An in vitro Comparative Evaluation of Canal Transportation and Amount of Removed Area by One Reciprocating and Two Rotary NiTi Single File Systems

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This certifies that the Master's Thesis of

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Abstract

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Introduction: This study was aimed to evaluate root canal transportation and amount of removed area in artificial resin blocks with three different nickel titanium (NiTi) single-file systems.

Material & Methods: Ninety J -shaped Endo-Training Blocks (0.02 taper, 16mm Length) were randomly divided into 3 groups (n=30) with each group having 3 sub-groups consisting of 10 samples for each file size (small, primary, medium) of the WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland), Trunatomy (Dentsply Sirona) and M3-L Platinum (United Dental Changzhou, Shanghai, China) NiTi single file systems. A preoperative (with dye) and postoperative images were taken of the samples using stereo microscope with build in camera, and the images were then layered using Adobe Photoshop CC (64 bit) (Adobe Systems Inc, San Jose, CA, USA), the amount of resin removed from both the inner and the outer sides of the canal and the amount of canal transportation was measured at the distance of 1, 3, 5 and 7 mm from the apex, as well as the amount of the canal in pre- and post-operative images using ImageJ program. One-way ANOVA and Tukey post hoc test were used to statistically analyze the data.

Results: M3-L Platinum had the highest amount of canal transportation while Trunatomy had the lowest amount with statistically significant result at some but not all the levels, the amount of area of removed resin listed from smallest to largest came as follows (Trunatomy, WOG, M3-L), the result were significantly different. ($p < 0.05$) in all the groups except in medium file size between WOG, M3-L.

Conclusions: Despite the differences between the systems, canal transportation was in general minimal, and so the shaping ability of these systems is proven to be satisfactory, some suggestions for the clinical use of these files are as follows; the use of Trunatomy files is recommended when minimally invasive endodontics is needed in narrow canals and

if used with severely curved canals care must be taken. WaveOne Gold files can be used safely in curved canals while M3-L files are better suited to be used with less curved ones.

Keywords: shaping ability, canal transportation, nickel-titanium files, single-file system, resin blocks.

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I. Introduction

The primary goal of endodontic instrumentation is to enlarge the root canal space for better access in order to eliminate bacteria and dentinal debris by instrumentation and irrigation while maintaining the original shape and path of the root canal (Hasheminia, et al., 2018)

Despite the continuous advancements of endodontic instruments, procedural errors such as zips, ledges, perforations, and root canal transportation are still a common misshape during endodontic treatment (Jain, et al., 2018). The presence of canal transportation complicates the removal of bacteria from the root canals and is responsible for these undesirable apical preparation outcomes. It is one of the main preparation errors in root canal treatment and one of the main causes of endodontic failure (Chole, et al., 2016; SCHÄFER and DAMMASCHKE, 2006).

Canal transportation may be defined as "the removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation.".

Canal transportation can worsen the prognosis of the endodontic treatment by various ways, it can cause overreduction of intracanal dentin which reduces the fracture resistance, and thus weakens the root, it can also leave an uninstrumented part of the root apex which harbors residual bacteria causing a persistent post-operative periapical lesion (Chole, et al., 2016; SCHÄFER and DAMMASCHKE, 2006).

The introduction of nickel–titanium (NiTi) endodontic instruments has led to significant improvement in canal shaping in general and reduction in canal transportation and other procedural errors (Gu, et al., 2017; Peters, 2004; Taşdemir, et al., 2005; Zupanc, et al., 2018), manufacturers over the years have worked on improving the nickel–titanium (NiTi) instruments by introducing different file designs and different methods of NiTi alloy

treatment to produce instruments that are more fracture resistance, and with enhanced flexibility (Zupanc, et al., 2018). Recently, the drive for simplicity during endodontic procedures have led manufacturers to produce endodontic systems with fewer number of files needed, with their latest systems needing only a single file to shape the whole canal system from start to finish. Three of the newest nickel–titanium (NiTi) single file systems are WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland), Trunatomy (Dentsply Sirona, Ballaigues, Switzerland) and M3-L Platinum (United Dental Changzhou, Shanghai, China).

