Research Paper

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The Shaping Ability of two Reciprocating File Systems in L-Shaped Simulated Root Canals

Medical Science

KEYWORDS : reciprocating motion, shaping ability, simulated curved canals, WaveOne, SafeSiders.

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ABSTRACT

Aim: The aim of this study is to evaluate the shaping ability of two reciprocating file systems (WaveOne and SafeSiders) in comparison with the hand instrument (K-file) during the preparation of L-shaped simulated root canals.

Materials and Methods: Sixty (n=60) endodontic resin training blocks were divided into three groups (n=20) according to the type of file used to prepare the canals (WaveOne, SafeSiders and K-files). Pre and post instrumentation images were recorded and superimposed after preparation, images were analyzed by (AutoCAD 2008). Comparison among the different files was evaluated for the working length change, canal aberration and width measurement assessment (total, inner and outer) at different points in canals: canal orifice, half-way to orifice, beginning of the curve, apex of the curve and apical end. Data were analyzed using one way ANOVA, Tukey HSD, paired T-test, and Fisher's Exact test.

Results: less working length change was found in WaveOne system with no significant difference between WaveOne and K-files instrumentation systems. SafeSiders and K-files instrumentation systems created significantly more canal aberration than WaveOne instrumentation systems, and in width measurement there was a significant difference between the mean values of total, inner and outer width of material removal among the three systems at all measuring points (orifice, half-way to orifice, beginning of curve, apex of curve and apical end).

Introduction

Cleaning and shaping of the root canal system is the main objective of root canal treatment, the biological objective is to clean the root canal system of the bacteria, bacterial byproducts, maintain the health of periradicaler tissue by preventive the forcing of debris and help of healing of tissue by creation of sufficient space for intra- canal medicaments and subsequent obturation (Schilder, 1974).

Schilder in (1974), give five mechanical objective which help to end the root canal treatment with continuously funnel shape with the smallest diameter at the apical end and the largest diameter of the orifice to gather with maintaining the original shape of root canal that help provide space for placing the obturation material.

Shaping root canals is difficult and time consuming, particularly in severely curved canals. Endodontic treatment started with hand instrument made from stainless steel which consider stiff material, using stainless steel hand files caused more canal transportation and required long preparation time (Li et al., 2004). Stainless steel files resulted in a significantly greater loss of the working length (Krishna et al., 2010)

To overcome the rigidity of stainless steel files, Nickel Titanium (NiTi) files were introduced in endodontic treatment, which are known for their flexibility in bending and torsion, as well a superior resistance to corrosion, compared with stainless steel files (Kazemi et al., 2000), the file is able to return to its original shapes, due to its pseudo elastic properties (shape memory) (Vaudt et al., 2007).

Reciprocation defined as any repetitive back and forth motion. Using of reciprocating motion resulting in the more canal centered when compare with continuous rotation (Franco et al., 2011). Reciprocating motion in curved root canals will increase the lifespan of nickel-titanium rotary file (You et al., 2010).

WaveOne single file system uses under reciprocating motion. A study showed the WaveOne Primary reciprocating single-file has better maintained the original canal anatomy, with less modification of the canal curvature in resin block in comparing with the ProTaper system up to F2 (Berutti et al., 2012).

The SafeSiders have a serial file system, stainless steel and (NiTi) files using under reciprocation motion.

The aim of this study is to evaluate the shaping ability of two reciprocating file systems (WaveOne and SafeSiders) in comparison with the hand instrument (K-file) during the preparation of L-shaped simulated root canals.

MATERIALS AND METHODS

Resin blocks

Sixty L-shaped endodontic -training blocks (Endo training block-L Dentsply-Maillefer, Ballaigues, Switzerland), each of these blocks had a 40-degree curvature according to Schneider method (Cunningham and Senia, 1992). Two grooves were drilled in each block on outer and inner side of curvature using a high speed hand piece with a long taper diamond bur, with numbers to facilitate superimposed of the images.

Sample distribution

Sixty (n =60) L-shaped simulated root canal blocks were divided into three groups (n=20) according to the type of file used to prepare the canals. The first group was prepared with WaveOne Primary files (Dentsply-Maillefer, Ballaigues, Switzerland) with reciprocation motion 150 degrees CCW and 30 degrees CW. The second group was prepared with SafeSiders systems (Essential Dental Systems, South Hackensack, NJ, USA) with 30 to 60 degree reciprocation motion. The third group (control group) was prepared with hand K-file stainless steel hand instrumentation (Dentsply-Maillefer, Ballaigues, Switzerland) using a step-back-back preparation technique.

