# Evaluation of centering ability of XP endo shaper, Edge Evolve and Hyflex CM in simulated curved canals (A comparative study)

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***Background and objectives:*** Cleaning and shaping principles of root canal must aim to respect the continuously tapering funnel from the root apex to the coronal access cavity, follow the original canal shape and maintain the apical foramen in its original spatial relationship to the periapical tissues and root surface. This study was conducted to compare centering ability using: XP endo shaper, Edge Evolve and Hyflex CM nickel-titanium instruments in simulated curved canals.

***Materials and methods:*** Sixty simulated curved canals of 40°curvature were divided into three groups and prepared to an apical size 30 using single-length technique for XP endo shaper, crown-down technique for Edge Evolve and Hyflex CM instruments. Centering ability was evaluated; the measurements were carried out at five different levels. Pre-and postoperative images of the canals were taken at a standardized position by a digital camera (Nikon D810 – 36 Megapixels, Japan) with 60mm macro lens. An assessment of the shape of the canal was determined using AutoCAD sofware. The data were analyzed statistically using one way ANOVA, Welch ANOVA, Least significant differences (LSD) and Games-Howell post hoc test.

***Results:*** the results of this study demonstrated that the Edge Evolve instruments showed a significantly better centering ability than both XP endo shaper and Hyflex CM at four levels of measurements except at last level (HO) which XP endo shaper scores the best centering ability. The Hyflex CM and XP endo shaper instruments scores similar results and were mostly close to each other after Edge Evolve instruments regarding canal centering ratio.

***Conclusions:*** The study demonstrated that Edge Evolve file maintained the original curvature significantly better than Hyflex CM and XP endo shaper files.

***Keywords:*** XP endo shaper, Edge Evolve, Hyflex CM, centering ability

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## Introduction

The most important step in root canal treatment is instrumentation of the canal to eliminate necrotic material, microorganisms and canal irregularities, to reach the ideal preparation of the canal which is a form of tapered funnel shape, from end point to the canal orifice that maintains the canal anatomy without any deviation from original canal curvature. Nickel titanium rotary instruments were introduced to overcome several undesirable characteristics of stainless-steel files, and because of the flexibility of these instruments which make them become very popular in endodontic practice and enable them to be used in conjunction with automated hand pieces, for better shaping during root canal preparation.[1,2]

One of the problems is when the instrument cannot follow the original path of the canal, because of its original straight shape and lack of flexibility necessary to bend through the canal's center tends to prepare the canal in a straighter path, the ideal preparation of the canal is not easy if the instrument is not stay centered in the canal during preparation and may cause many problems such as transportation, and undesirable aberrations such as blockage, elbows, zips, ledges, perforations, and the change in working length.[3,4]

In order to overcome these problems, manufacturers have been trying to make NiTi files of superior mechanical properties, particular design characteristics (cross-section, cutting angle, helical angle, radial grooves/edge, flutes, etc.), flexibility, and new manufacturing processes, previous studies have been listed the main advantages of NiTi files in the preparation of curved root canals, such as: creating less procedural errors when compared to stainless steel instruments, preserve working length, allowing more centralization of root canal preparation and better tapered, in addition to being faster. An advance in technology and manufacturing processes helps the practitioner to get closer to ideal root canal therapy, the perfection of the file was produced by touching all the walls of the canal without changing its shape [5,6]. In this study we use XP endo shaper (max wire), Edge Evolve (Fire wire) and Hyflex CM (controlled memory) NiTi files, so comparison of these different types of recently produced NiTi files, each of them has its own properties and characteristics can highlight the way to solve the above mentioned problems of root canal shaping. The aim of this study is to evaluate and compare the centering ability of three types of rotary nickel-titanium instruments.

## Materials and Methods

Sixty simulated curved canals, made of clear polyester resin (Dentsply, Maillifer, Switzerland) were used; the diameter and the taper of all simulated canals were equivalent to an ISO standard size 10 and taper 02 root canal instrument. The curvature was defined mathematically with a radius of 5.5 mm, resulting in an angle of 40° according to the method of Pruett.[7]

The resin blocks divided into three groups of 20 canals each, the first penetration was done with #10 K-file hand instrument to the full working length (15 mm). Patency was checked with the same size after each sequence. Prior to their preparation, each simulated canal was filled with a drawing ink (Blue color) and photographs of the un-prepared canals were taken by digital camera (Nikon D810 – 36 Megapixels) with 60mm macro lens in a standardized technique; the image was taken while the resin block is placed on the wooden platform, directly in front of the screen of the platform and the image was taken and transferred to the computer (Figure 1A).