WaveOne Gold (WOG) (Dentsply Sirona, Ballaigues, Switzerland) is a reciprocating single file system, the reciprocating motion was introduced to reduce the incidence of file fracture in rotary files caused by flexural fatigue and torsional stress which occurred while rotating instruments in the canal (Aidasani, et al., 2017; Hamid, et al., 2018). The reciprocating motion promises to be better at maintaining the canal contour in curved canals and induce less dentinal defects compared to the rotary motion (Shubhashini, et al., 2016). Compared to the previously released "M- wire" WaveOne files, the new WOG file's NiTi alloy is made with gold wire post -manufacturing heat treatment procedure (Özyürek, et al., 2017), that increases the file's elasticity and increase the cyclic fatigue resistance (Adıgüzel and Capar, 2017), it also has showed superior elasticity compared to conventional NiTi and M- wire instruments (Fangli, et al., 2019), and produce a more centered preparation (Zupanc, et al., 2018). This system has two cutting edges with an off-centered parallelogram cross-section design (Ismail, et al., 2019). In this study 3 sizes of the WOG

file system will be used: small (#20, 0.07 taper), primary (#25, 0.07 taper), medium (#35, 0.06 taper).

On the other hand, Trunatomy (Dentsply Sirona, Ballaigues, Switzerland) and M3-L Platinum (United Dental Changzhou, Shanghai, China) are rotary single file system. The rotary file motion promises an increased cutting efficiency compared to the reciprocating motion, and decreased depress extrusion (Aidasani, et al., 2017; Shubhashini, et al., 2016).

The difference between the Trunatomy (TRN) (Dentsply Sirona, Ballaigues, Switzerland) single file system and the other systems is that it is manufactured using a post-manufacturing thermal process that makes it super-elastic and have less memory compared to conventional NiTi or M-Wire, which can be helpful in cases with difficult straight-line access, according to the manufactures, the file size prime is up to 3 times more flexible than other Dentsply Sirona file systems, and substantially more flexible than other brands, it has smaller maximum flute diameter (0.8mm) compared to the generic variable tapered NiTi files (up to 1.2mm). TRN also has an off centered parallelogram cross-section slip design, this design along with its slim structure and super elasticity help preserve dentine structure and negotiate curved canals (Amr M. Elnaghy, et al., 2020), the slip shape provides more space for debridement (A. M. Elnaghy, et al., 2020). In this study the three sizes which are: small (#20, 0.04 taper), prime (#26, 0.04 taper) and medium (#36, 0.03 taper) are used.

M3-L platinum (M3-L) (United Dental Changzhou, Shanghai, China) is a heat-treated M-wire NiTi alloy which give it increased resistance to cyclic fatigue (Zupanc, et al., 2018). This file system has a patented flat-sided S-shaped cross section which according to the manufacturers give it an increased ability for debris removal, high efficiency and reduced risk of fracture, the file has also a non-cutting file's tip for a gentle treatment near the apex. In this study the three sizes which are Small (#20, 0.07 taper), primary (#25, 0.065 taper), medium (#35, 0.06 taper) are used.

Due to the constant development of endodontic instrument its recommended that each new system would be investigated to evaluate the difference aspects of its performance, since TRN and M3-L are one of the newest single file systems, there are few studies that evaluated their torsional and cyclic fatigue resistance (Amr M. Elnaghy, et al., 2020), but rarely studied their shaping ability. So, the aim of this study is to evaluate the shaping ability of these two new rotary single file systems compared with the established reciprocating WOG single file system by calculating the amount of canal transportation and amount of removed area.

Null hypothesis

This study is designed to assess the hypothesis that there is no significant difference between the three NiTi single file systems in regards to the canal transportation and amount of removed area.

II. Materials and Methods

1. Simulated Canal Preparation

Ninety J -shaped Endo-Training Blocks (Dentsply Sirona, Ballaigues, Switzerland) were used to evaluate the shaping ability of WOG, TRN and M3-L. each with a 0.02 taper, and with a 16 mm length, the blocks were randomly assigned to 3 groups (n = 30): WOG group, TRN group, and the M3-L group, with each having three sub-groups (n = 10) for each file size of the system (Small, Primary, Medium) (figure 1).