Preoperative imaging

A preoperative image of each simulated resin block was recorded by a digital microscope (Dino-Lite, Taiwan, AM413ZT) that has 1.3 megapixels sensor and up to 8×magnification. In order to get a standardized and reproducible picture, an accessories Dino-Lite stand MS35B was used for the best fitting of a digital microscope. A digital microscope was placed at a fixed distance (10 cm) from the blocks. A custom made template was made from self-cured acrylic to ensure placement of the block in a fixed place under digital microscope lens in mesio-distal view. Each canal was injected with red ink before taking the image, and the image was saved as a JPEG file (Figure1).

Simulated canal preparation

Simulated canals were instrumented to the full working length (16 mm), the length was measured by using digital calipers (Caliper, Steco, Germany) after recording a preoperative image.

Distilled water used as irrigation with a disposable syringe, gauge 27 needle and EDTA (Cream for root canal cleaning and preparation, META BIOMED, Korea) as a lubricant. Glide path with K- files (Dentsply-Maillefer, Ballaigues, Switzerland) size 08/0.02 and 10/0.02 was created prior to instrumentation with the all the groups. Each file was used to enlarge four canals only (Saber et al., 2014; Bürklein et al., 2012).

Group I: Twenty simulated root canals (L-shaped) was prepared using WaveOne Primary files tip size 25 in a reciprocating motion as manufacturer's instruction using crown down preparation technique with the reciprocation hand piece (Dentsply-Maillefer, Ballaigues, Switzerland) at 350 RPM speed. The shaping procedure started with slow in-and-out pecking motion. The flutes of the instrument cleaned after three pecks.

Group II: Twenty simulated root canals (L-shaped) were prepared using SafeSiders rotary system in a reciprocating motion as manufacturer's instructions using crown down preparation technique with the reciprocation hand piece Endo-Express®, Essential Dental Systems, South Hackensack, NJ, USA) at 2500 RPM speed. The shaping procedure started with (08/0.02, 10/0.02, 15/0.02, 20/0.02, Pleezer, 25/0.02, 30/0.02, 30/0.04, 35/0.02, 40/0.02, 25/0.06) to the full working length.

Group III: Twenty simulated root canals (L-shaped), the control group was prepared using K-files stainless steel (Dentsply-Maillefer, Ballaigues, Switzerland) hand instrumentation using step-back preparation technique. The shaping procedure started with 15/0.02, 20/0.02/, 25/0.02 to the full working length, then step-back continuous with 30/0.02 (W.L-1), 25/0.02 (W.L), 35/0.02 (W.L-2), 25/0.02 (W.L), 40/0.02 (W.L-3), 25/0.02 (W.L).

Assessment of canal preparation

A post-operative image of each sample shoot in the same conditions used in shooting the pre-operative image after injecting the block with red ink. The preoperative and post-operative images were superimposed using imaging software (Adobe Photoshop Cs4). The composite image was assessed using a computer program AutoCAD 2008 (Autodesk, SanRafeal, CA, SA).

Working length change

Following preparation, the final length of each canal was re-measured after preparation using digital calipers (STECO, Germany). A#25 K-files (Dentsply-Maillefer, Ballaigues, Switzerland) was inserted into the prepared canal. The final length of the canal, then subtracted from the original length to give the loss of working length (Yoo and Cho, 2012).

Canal aberrations assessment

Each simulated resin block was assessed for the presence of canal aberrations, including, zip and elbow, ledges, perforation, danger zone and coronal narrow, according to (Al-Omari et al., 1992A; Al-Omari et al., 1992 B).

1-Apical zip: irregular widening of the area at the endpoint of the canal where the resin had been largely removed from the outer aspect of the curve.
2-Elbow: a narrow region of the canal associated with and coronal to a zip.
3-Danger zone: excessive removal of resin from the inner aspect of the curve.
4-Coronal narrow: a narrowing of the canal associated with and coronal to a danger zone.
5-Perforation: a separate and distinct false canal towards the end-point of the canal which was not confluent with the original canal and which occurred along the outer aspect of the curve.
6-Ledge: a distinct irregularity along the outer wall of the canal at or near the curve, not substantial enough to be considered a perforation.