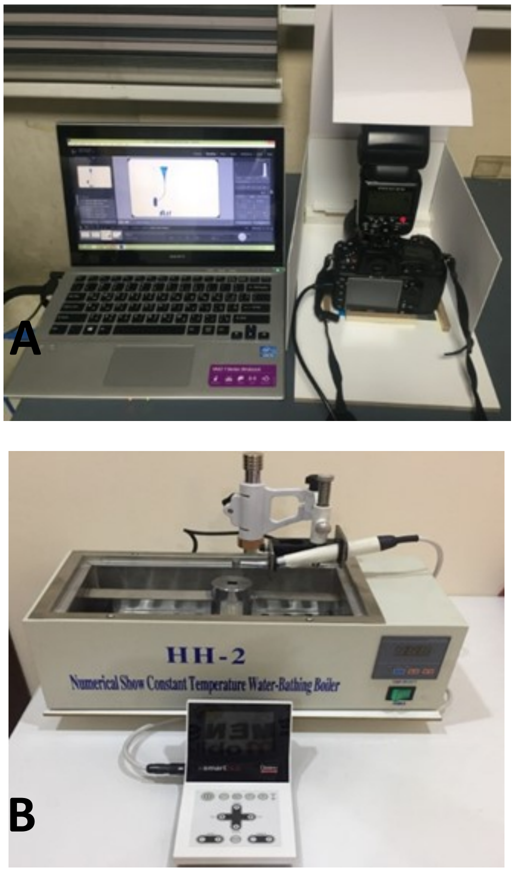


**Figure 1: A- Imaging of resin blocks with the standardized position of digital camera. B- Cylinder shaped steel holder inside a water bath fixed to dental surveyor with endo motor.**

Then the canal irrigated with distilled water using a disposable syringe with a 22-gauge needle to remove the ink to prevent its dryness and blocking the canal, the pre-operative image of the resin block that was stored in the computer.[8] Before instrumentation, for standardization of all samples a cylinder-shaped steel holder was made which the resin block was positioned inside to obscure the vision and simulate the clinical conditions thus ensuring that the process is carried out purely tactile sensation without bias to certain instrument, the cylinder-shaped steel holder was fixed inside a water bath to simulate the clinical conditions as much as possible for a group of samples that needs instrumentation at a specific temperature, then this water bath with resin block holder was placed on survey tray at 0 degree (parallel to horizontal plane) that measured with bar leveler, and the angle between this plane and the arm of the surveyor was 90 degree. The endo-motor handpiece that used for canal preparation that has been fixed to the arm of the survey and was perpendicular to the center of canal orifice (Figure 1B).

Glycerin was used to coat the instrument to act as a lubricant and copious irrigation with tap water was performed repeatedly before and after the use of each instrument; approximately 5 ml of water for each canal. Each instrument was used to enlarge one canal as follow[9,10]:

**Group A:** The XP endo shaper (FKG, La Chauxde-Fonds, Switzerland) was completed in a crown-down manner according to the manufacturer's instructions using a gentle in-and-out motion, the XP-endo Shaper is a "One File Shaper" it can start shaping at ISO diameter 15 and to achieve ISO diameter 30, but also to increase the taper from .01 to at least .04, it allows reaching a final canal preparation of minimum 30/.04 and this with only one file11. Before instrumentation, each resin block was placed inside a cylinder-shaped steel holder in a water bath which was filled with water and the temperature was set on (37 °C) to mimic clinical conditions.[12]

Once the instrument has negotiated to the end of the canal and has rotated freely, it was freely removed. The Endo-mate motor that used with XP endo shaper instruments was set into a permanent rotation at 800 rpm with a 16:1 reduction and torque at 1 Ncm. This was within the range suggested by the manufactures.[11]

**Group B:** The Edge Evolve (Edge Endo, New Mexico, USA) endodontic instrument was completed in a crown-down manner according to the manufacturer's instructions using a gentle in-and-out motion. The preparation sequence was as follow:

Taper .04 /size 20, 25, 30

Once the instrument has negotiated to the end of the canal and has rotated freely, it was freely removed. The Endo-mate motor that used with Edge Evolve endodontic instruments was set into a permanent rotation at 300 rpm with a 16:1 reduction and torque at 2 Ncm. This was within the range suggested by the manufactures.[13]

**Group C:** The Hyflex CM (Coltene/ Whaledent, Allstatten, Switzerland) endodontic instrument was completed in a crown-down manner according to the manufacturer's instructions using a gentle in-and-out motion. The preparation sequence was as follow:

Taper .04 /size 20, 25, 30

Once the instrument has negotiated to the end of the canal and has rotated freely, it was freely removed. The Endo-mate motor that used with Hyflex CM endodontic instruments was set into a permanent rotation at 500 rpm with a 16:1 reduction and torque at 2.5 Ncm. This was within the range suggested by the manufactures.[14]

Then canals were injected again with the drawing ink (red color) and the imaging procedure is repeated. Pre- and post-operative digital photographs were stored in computer and measurements were accomplished using AutoCAD software program. The difference between the canal configuration before and after instrumentation was determined for both the inner and the outer side of the curvature at five reference points.[15-18]

Point 1 (O): the canal orifice.

Point 2 (HO): the point half-way from the beginning of the curve to the orifice.

Point 3 (BC): the point where the canal deviates from the long axis of its coronal portion and is called the beginning of the curvature.

Point 4 (AC): the point where the long axes of the coronal and the apical portions of the canal intersect and are called the apex of the curve.

Point 5 (EP): the end point of preparation.

The mean centering ratio is a measure of the ability of the instrument to stay centered in the canal and the following mathematical formula was used to obtain a parameter:

$$\beta = [(D1 - D2)/ D] \times 100$$

Where; parameter β represent centering propensity of the filed canal (Figure 2).

**D1(X2-X1):** being the distance between the edge of the original (pre-operative) canal and the edge of the filed canal (postoperative) on the concave side.

**D2 (Y2-Y1):** is the distance between the edge of the original (pre-operative) canal and the edge of the filled (post -operative) canal on the convex side.

**D (X2 + Y2):** being the width of the filed canal.

The smaller the ratio, the better the instrument remained centered in the canal.

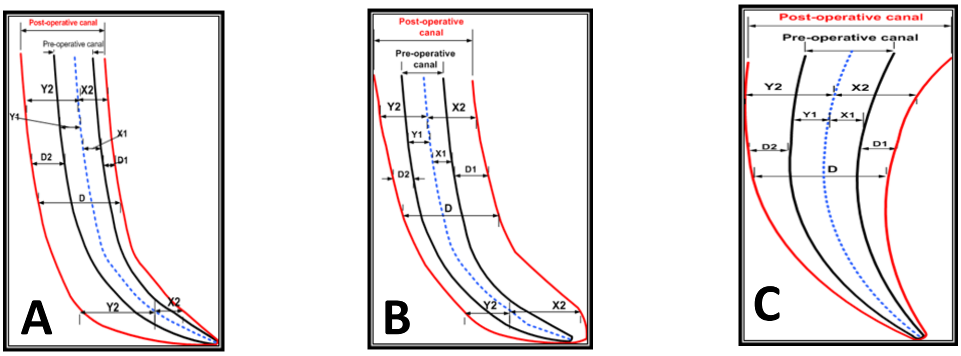


**Figure 2: Diagram representing transportation toward A. concave side of the canal: negative value, B. convex side of the canal: positive value, C. Diagram representing optimum centering ability without transportation.**

The measurements of (D1, D2, and D) are calculated in micrometers (µm), The value obtained from parameter β expressed in percentage (%) terms, the ideal result should be (0%) presenting no shift of long axis of filed canal, indicating an optimum centering ability and no transportation, while increasing the value indicates an increase in deviation of the long axis of the filed canal from that of the pre-operative canal whether to the convex or concave side, thus decreasing the centering ability.[15,16,18]

Statistical analysis was performed using SPSS version 22.0 software (SPSS Inc, Chicago, IL). The data were analyzed using one way ANOVA,Welch ANOVA, Least significant differences (LSD) and Games-Howell post hoc test.

