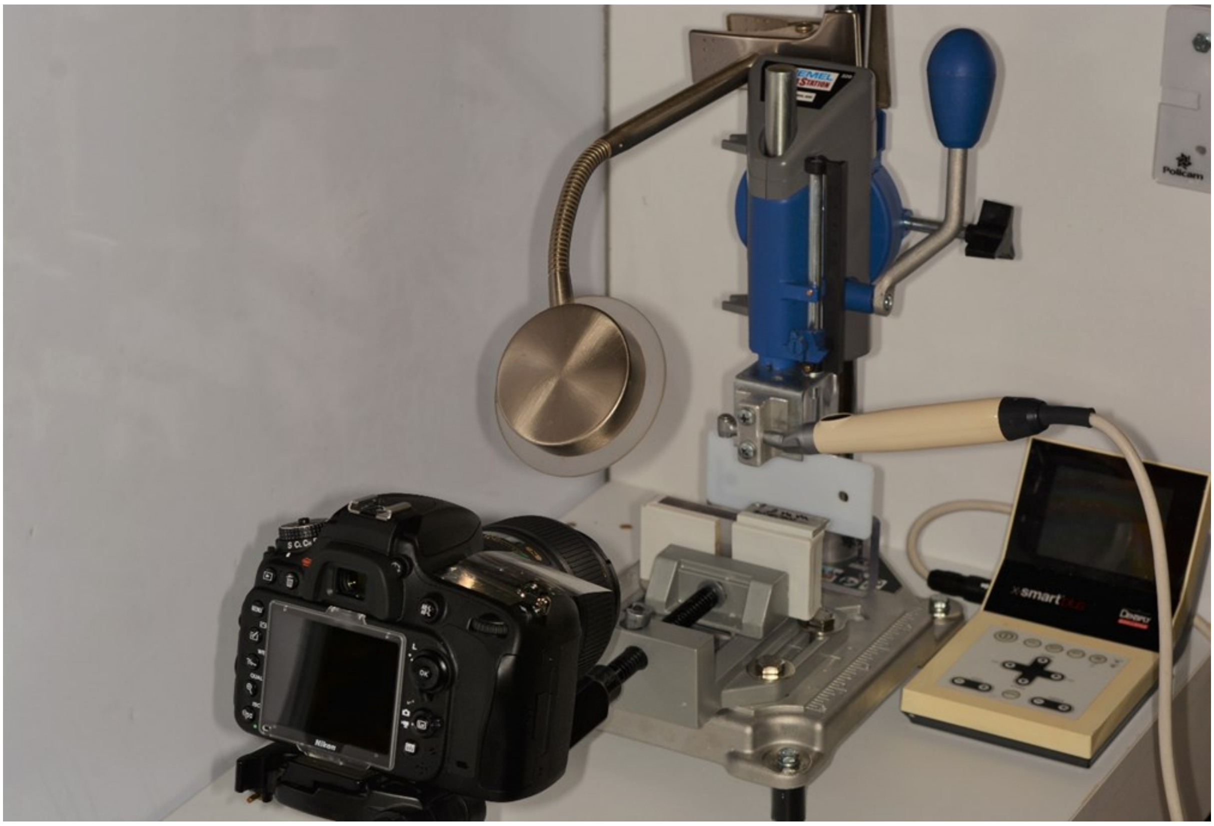

Figure 1: Customized device for resin blocks preparation.

Figure 2:Customized device for resin blocks photography.