Width measurements

The amount of resin removed as a result of instrumentations was measured at fixed measurement position points at the inner side of curvature, outer side of curvature and total amount removed.

Superimposed image using Adobe Photoshop detailed the outline of the original canal per-operative and the outline of the canal post-operative; it was possible to quantify the amount of resin material removed by measuring the difference in width between the original canal and prepared canal. All measurements were made by drawing a line perpendicular to the axis of the original canal and converted into 'real' distances using a computer program AutoCAD 2008. Measurements were taken at fixed measurement position. The total width of the prepared canal and the width of the resin removed from the outer and inner aspects of the curve from the original canal to prepared canal were determined.

The removed resin was calculated at five different points using Alodeh & Dummer, (1989) methods. The total, inner and outer width was measured perpendicular to the long axis of the canal (Figure 2).

Position 1: Canal orifice.
Position 2: Half-way from the beginning of the curve to the orifice.
Position 3: Beginning of the curve. The point where the canal start to deviate from the long axis of the straight part of the canal.
Position 4: Apex of the curve. This was determined by the intersection of two lines, one drawn along the outer border of the straight part of the canal and the second drawn along the outer border of the apical aspect of the canal.
Position 5: Apical end, this represents the end point of the preparation.

Statistical analysis

All data recorded and stored on PC and analyzed using the SPSS statistical analysis program. Working length changes and width measurements between systems were analyzed using one way ANOVA and Tukey HSD, width measurements within the systems were analyzed using paired T-test whiles canal aberrations were analyzed using Fisher's Exact test. Probability of $P<0.05$ was set as a reference for statistical significance.

RESULTS

Working length change

The mean loss of working length that occurred with different instrument is shown in Table 1. There was a significant dif-

ference in the loss of working length between the three groups (P=0.028). WaveOne has less working length change which is significantly less compared with SafeSiders. There was no significant different between working length change in canals prepared by SafeSiders and K-files.

Incidence of canal aberration with L-shaped canals
Regarding the incidence of canal aberrations, the results are summarized in Table 2

Apical zip/Elbow
There were significant differences among the three groups (P=0.000). WaveOne has a lowest percentage of apical zip and elbow incidence in comparison with than SafeSiders and K-files, with no significant differences between SafeSiders group and K-files group.

Danger zone /Coronal narrow
There were significant differences among the three groups (P= 0.000). WaveOne has no danger zone and coronal narrow incidence in comparison with SafeSiders and K-files, with no significant differences between SafeSiders group and K-files group.

Ledge

However, there was no significant difference in ledge incidence among the three groups (P=0.841).

No perforation was observed among the three groups.

Width measurements within the systems
WaveOne
Statistical analysis using a paired T-test revealed that there was a significant difference between the outer mean values and inner mean values at all measurement points except at apex of curve, in WaveOne system (Figures 4 and 5).

SafeSiders
Statistical analysis using a paired T-test revealed that there was a significant difference between the outer mean values and inner mean values at all measurement points except at half way of orifice, in SafeSiders system (Figures 6 and 7).

K-files
Statistical analysis using a paired T-test revealed that there was a significant difference between the outer mean values and inner mean values at all measurement points except at apex of curve, in K-files system (Figures 8 and 9).

Width measurements between the systems
The mean values of the total width of canals prepared with the three systems are summarized in the Table 4. The one way ANOVA test revealed that there was a significant difference between the mean values of the total width of material removal among the three systems at all measuring points (orifice, half-way from the beginning of the curve to the orifice, beginning of curve, apex of curve and apical end) (Figure 10).

The mean values of the outer width of canals prepared with the three systems are summarized in the Table 5. The one way ANOVA test revealed that there was a significant difference between the mean values of the outer width of material removal among the three systems at all measuring points (orifice, half-way to orifice, beginning of curve, apex of curve and apical end) (Figure 11).

The mean values of the inner width of canals prepared with the three systems are summarized in the Table 6. The one way ANOVA test revealed that there was a significant difference between the mean values of inner width of material removal among the three systems at all measuring points ((orifice, half-way to orifice, beginning of curve, apex of curve and apical end)) (Figure 12).

DISCUSSION
Method
The aim of our study to compare the shaping ability of the two reciprocation system using WaveOne and SafeSiders based on different reciprocation motion in comparison to the hand K-files using step-back technique as standard technique by determined the working length change, canal aberration and width measurement by determining the total amount of the resin that removes from the outer (concave) and the inner (convex) sides of the curvature in L-shaped simulated resin blocks. As previous studies have been demonstrated using of endodontic instruments in reciprocating motion, maintaining the original curvature of canal (Berutti et al., 2012; Franco et al., 2011; You et al., 2011).