## Results

The results of the descriptive statistics that included the minimum, maximum, mean, and standard deviation values of the canal centering ratio at five measuring levels for the three groups in (%) shown in table 1 and figure 3.

Table 1 showed that at all the five measuring levels, Edge Evolve (group B) showed the lowest mean value of centering ratio, while the Hyflex CM (group C) showed the highest mean value of centering ratio. The lowest mean value of centering ratio was showed by Edge Evolve at level (O) (1.194%), while the highest value showed by Hyflex CM at level (EP) (36.960%).

To identify the presence of statistically significant difference for centering ability of the canal among the groups after instrumentation at five levels, ANOVA test was carried on with reference to homogeneity of variance which is one of the most important parts on ANOVA test we can state that all five levels meet the criteria for centering ability which is given in table 2, if the *P*-value is less than or equal to our α level (0.05) for this test, then the $H_0$ is rejected and the variances are equal. If the *P*-value is greater than α level for this test, then we fail to reject $H_0$ which increases our confidence that the variances are equal, and the homogeneity of variance assumption has been met (Tables 3, 4 & 5).

**Table 1: Descriptive statistical results of the canal centering ratio (%) after instrumentation for three groups at five levels.**

| Level | Groups | N | Mean | Standard Deviation | Standard Error | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| O | A | 20 | 1.6780 | 0.34430 | 0.07699 | 1.08 | 2.50 |
| | B | 20 | 1.1945 | 0.24128 | 0.05395 | 0.64 | 1.58 |
| | C | 20 | 1.4015 | 0.25671 | 0.05740 | 0.75 | 1.72 |
| **HO** | A | 20 | 3.3695 | 0.52043 | 0.11637 | 2.28 | 4.56 |
| | B | 20 | 6.6195 | 1.28442 | 0.28721 | 3.97 | 8.92 |
| | C | 20 | 6.0040 | 1.19327 | 0.26682 | 3.20 | 8.71 |
| **BC** | A | 20 | 11.1650 | 2.16223 | 0.48349 | 7.92 | 17.65 |
| | B | 20 | 8.6205 | 1.69588 | 0.37921 | 4.65 | 11.75 |
| | C | 20 | 9.0720 | 1.66256 | 0.37176 | 6.19 | 12.83 |
| **AC** | A | 20 | 25.0935 | 5.02280 | 1.12313 | 12.23 | 32.74 |
| | B | 20 | 3.9550 | 0.78472 | 0.17547 | 2.03 | 5.38 |
| | C | 20 | 16.7410 | 3.24599 | 0.72582 | 11.06 | 24.14 |
| **EP** | A | 20 | 24.0865 | 4.23578 | 0.94715 | 17.13 | 32.54 |
| | B | 20 | 23.9665 | 3.98342 | 0.89072 | 16.27 | 32.76 |
| | C | 20 | 36.9605 | 5.03437 | 1.12572 | 27.17 | 45.57 |