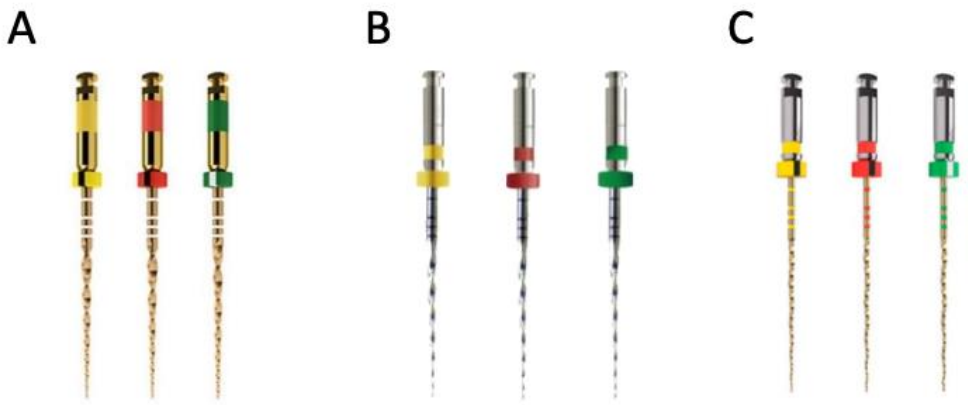

Figure 1. File systems used in this study. **(A)** WaveOne Gold, **(B)** M3-L Platinum, **(C)** Trunatomy

A Stereo microscope with build in camera (Leica Microsystems S9, Germany) was used to take photos of the resin blocks before and after instrumentation with two rulers taped to

the Stereo microscope stage plate for resin block stabilization and image standardization, and later the rulers were used as a reference for measurement in the photos. To improve the color contrast of the before and after photographs, the canals were injected with a pink ink (Graf von Faber-Castell) before instrumentation (figure 2A).

As mentioned before single file systems allow for the use of a single file for the entire root canal ,all of the file systems that were used comes in 3 different sizes following different sizes of root canals , according to the manufacturer instruction the file size small and primary can be used for both small and medium size root canals in which a glide path was made using hand files #10 or #15, while medium sized single files are intended to be used with large root canals in which a size 20 or 25 K-file fits loose in the canal and is not necessary to negotiate and prepare a glide path with smaller instruments. So, a glide path was prepared using hand file #10 & #15 K-files for blocks instrumented with single files size small and primary while blocks instrumented using the single file system size medium was first prepared using hand file #10, #15 & #20 K-files to simulate a large root canal, the working length was 16 mm.

The X-Smart Plus Endo Motor (Dentsply Sirona, Ballaigues, Switzerland) was used for all the file systems, the endo motor has a pre-set program for WOG and TRN file systems and for the M3-L file system, the recommended torque (2.0 N.cm) and rotational speed (500 rpm) was set manually.

These single file systems are intended for a single time use, since the average number of canals in a molar is 5 canals, Each file in each system was used for 5 resin blocks and then

discarded except in case of broken files (four TRN files had to be replace, one #20 TRN, two #26 TRN, one #36 TRN), The files were inserted into the canals in a slow inward-outward motion and after 3 inward-outward motions, the instrument was removed and the canal was irrigated with 2 mL of normal saline, the needle was inserted as deep as possible into the root canal without binding, and file flutes were cleaned from debris. This was repeated until the file reached the working length twice.

After instrumentation the resin blocks were photographed again using the stereo microscope build in camera in the same position. Then the pre- and post-instrumentation photos were layered using the program adobe photoshop CC (64 bit) (Adobe Systems Inc, San Jose, CA, USA) (figure 2B), the rulers taped to the Stereo microscope stage plate were used as a reference to convert the measurement accurately in photoshop from pixels to mm, then a dot every 1 mm was marked from the apex to the orifice to be used later as a reference point of measurement.

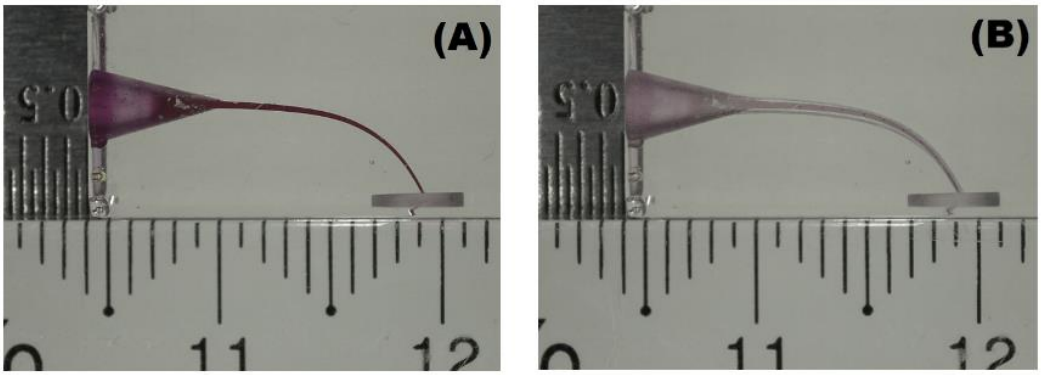

Figure 2. (A) Pre- instrumentation image of resin block with pink ink dye. **(B)** The pre- and post- instrumentation images layered using adobe photoshop.