Photographic assessment in resin blocks has been used in several previous studies as an assessment method for shaping ability of the rotary system (Madureira et al., 2010; Suneelkumae et al., 2010; Aydin et al., 2012; Goldberg et al., 2012; Muñoz et al., 2014; Dhingra et al., 2014).

To assess the shaping ability of different endodontic system two experimental models have been used both in simulated curved canals and human teeth. In contrast to using human teeth in the assessment of shaping ability of the endodontic system simulated curved canal in resin block are able to provide standardizes condition in term of diameter, length and angle of canal curvature and consider as an ideal experimental model to allow direct comparison of the shaping ability of different system (Schäfer et al., 1995). This method of assessment based on the superimposition of pre and post-operative images which provide the information about incidence of canal aberration and help in measurement the amount of material removed at each evaluation points which reflects the behavior of the instrument in several critical points along the canal.

However the hardness difference between dentin and experimental resin should be taken in consideration in extrapolating of the resistance to the clinical situation (Peters 2004; Suneelkumar et al., 2010). Another drawback of using rotary instruments in resin block is heat generation, which may soften the resin material (Kum et al., 2000).

Each instrument has been used for four times as the WaveOne single-file reciprocating system is recommended to be used as single-patient instruments, and most of times the maximum number of root canals per tooth is four (Saber et al., 2014) and we applied this principle for all systems to have the standardization.

Working length change
Our study showed working length changes occurred in all canals with all instrumentation systems following the preparation. There was no significant difference between WaveOne and K-files and no significant difference between working length change in canals prepared with SafeSiders and K-files instrumentation systems , this finding is consistent with (Yoo and Cho, 2012) when they found no significant difference in working length change between WaveOne and K-files. There was significantly different between WaveOne and SafeSiders in a working length change in L-shaped canals, this finding is consistent with study (Rhodes et al., 2011) but they used the Votex file system (Dentsply, Tulsa Dental Specialities, Tulsa, OK, USA) (M-wire).

On the other hand, there was no significant difference between working length change in canals prepared with SafeSiders and K-files instrumentation systems as SafeSiders system mainly composed of stainless steel instruments with few (NiTi) instru-

ments, this observed is consistent with the investigation of (Krishna et al., 2010) who compared (NiTi) files to stainless steel files they found greater working length change with stainless steel files. The possible reasons are due to less flexible instruments with a tendency to straightening of curved canals during canal preparation (Schäfer 1995; Thompson and Dummer, 2000A).

Canal aberrations

The use of WaveOne instrumentation system resulted in less canal aberration in L-shaped canals after instrumentation compared to SafeSiders and K-files instrument systems, this difference was statistically significant. This result was consistent with (Yoo and Cho, 2012; Lim et al., 2013; Kim et al., 2013; Sabar et al., 2014; Gergi et al., 2014) where they used WaveOne in preparation of resin blocks and natural teeth. This can be attributed to several reasons: first, WaveOne instrument is made from M-wire (NiTi) which characterized by superior flexibility compared with conventional (NiTi) wire (Pereira et al., 2012). Secondly, WaveOne files have a variable cross section from D1 to D8 modified convex triangular and from D9 to D16 convex triangular with non-cutting tip to improve the flexibility of files and the safety of the instrument (Webber et al., 2011).

SafeSiders and K-files instrumentation systems created significantly more canal aberration with no significant difference between both systems. Similar results have been established by (Kassim and Al-Azzawi, 2012; Schirrmesister et al., 2006) when compared (NiTi) instrumentation systems to stainless steel instrumentation systems in resin bock and with Miglani et al., (2004) when compared (NiTi) instrumentation systems to stainless steel K-files instrumentation systems in first mandibular premolars. Because of the rigidity of stainless steel files highly incidence of canal aberration appears (Al-Omari et al., 1997; Schäfer et al., 1995; Kassim and Al-Azzawi, 2012).

Rhodes et al., (2011) and Ceyhanli et al., (2014) reported similar result when compared SafeSiders to (NiTi) instrumentation systems in natural teeth. The reason for that using of larger sized stainless steel instrument will increase the rigidity of file ending by more canal aberration (Rhodes et al., 2011). The rigidity of files on both systems could be the reason no significant difference between SafeSiders and K-files systems in incidence of canal aberration.