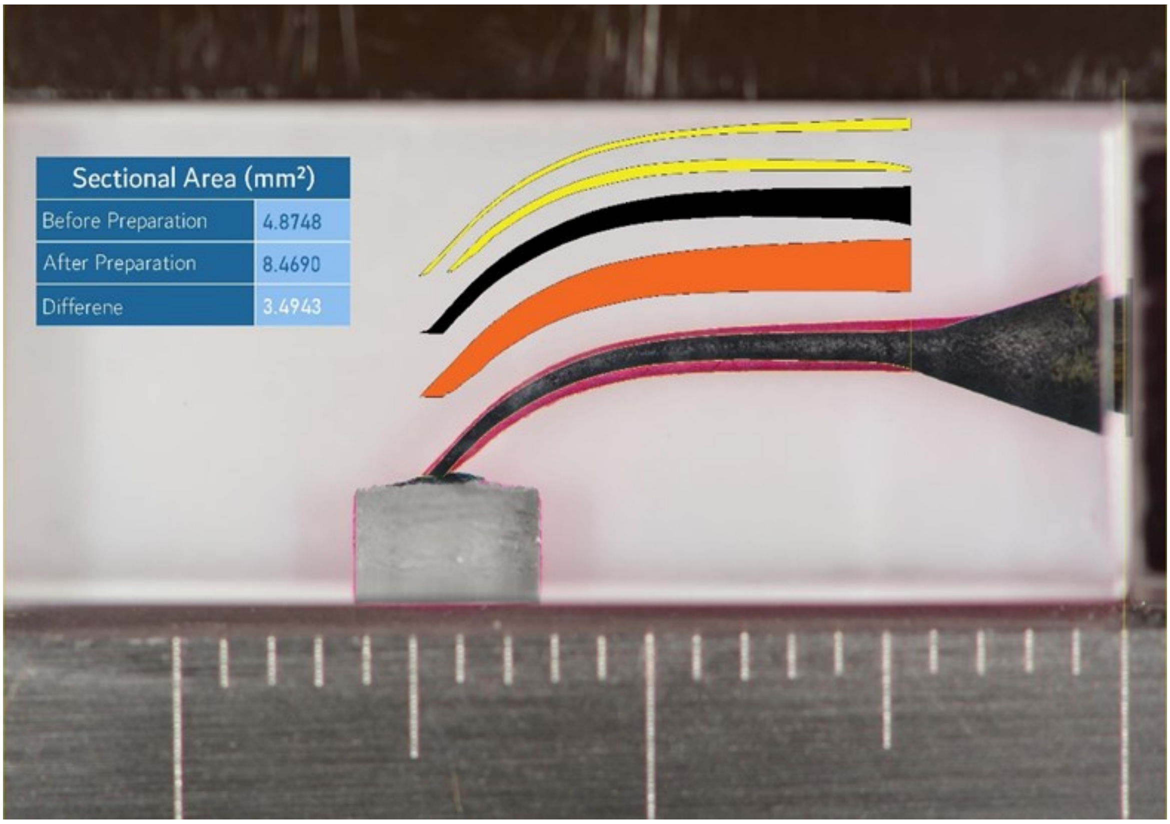

Figure 3: This image shows the superimposed canals in AUTO CAD application and the calculation of the longitudinal sectional area of the canals before and after preparation with the difference between them calculated in mm².

RESULTS

Descriptive statistics

The normality of data was checked using the Shapiro-Wilk test, accordingly non-parametric tests were used when indicated. Kruskal Wallis test (non-parametric test) was used to compare the groups, and the Dunn-Bonferroni test was applied as a post-hoc test. A p-value of ≤ 0.05 was considered as statistically significant. There were no instrument fractures, all the 50 files complete the 5 repeats completely. Also, there was no canal aberration in all the 250 samples. The mean values and standard deviation of the five systems are presented in Table (1). The following data represents the descriptive data schedules.

Table 1: Mean values and standard deviation (M (SD)), of the Longitudinal sectional area difference, Canal wall surface area difference, Canal volume difference, SMI (structure model index) difference, for all five

	Canal sectional area difference M (SD)	Canal surface area difference M (SD)	Canal volume difference M (SD)	Structure material difference (SMI) M (SD)
One Curve	1.702 (0.217)	5.346 (0.681)	1.352 (0.361)	0.276 (0.044)
2 Shape	1.740 (0.164)	5.465 (0.514)	1.709 (0.272)	0.271 (0.033)
K3 i-File	1.171 (0.204)	3.679 (0.639)	1.107 (0.219)	0.179 (0.036)
E3 Azure	2.156 (0.207)	6.773 (0.651)	2.105 (0.227)	0.351 (0.040)
Neolix	3.678 (0.188)	11.554 (0.592)	3.147 (0.397)	0.597 (0.047)

Results of the post-hoc test (Dunn-Bonferroni), Table (2):

Canal longitudinal sectional area difference: statistically there was no significant difference (P > 0.05) between One Curve and 2 Shape. And there was a significant difference (P < 0.05) between all the other systems when compared with each other. **Canal surface area difference:** statistically there was no significant difference (P > 0.05) between One Curve and 2 Shape. And there was a significant difference (P < 0.05) between all the other systems when compared with each other. **Canal volume difference:** statistically there was no significant difference (P > 0.05) between One Curve and 2 Shape, and between One Curve and K3 i-File. And there was a significant difference (P < 0.05) between all the other systems when compared with each other. **Structure Model Index (SMI):** statistically there was no significant difference (P > 0.05) between One Curve and 2 Shape. And there was a significant difference (P < 0.05) between all the other systems when compared with each other.