2. Canal transportation measurement

Using Image J program (LOCI, University of Wisconsin, USA), the amount of resin removed on both the inner and the outer sides of the simulated canals was determined by measuring the distance (in millimeters) from the pre to the post instrumented canal wall (figure 3), measurements were made at four different points, at 1 and 3 mm away from the apex which represent the apical third of the canal, at 5 mm which represent the middle third, and at 7 mm representing the coronal third.

Canal transportation was defined as the difference between the outer resin removed and inner resin removed (Alrahabi and Zafar, 2018; Burroughs, et al., 2012) represented in the following form:

D (canal transportation) = DO (outer resin removed) – DI (inner resin removed)

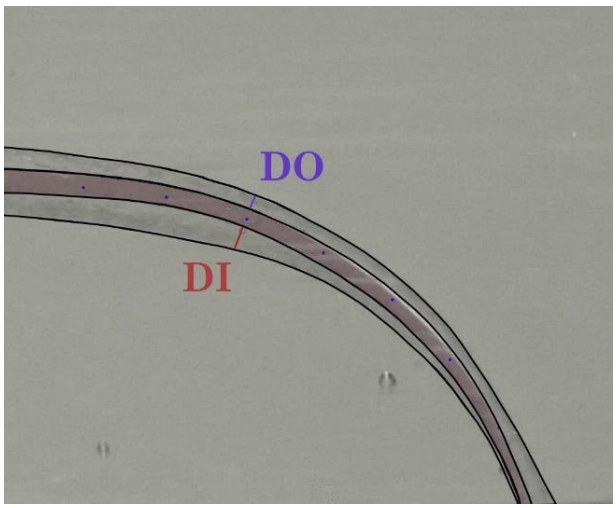

Figure 3. Close up of the layered resin blocks showing the measurement of the distance (in millimeters) from the pre to the post instrumented canal wall, DO (outer resin removed), DI (inner resin removed).

3. Area of removed resin measurement

Image J program (LOCI, University of Wisconsin, USA) was used to calculate the area in the simulated canals in both Pre and post instrumentation photos, Then the amount of removed area by each file was measured in mm^2 by subtracting the pre instrumented canal area from the post instrumented canal area.

Amount of removed area = area of canal after preparation – area of canal before preparation

4. Statistical analysis

The statistical analysis for canal transportation was carried for each file size separately at each level using One-way ANOVA and Tukey post hoc tests using SPSS 27.0 (IBM Corp. 2017, Armonk, NY, USA). the same tests were used to compare the data for amount of removed area for each file size separately.

III. Results

1. Canal transportation

The amount of resin removed from the outer and inner sides of the simulated canals were measured to calculate the amount and direction of canal transportation.

In the three sizes, the canal transportation was to the external side at 1 mm, and to the inner side at 5 and 7 mm from the apex, at 3 mm from the apex, the file size small and medium had more resin removed at the outer side with TRN files while WOG and M3-L files resulted in removal of resin more to the internal side, in file size primary, the M3-L files had resin removed more to the outer side while WOG and Trunatomy files had it more removed to the inner side.

In general, the single file system M3-L had the highest amount of canal transportation while TRN single file system had the lowest amount, the mean of canal transportation in file sizes small, primary and medium are detailed in table 1 and figure 4, 5, 6 respectively, the results of statistical analysis for the amount of canal transportation are detailed as follows:

File size Small

The file system M3-L resulted in significantly greater canal transportation than WOG system at 1 mm level ($p < 0.05$), at 5 mm the difference in canal transportation between

all the groups was significant with the three groups listed from smallest to largest amount of canal transportation as follows (TRN, WOG, M3-L) ($p < 0.05$) (figure 4).