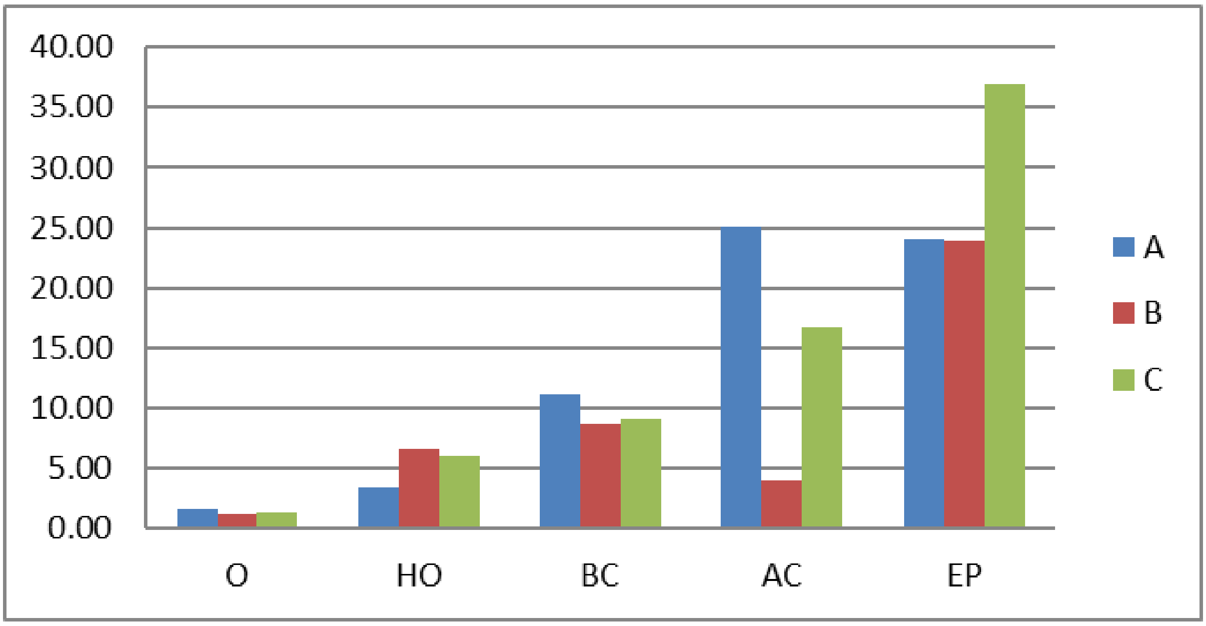


**Figure 3: Mean value for the centering ability of three different instruments at five level measurements in percentage (%)**

**Table 2: Test of Homogeneity of Variances for Centering ability**

| Levels | Levene Statistic | df1 | df2 | P Value |
|---|---|---|---|---|
| **O** | 1.063 | 2 | 57 | 0.352 |
| **HO** | 4.823 | 2 | 57 | 0.012 |
| **BC** | 0.244 | 2 | 57 | 0.784 |
| **AC** | 7.286 | 2 | 57 | 0.002 |
| **EP** | 0.385 | 2 | 57 | 0.682 |

**Table 3: Welch test for comparing mean values between the instrument sequences at level HO and AC**

| Levels | Statistic | df1 | df2 | P Value |
|---|---|---|---|---|
| **HO** | 81.882 | 2 | 32.076 | <0.001 |
| **AC** | 7.286 | 2 | 57 | 0.002 |

**Table 4: The multiple comparison Games-Howell for level HO and AC**

| Instrument levels | | | Mean Difference (I-J) | Std. Error | P Values |
|---|---|---|---|---|---|
| HO | A | B | -3.25000* | 0.310 | <0.001 |
| | | C | -2.63450* | 0.291 | <0.001 |
| | B | A | 3.25000* | 0.310 | <0.001 |
| | | C | 0.61550 | 0.392 | 0.271 |
| | C | A | 2.63450* | 0.291 | <0.001 |
| | | B | -0.61550 | 0.392 | 0.271 |
| **AC** | A | B | 21.13850* | 1.137 | <0.001 |
| | | C | 8.35250* | 1.337 | <0.001 |
| | B | A | -21.13850* | 1.137 | <0.001 |
| | | C | -12.78600* | 0.747 | <0.001 |
| | C | A | -8.35250* | 1.337 | <0.001 |
| | | B | 12.78600* | 0.747 | <0.001 |

**Table 5: ANOVA test of Centering Ability at the level (O, BC, and EP)**

| Instrument level | | Sum of Squares | df | Mean Square | F | P Value |
|---|---|---|---|---|---|---|
| **O** | Between Groups | 2.354 | 2 | 1.177 | 14.550 | <0.001 |
| | Within Groups | 4.610 | 57 | 0.081 | | |
| | Total | 6.964 | 59 | | | |
| **BC** | Between Groups | 73.727 | 2 | 36.863 | 10.721 | <0.001 |
| | Within Groups | 195.992 | 57 | 3.438 | | |
| | Total | 269.719 | 59 | | | |
| **EP** | Between Groups | 2230.655 | 2 | 1115.328 | 56.564 | <0.001 |
| | Within Groups | 1123.933 | 57 | 19.718 | | |
| | Total | 3354.589 | 59 | | | |

In order to discover the difference between the groups in level O, HO, and AC, LSD test enables us to find the differences. Table 6 displays the multiple comparison tests between the mean values of sequences in each instrument. Therefore, it can be concluded that the differences are given among all instruments at O level since their p-values are less than 0.05. However, it is worth stating that there is no difference between at level BC and EP between the instrument (B and C) and (A and C) respectively.