Width measurements

Total width measurement shows the canals prepared with WaveOne systems, preserved the shaped of L-shaped canals with gradually decreased the amount of resin material removed from the orifice to the apical end produced a continuously tapered funnel shaped. This result was consistent with (Yoo and Cho, 2012; Berutti et al., 2012; Bürklein et al., 2012; Goldberg et al., 2012; Lim et al., 2013; Kim et al., 2013; Sabar et al., 2014; Gergi et al., 2014; Dhingra et al., 2014) when they used WaveOne systems in preparation of resin blocks and natural teeth.

Comparing the amount of resin removed between inner width and outer width we found more resin had been removed from the outer width at the orifice and half to orifice, unlike Yoo and Cho, (2012) they found more material removed from the inner width. The possible reason that the direction of files insertion in the canals. At the beginning of curve more material removed from inner width, with equal amount of material removed from inner width and outer width at apex of curve and more form outer width with at apical end this result is consist with (Yoo and Cho, 2012).

Several reasons can be attributed that Wave One system has excellent shaping ability As reported previously: first WaveOne instrument is made from M-wire (NiTi) which is characterized by superior flexibility compared with conventional (NiTi) wire (Pereira et al., 2012). Secondly WaveOne files have variable cross section form D1 to D8 modified convex triangular cross section and form D9 to D16 convex triangular cross section. The non-cutting tip to improve the safety of the WaveOne (Webber et al., 2011).

Thirdly the reciprocation motion with a large counter clockwise angle which advance of the files in the canal and small clockwise angle allows the files to be immediately disengaged. This helping the files to safety progress in the canal with the uniform cutting action (Yoo and Cho, 2012; Franco et al., 2011).

SafeSiders system showed more resin material removed from outer width in apical end as similar result was found with Ceyhanli et al., (2014) where they compared SafeSiders system to ProTaper and RaCe more canal transportation was found with SafeSiders system, although more outer material removed in comparing to WaveOne there is no significant difference between the two systems, the reason for that could be as SafeSiders used under reciprocating motion it will eliminated the excessive engagement of the files (Musikant et al., 2004).

In apex of curve and beginning of curve more resin material removed from the inner width which result in canal straightening. This result was consistent with Rhodes et al., (2011) where they compared the SafeSiders system to Vortex (NiTi) instruments in natural teeth. As SafeSiders system mainly consists of stainless steel files the increased rigidity of the larger sized stainless steel files with cutting tip will end with more canal straightening (Rhodes et al., 2011).

In half way to orifice more resin material removed from the inner width, although there is no significant difference between the inner width and outer width and orifice more resin material removed from the outer width with no significant difference between SafeSiders system and WaveOne system at orifice this is because it assessed with a straight part of the canal.

Stainless steel K-files instrumentation system showed that more resin material has been removed from the outer width at apical end. This result is consist with Yoo and Cho, (2012); Sadeghi, (2011); and Li et al., (2004) as they found that more outer canal preparation in apical end when they used the K- files stainless steel in resin block. The excessive material removed from the apical end of the canal is due to less flexible of stainless steel file tend to straighten itself within the canals (Sadeghi, 2011; Schäfer et al., 2004).

In apex of curve more resin material removed from the inner width, although there is no significant difference between the inner width and outer width Yoo and Cho, (2012) reported similar result with no significant difference between K-files and SafeSiders in inner width and at beginning of curve more resin material removed from inner width this result is an agreement with Yoo and Cho, (2012); and Li. et al., 2004) as mention previous less flexible of stainless steel file tend to straighten itself within the canals lead to straighten of canals (Sadeghi, 2011; Schäfer et al., 2004).

In half way to orifice and orifice more resin material removed from outer width, unlike the result of Sadeghi, (2011) with more resin material removed from the inner walls. Different from the result obtained due to different variable as operators, study design and techniques used (Sadeghi, 2011).

CONCLUSIONS

1- In total width measurement WaveOne instrument systems, preserved the shaped of L-shaped canals with gradually decreased the amount of resin material removed from the ori-

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fice to the apical end produced a continuously tapered funnel shaped, with less canal aberration.

2- SafeSiders and K-files instrumentation systems created significantly more canal aberration than WaveOne instrumentation systems with no significant difference between both systems.