Table 1. The mean value of Canal transportation

	Wave One Gold			Trunatomy			M3-L		
	Small	Primary	Medium	Small	Primary	Medium	Small	Primary	Medium
1 mm	+ 0.040 [a] (±0.014)	+ 0.141 [a] (±0.060)	+ 0.244 [b] (±0.046)	+ 0.067 [b] (±0.028)	+ 0.058 [b] (±0.033)	+ 0.220 [b] (±0.087)	+ 0.076 [a] (±0.028)	+ 0.062 [b] (±0.045)	+ 0.219 [b] (±0.086)
3 mm	- 0.014 [b] (±0.009)	- 0.046 [b] (±0.036)	- 0.047 [b] (±0.031)	+ 0.032 [b] (±0.018)	- 0.021 [a] (±0.013)	+ 0.047 [b] (±0.039)	- 0.035 [b] (±0.027)	+ 0.067 [a] (±0.051)	- 0.078 [b] (±0.036)
5 mm	- 0.101 [a] (±0.027)	- 0.144 [a] (±0.050)	- 0.249 [b] (±0.077)	- 0.024 [a] (±0.020)	- 0.040 [a] (±0.037)	- 0.107 [a] (±0.047)	- 0.169 [a] (±0.061)	- 0218 [a] (±0. 048)	- 0.261 [b] (±0.049)
7 mm	- 0.083 [b] (±0.030)	- 0.098 [b] (±0.050)	- 0.138 [b] (±0.067)	- 0.073 [b] (±0.056)	- 0.102 [b] (±0.036)	- 0.075 [b] (±0.058)	- 0.128 [b] (±0.057)	- 0.188 [a] (±0.058)	- 0.218 [a] (±0.073)

a: significant difference compared to other files, b: no significant difference compared to other files.
+ → outward transportation, - → inward transportation.
The numbers in parentheses are standard deviations.

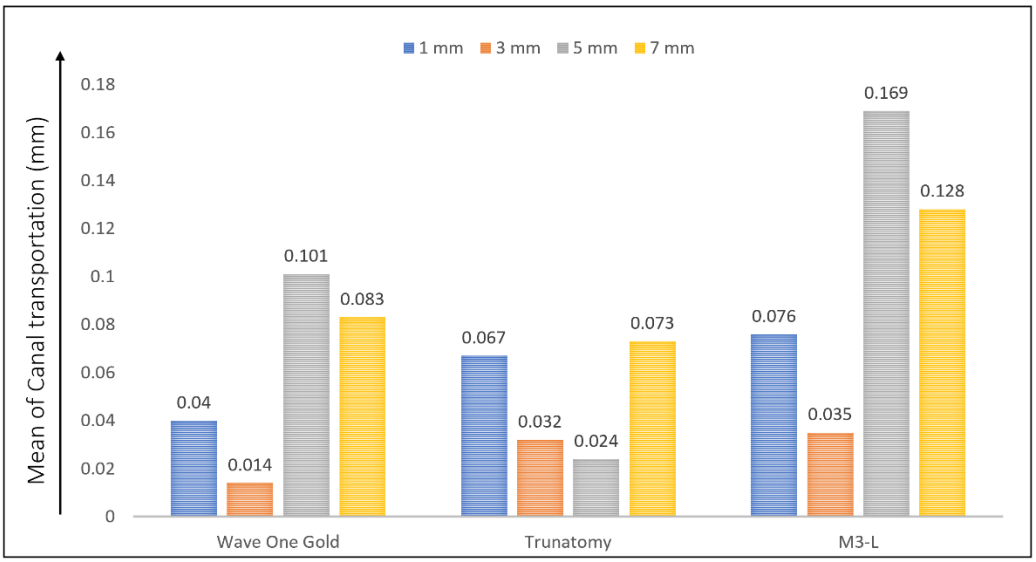

Figure 4. the mean of canal transportation in file size Small.

In the case of WOG and M3-L the area with most amount of canal transportation was at level 5 mm away from the apex, while the least amount of canal transportation was at 3 mm, on the other hand, TRN files produced the largest amount of canal transportation at 7 mm and the least amount was at 5 mm.

File size Primary

The file system WOG had significantly the largest amount of canal transportation at 1 mm, at 3 mm TRN had the lowest amount of canal transportation ($p < 0.05$), while M3-L had the highest ($p < 0.05$), at 5 mm the difference in canal transportation between all the groups was significant with the three groups listed from smallest to largest amount of canal transportation as follows (TRN, WOG, M3-L) ($p < 0.05$). at 7 mm M3-L had the largest amount of canal transportation ($p < 0.05$) (figure 5).