**Table 6: LSD test for multiple comparisons between the instruments for Level (O, BC, and EP)**

| Instrument level | | | Mean Difference (I-J) | Std. Error | P Value |
|---|---|---|---|---|---|
| O | A | B | .48350* | 0.090 | <0.001 |
| | | C | .27650* | 0.090 | 0.003 |
| | B | A | -.48350* | 0.090 | <0.001 |
| | | C | -.20700* | 0.090 | 0.025 |
| | C | A | -.27650* | 0.090 | 0.003 |
| | | B | .20700* | 0.090 | 0.025 |
| **BC** | A | B | 2.54450* | 0.586 | <0.001 |
| | | C | 2.09300* | 0.586 | 0.001 |
| | B | A | -2.54450* | 0.586 | <0.001 |
| | | C | -0.4515 | 0.586 | 0.444 |
| | C | A | -2.09300* | 0.586 | 0.001 |
| | | B | 0.4515 | 0.586 | 0.444 |
| **EP** | A | B | 0.12 | 1.404 | 0.932 |
| | | C | -12.87400* | 1.404 | <0.001 |
| | B | A | -0.12 | 1.404 | 0.932 |
| | | C | -12.99400* | 1.404 | <0.001 |
| | C | A | 12.87400* | 1.404 | <0.001 |
| | | B | 12.99400* | 1.404 | <0.001 |

## Discussion

One of the major determinants of quality canal shaping ability of an endodontic instrument is its ability to stay well centered within the root canal space and not produce procedural errors.[19]

Numerous methodologies exist to assess the root canal centering ability of endodontic instruments, in this study; canal preparation was assessed using a readymade resin block model where area differences in the amount of canal centering ability in the pre- and post-instrumented canals were assessed according to the instrument. Five defined levels were measured for area differences, the lower the resultant area difference between the pre and post-instrumentation images in this defined area can be interpreted as an endodontic instrument with superior shaping abilities due to the fact that it has caused less canal morphological changes, good centering ability, and therefore better maintained the original canal anatomy.[16,18]

Studying the root canal instrumentation and characteristics of different instruments is important because it provides the clinician with valuable insight into the ever -expanding endodontic armamentarium available so that they can make informed decisions regarding the most effective and safe instruments to complete root canal preparation objectives.

When comparing the centering abilities of different instruments, it is important to have a similar apical preparation diameter, in this study the final apical preparation was set to size 30 and taper 4% in each group for the standardization, and according to Weine 2004 who believed in limiting the apical enlargement to size 25 or 30 to minimize undesirable effect like; ledging or zipping, due to decrease of instruments flexibility with increase in its size, all canals were be enlarged to apical size 30 and taper 4%, larger preparations of root canal may increase the risk of canal transportation and unwanted undermining of the tooth structure.[20-23]

To assess instrument centering abilities, resin blocks were used in this study because they provide a number of advantages over extracted teeth; First, standardization of resin blocks in canal curvature and length, which difficult to be seen in extracted teeth.

Second, allows for imaging of the final canal instrumentation by direct measures as well. Lastly, Hardness of dentin varies when we use extracted teeth as much as 25%, especially when derived from many different donors.[24] This may cause many problems in root canal instrumentation research because it hinders the ability to compare one sample to another when such variability exists in the samples naturally. Therefore, Dr. Weine in 1975 developed simulated root canals in resin blocks for research models standardization instead of using extracted teeth with wide disparities, as well as to facilitate canal preparation technique research. A study was done on these resin models which showed that there were no significant differences found in the shape prepared by hand filing techniques in extracted teeth compared with simulated canals in resin blocks.[25]

While there are many advantages to using simulated canals in resin blocks, there are several factors that should be considered when interpreting results from an instrumentation study using these models, the evaluation of the canal preparations is limited to the longitudinal plane of the canal, which only represents two-dimensions when in reality endodontic instruments are preparing the canal in three-dimensions, resin blocks have different thermal properties than dentin.[19,24] Endodontic rotary instruments generate a significant amount of frictional heat during instrumentation procedures, which may be capable of melting the resin of the blocks in some instances. This represents a scenario that is vastly different from clinical applications of endodontic instruments as this is not an occurrence observed in teeth clinically.[24]

In this study for canal preparation (X-smart plus motor) was used that can be set for various types of rotary instruments and is able to rotate the instrument in an inverted direction when the instruments are locked in the canal to prevent the fracture of the instrument.[26]

The findings of this study displayed that all of the three systems showed a trend to straighten the canals; yet it was the Edge Evolve system who preserved the best rate of centering among the inner/outer walls over the total length of the simulated curved canals (i.e. values closest to 0%) than that of the XP endo shaper and Hyflex CM instruments in four measurement levels.