3- Less working length change was found in the WaveOne system with no significant difference between WaveOne and K-files instrumentation systems, with no significant difference between working length change in canals prepared with SafeSiders and K-files instrumentation systems.

Figure 1. Digital Microscope attached to Dino-Lite stand ans placed at a fixed distance from the sample

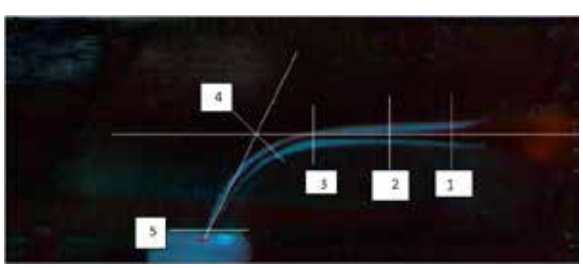


Figure 2. Superimposed image shows the five assessment levels in L-shaped canal: Position 1: canal orifice, Position 2: half way to orifice, Position 3: beginning of the curve, Position 4: apex of the curve and Position 5: apical end.

Table 1. Working length change in canals prepared with WaveOne, SafeSiders and K-files

Instrument systems	WaveOne Mean±SD	SafeSiders Mean±SD	K-files Mean±SD	ANOVA P-value
Working length changes (mm)	0.133a±0.430	0.655b±0.691	0.538a, b±0.724	0.028

SD: Standard Deviation

[a,b,c] P<0.05 The identical letters in each row illustrate the values which present no significant difference.

Table 2. Incidence of canal aberration with L-shaped canals

Canal aberration	WaveOne % (n=20)	SafeSiders % (n=20)	K-files% (n=20)	Significance
Apical zip	10%a	55%b	85%b	P=0.000
Elbow	10%a	55%b	85%b	P=0.000
Danger zone	0a	45%b	60%b	P=0.000
Coronal narrow	0a	45%b	60%b	P=0.000
Perforation	0	0	0	P=1.0
Ledge	10%	15%	20%	P=0.841

[a,b,c] P<0.05 The identical letters in each row illustrate the values which present no significant difference.

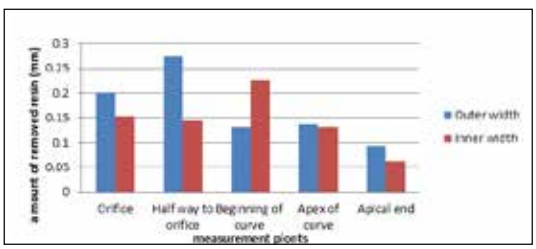


Figure 4. Outer and inner width measurements in L-shaped canals prepared with WaveOne system

Figure 5. L-shaped canal prepared with WaveOne system.

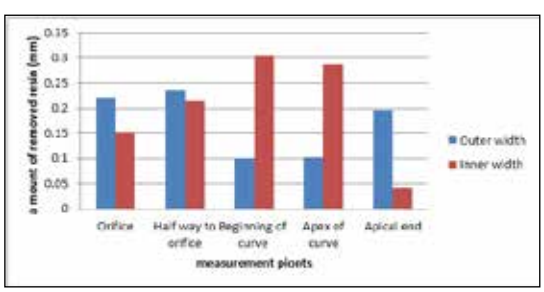


Figure 6 . Outer and inner width measurements in L-shaped canals prepared with SafeSiders system.

Figure 7 . L-shaped canal prepared with SafeSiders system.

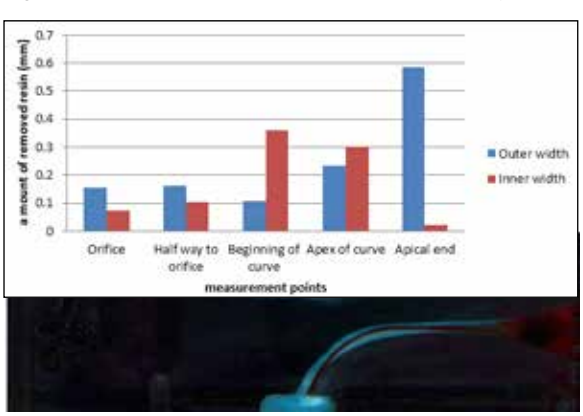


Figure 9. L-shaped canal prepared with K-files system.