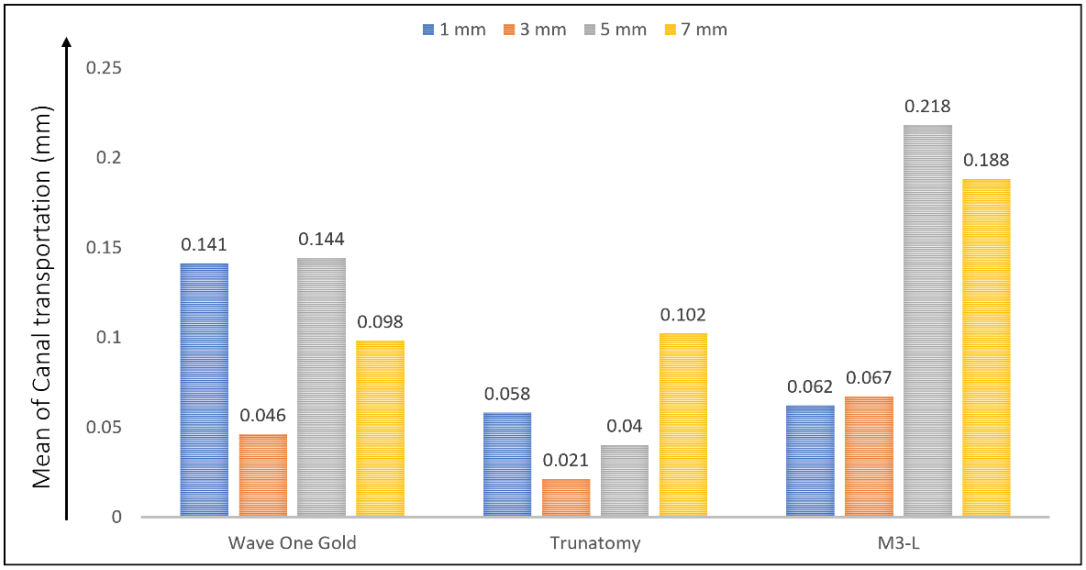

Figure 5. The mean of canal transportation in file size Primary

In the file size primary, the area with the largest amount of canal transportation was similar to the file size small, the smallest amount of canal transportation was at 3mm from the apex for all the systems.

File size Medium

In the medium file size, there was no significant difference between the groups except at 5mm TRN had the smallest amount of canal transportation ($p < 0.05$), and at 7 mm M3-L had the largest amount of canal transportation ($p < 0.05$) (figure 6).

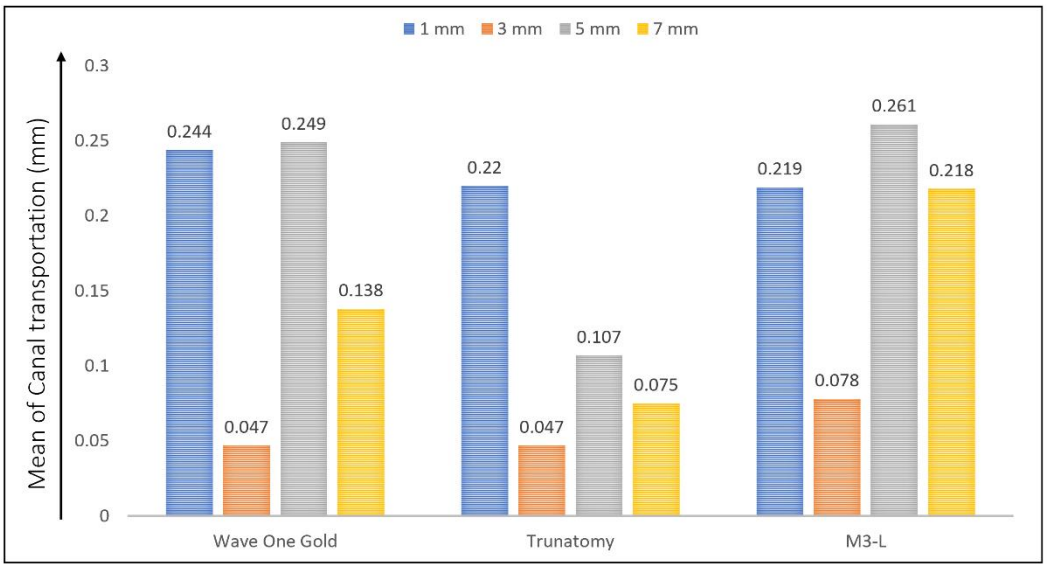

Figure 6. The mean of canal transportation in file size Medium

WOG and M3-L produced the most amount of canal transportation at both 5 and 1 mm while TRN was mostly at 1 mm, the smallest amount of canal transportation was at 3mm for all the systems.