Currently there are no studies done on Edge Evolve file till now to agree or disagree with, these observations could be related to the following reasons: first reason could be attributed to Fire wire Edge Evolve which is an annealed heat-treated (AHT) nickel-titanium alloy, and have triangular open flute design, due to this proprietary processing, Edge Evolve files may be slightly curved, this is not considered a manufacturing defect and can easily be straightened with the fingers, once it is inside the canal; the Edge Evolve follows and conforms to the natural canal anatomy and curvatures.[13]

This result agrees with Versani et al., in 2017 showed in his study that XP endo shaper significantly altered the overall geometry of the root canal when compared with Edge File which is fire wire NiTi alloy, This may be explained because the XP-endo Shaper instrument must be activated at a high rotational speed using long up-and-down movements throughout canal preparation.[30]

XP endo shaper, this file has a retracted form to rectilinear geometry when it is in a martensitic phase (rest position or static) and a structured form when in the austenite phase (working position or dynamic state). The transition from the martensite phase to the austenite phase occurs naturally in the body temperature between 32°C and 37°C with austenitic transformation finishing temperature around 35°C. In a dynamic state, the instrument has a twisted shape, with several twists twisted along its length, and because of this property a constant temperature water bathing boiler was used and filled with water and the temperature was set on (37C) to mimic clinical conditions during instrumentation with this file.[12]

This finding of XP endo shaper disagrees with other studies such as Živković S. et al, in 2017 and Al-khazali and Salim in 2018 that showed in their results best-centering ability of this file when compared with other instruments.[27,28] In this study the centering ability of XP endo shaper is less than Edge Evolve may be because the file has "snake" shaper, superelasticity and extreme flexibility these properties when combined with continuous rotation at very high speed "800-1000 rpm" and minimal torque may cause the file not to remain in the center of the canal during instrumentation, and finally, the deviation from the center of the canal instrumented by XP endo shaper may be related to six cutting edges at the tip called (booster tips) which enable it to start shaping after a glide path of at least ISO 15, and to gradually increase its working field to achieve an ISO 30.[11]

In this study the result of Hyflex CM disagrees with study done by Burklein et al, 2014 and Perez, 2015 which showed better centering ability of Hyflex CM compared with other files, this disagreement may be because the canals instrumented in these studies were "S" shaped and the taperness of other files was larger than Hyflex CM.[31,32]

Hyflex CM is characterized by flexibility and manufactured using a unique thermomechanical process that controls the material's memory, making the files extremely flexible. These files demonstrate martensitic properties at room temperature,[19] which is not observed with conventional NiTi metal. This gives the file the ability to follow the anatomy of the canal very closely, without creating undesirable lateral forces on the outer canal wall, reducing the risk of ledging, transportation, or perforation, also because of symmetrical "S" shaped cross section with three cutting edges except the instruments with size 25, .04 taper, which have a square cross-section with four flutes,[29] a concept emerged which revolutionized the technology of rotary endodontic files, which was based on 'Controlled memory' in contrast to the classical 'Shape memory' one.[14]

## Conclusion

This study showed that Edge Evolve file scores better-centering ability than XP endo shaper and Hyflex CM at four levels of measurements except at (HO) level which

CM file showed the second better centering ability at three levels (O, BC, and AC) than XP endo shaper which was better than Hyflex CM at (HO and EP) level, therefore, this file should be used with care to avoid excessive removal of resin and consequently dentine in curved canals.

The greatest canal transportation and least centering ability in all rotary file system used in this study were at the apical portion of the canal at endpoint (EP) level, and the least canal transportation and the best ability to stay centered was recorded in the coronal third at orifice (O) level.

## Conflicts of interest

The authors reported no conflict of interest.

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