Table 4. The mean values of the total width of canals prepared with WaveOne, SafeSiders and K-files

Instrument types Measurement points	WaveOne Mean±SD (mm)	SafeSiders Mean±SD (mm)	K-files Mean±SD (mm)	ANOVA P-value
Orifice	0.921a±0.033	0.947a,c±0.050	0.770b±0.044	0.000
Half-way to orifice	0.756a±0.067	0.815b±0.062	0.594c±0.042	0.000
Beginning of curve	0.598a±0.036	0.643a,c±0.080	0.705b±0.065	0.000
Apex of curve	0.507a±0.035	0.638b±0.073	0.781c±0.097	0.000
Apical end	0.341a±0.097	0.422a,c±0.162	0.808b±0.369	0.000

SD: Standard Deviation

[a,b,c] P<0.05 The identical letters in each row illustrate the values which present no significant difference.

Figure 10. Total width measurements in L-shaped canals prepared with WaveOne, SafeSiders and K-files.

Table 5. The mean values of the outer width of canals prepared with WaveOne, SafeSiders and K-files

Instrument types Measurement points	WaveOne Mean±SD (mm)	SafeSiders Mean±SD (mm)	K-files Mean±SD (mm)	ANOVA P-value
Orifice	0.202^{a}± 0.032	$0.220^{a,c}$± 0.050	0.154^{b}±0.067	0.001
Half way of orifice	0.274^{a}± 0.041	0.237^{b}±0.037	0.163^{c}±0.061	0.000
Beginning of curvature	0.132^{a}± 0.033	0.101^{b}±0.032	$0.106^{a,b}$±0.049	0.030
Apex of curvature	0.137^{a}± 0.031	$0.103^{a,c}$±0.035	0.235^{b}±0.099	0.000
Apical end	0.093^{a}± 0.059	$0.196^{a,c}$±0.139	0.586^{b}±0.362	0.000

SD: Standard Deviation
a,b,c P<0.05 The identical letters in each row illustrate the values which present no significant difference.

Figure 11. Outer width measurements in L-shaped canals prepared with WaveOne, SafeSiders and K-files.

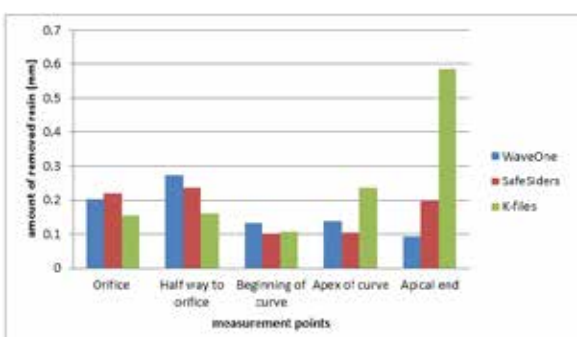


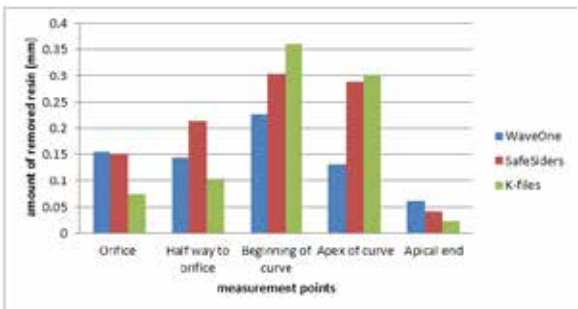
Table 6. The mean values of the inner width of canals prepared with WaveOne, SafeSiders and K-files

Instrument types Measurement points	WaveOne Mean±SD (mm)	SafeSiders Mean±SD (mm)	K-files Mean±SD (mm)	ANOVA P-value
Orifice	0.154^{a}±0.033	$0.151^{a,c}$±0.058	0.074^{b}±0.038	0.000
Half-way to orifice	0.144^{a}±0.032	0.214^{b}±0.060	0.103^{c}±0.054	0.000
Beginning of curve	0.226^{a}±0.032	0.304^{b}±0.063	0.360^{c}±0.079	0.000
Apex of curve	0.131^{a}±0.028	$0.288^{b,c}$±0.070	0.301^{c}±0.092	0.000
Apical end	0.062^{a}±0.035	$0.042^{a,b}$±0.037	0.023^{b}±0.042	0.011

SD: Standard Deviation

[a,b,c] P<0.05 The identical letters in each row illustrate the values which present no significant difference.

Figure 12. Outer width measurements in L-shaped canals prepared with WaveOne, SafeSiders and K-files.



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