2. Area of removed resin

The difference in amount of removed area between all the groups was similar in the three file sizes, listed from smallest to largest amount of removed area, the order is as follows (TRN, WOG, M3-L), the result of statistical analysis was significant ($p < 0.05$) in all the groups except in medium file size between WOG, M3-L. the mean of amount of removed area in file sizes small primary and medium are detailed in figure 7.

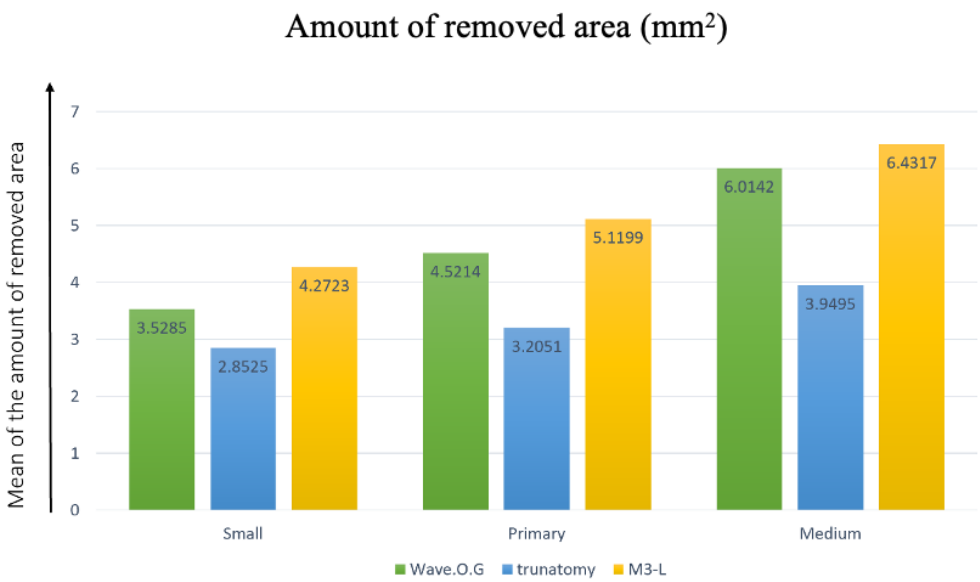

Figure 7. The mean of the amount of removed area in file sizes Small, Primary and Medium.

IV. Discussion

The present study investigated the performance of three single file systems by calculating the amount of canal transportation and amount of removed area by each file. Previous studies(A. M. Elnaghy, et al., 2020; Jain, et al., 2018; Özyürek, et al., 2017; Vallabhaneni, et al., 2017) have used only one size of an endodontic system to test the shaping and centering ability of the enter system, in this study three file sizes where studied (small, primary, medium) to get a more rounded evaluation of the performance and centering ability of the system in all canal sizes of the root.

The amount of canal transportation was calculated by subtracting the amount of resin removed in the inner side from the amount of resin removed in the outer side. A positive value of canal transportation indicated an outward transportation, and a negative value indicated an inward one. The values closer to zero indicated a more balanced preparation.

Based on this, the direction of canal transportation was to the external side at 1 mm in all 3 file systems, which is consistent with what previous studies have reported (Elemam, et al., 2016; Pasternak-Júnior, et al., 2009; Silva, et al., 2015). The transportation was to the inner side at 5 and 7 mm from the apex. Silva et al. (Silva, et al., 2015) have reported similar results in regard to the direction of canal transportation in middle and coronal thirds. At 3 mm from the apex, the file size small and medium had more resin removed at the outer side with TRN single file system while WOG and M3-L were to the internal side, in file size primary, the M3-L was more to the outer side while WOG and TRN had it more removed