Table 2: Results of the post-hoc test (Dunn-Bonferroni) for all 4 parameters.

Canal longitudinal Sectional area difference

	Two shape	K3	AZURI	Neolix
One curve	1.000	< 0.001	< 0.001	< 0.001
Two shape		< 0.001	< 0.001	< 0.001
K3			< 0.001	< 0.001
AZURI				< 0.001

Canal Surface area difference

	Two shape	K3	AZURI	Neolix
One curve	1.000	< 0.001	< 0.001	< 0.001
Two shape		< 0.001	< 0.001	< 0.001
K3			< 0.001	< 0.001
AZURI				< 0.001

Volume difference

	Two shape	K3	AZURI	Neolix
One curve	0.117	0.162	< 0.001	< 0.001
Two shape		< 0.001	<0.008	< 0.001
K3			< 0.001	< 0.001
AZURI				< 0.001

Shaping ability

	Two shape	K3	AZURI	Neolix
One curve	1.000	< 0.001	< 0.001	< 0.001
Two shape		< 0.001	< 0.001	< 0.001
K3			< 0.001	< 0.001
AZURI				< 0.001

Cross-sectional area difference:
The cross-section difference was calculated by subtracting the cross-section area value of R1 from the R5, and the resulting data was as follows: for the One Curve and Neolix the data was in a positive value, which means that the final canal cross-section area after 5 repeat was larger than the R1. While for the other 3 systems (2Shape, K3 i-File, E3 Azure), the result was in the negative values, which means that the final canal cross-section area was smaller than the R1, all data shown in Table (3).

Table 3: Descriptive comparison between cross-sectional area differences of R5-R1 between all systems.

	N	Mean	Std. Deviation	Std. Error
One curve	10	0.00926	0.028218	0.008923
Two shape	10	-0.00838	0.014092	0.004456
K3	10	-0.00094	0.012465	0.003942
Azure	10	-0.00456	0.021730	0.006872
Neolix	10	0.01891	0.031292	0.009895

DISCUSSION

The results obtained in the present study reject the null hypothesis (H_0) that stated that the design of the cross-section of the Ni-Ti endodontic files would not affect the shaping ability during root canal preparation with repeated use. And the main finding of this study was that the cross-sectional design of the active part of the rotary instrument has a clear effect on its shaping ability. And this fact is completely coincides with the results of a study done by David Donnermeyer in 2020 (1) The least cutting efficiency was noticed with the square cross-section of the K3 i-File. While there was a close relationship between the values of the (One Curve, 2Shape, and E3 Azure files). And the most aggressive cutting efficiency was noticed with Neolix, which had produced the largest canal in all the calculated variables.

So the sequence of files designs according to their shaping ability and the cutting efficiency from the most aggressive to the least was as follow: Neolix (SMI: 0.597), E3 Azure (SMI: 0.351), One Curve (SMI: 0.276), 2Shape (SMI: 0.271), and lastly K3 i-File (SMI: 0.179). There was a statistically non-significant difference ($P > 0.05$) between the One Curve and the 2Shape systems, and this is due to the similarity of their design. While there was a statistically significant difference ($P < 0.05$) in comparing all the other systems with each other. The high cutting power of the Neolix could be related to the mode of cutting of the material by filing or crushing due to the form and texture of the metal surface of the file, which is highly rough and irregular in texture under scanning electron microscope examination, it has no cutting blades. While the other three systems (One Curve, 2Shape, and E3 Azure files), have a cutting blades. So they depend on cutting the dentin tissue from the inner surface of the canal rather than filling or crushing. The inner surface of the prepared canals with these systems (One Curve, 2Shape, and E3 Azure files), was noticed to be smoother than those prepared with Neolix.

Regarding the K3 i-File, which was the least file in aggressiveness and the weakest in shaping ability, this could be related to the neutral cutting angle of the cutting edges of the file, if we compare it with the (One Curve, 2Shape, and E3 Azure files) which has active cutting angles of their cutting edges. Also, the difference between the square and rectangular cross-sectional designs of the K3 i-File and the Neolix is that, the square one with a smooth sharp edge, and the rectangular with a rough margin at the cutting edges.

CONCLUSION

The conclusion derived from the present study is that the cross-sectional design of the instrument has an effect on the shaping ability and on the final shape of the prepared canal, including the diameter, the volume of the canal, as well as the texture of the inner surface of the canal.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest relevant to this article.

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