to the inner side. Previous studies have demonstrated that canal transportation can occur in several directions depending on factors other than the curve of the canal itself, such as physical properties of the instrument's alloy and its design (Pasternak-Júnior, et al., 2009) larger tapered instruments resulted in more straitening of the curve and thus causing canal transportation to the outer side at the apical part and to the inner side at the middle and coronal sides (Silva, et al., 2015), smaller tapered instruments tend to be more flexible making it easier to follow the natural curve of the canal resulting in transportation to the outer side at the middle part of the canal (Silva, et al., 2016; Silva, et al., 2015), flexibility of the TRN files comes from the instrument's alloy special post manufacturing heat treatment in addition to its smaller than normal taper (Amr M. Elnaghy, et al., 2020) which can be the reason behind TRN files behavior at 3 mm. canal transportation towards the danger zone "the inner side of the curve" can increase the chances of strip perforation and reduced the fracture resistance of the roots (Zhou, et al., 2020), according to this finding in the case of thin roots the use of TRN files is advantageous.

The amount of canal transportation was significantly different between the three groups as follows, In the file size small at 1 mm, M3-L resulted in significantly larger amount of canal transportation compared to WOG, which gave the least amount of transportation, and at 5 mm M3-L was also significantly larger than TRN and WOG respectively.

In the file size primary M3-L was also significantly responsible for producing the largest amount of canal transportation at all levels except at 1 mm where WOG had significantly larger amount of canal transportation produced, TRN produced significantly the lowest

amount of canal transportation at 3 and 5 mm. In the file size medium M3-L resulted in the largest amount at 7mm and TRN resulted in the lowest at 5 mm. According to these results, in general, TRN file systems was responsible for the lowest amount of canal transportation while M3-L resulted in the largest amount.

TRN files help preserve dentine structure and negotiate curved canals due to their NiTi alloy post-manufacturing thermal process that makes it super-elastic and have less memory compared to conventional NiTi or M-Wire, along with its smaller maximum flute diameter (0.8mm) (Amr M. Elnaghy, et al., 2020). however, one drawback to the use of TRN files is that they are more susceptible to fracture, this can be explained by the lower cyclic fatigue TRN files have compared to WOG and M3-L, which is caused by lower austenitic transformation temperature compared to other systems resulting in its reduced flexibility and having a lower toughness value compared to the other systems which make it more prone to fractur.

Although WOG and M3-L files had the same taper, WOG files resulted in lower amounts of canal transportation than M3-L files, this can be attributed to the properties of NiTi alloy.

WOG is a gold heat treated instrument which is known for higher flexibility and a lower or similar ultimate strength value than the M3L (M wire) (Zupanc, et al., 2018). The increased flexibility of WOG file increases its distortion angle; the instruments ability to be plastically deformed under stress without fracture, along with its use in a reciprocating action compared to the rotary M3-L file, could be the reason why WOG file systems performed better than the M3-L ones.

The effect of reciprocating vs rotary files has been studied extensively over the years; most studies have reported lower amounts of canal transportation with reciprocating systems (Franco, et al., 2011; Hasheminia, et al., 2018; Vallabhaneni, et al., 2017). You et al. (You, et al., 2011) have reported no difference between the two. On the other hand, other studies have reported that rotary systems were the one responsible for lower canal transportation (Alrahabi and Zafar, 2018; Nabavizadeh, et al., 2014). Vittorio Franco et al. (Franco, et al., 2011) have reported that rotary file systems caused transportation more to the outer side while reciprocating systems caused it more to the inner side. M Alrahabi et al. (Alrahabi and Zafar, 2018) have reported a difference in the behavior or reciprocating file when used in natural teeth vs resin blocks causing more canal transportation in resin blocks, in this study the direction and the amount of canal transportation were less dependent on the mode of action (rotary vs reciprocating) and more related to the shape, taper and the NiTi alloy's physical properties of each file system.

In regards to level of the canal with the largest amount of canal transportation, Jain A et al. (Jain, et al., 2018) reported that canal transportation was highest at the apical part at 1, 3 mm away from the apex, other authors have reported that the largest amount of canal transportation was observed at 5 mm away from the apex (Ceyhanli, et al., 2015; Elemam, et al., 2016; Silva, et al., 2015) in the current study, WOG and M3-L give similar result in regards to level of the canal with the most amount of canal transportation which was at 5 mm away from the apex, Whereas in the case of TRN files, the largest amount of canal

transportation was at (7 and 1 mm)in file size small and primary, and at (1 and 5 mm) in the file size medium respectively.

In general canal transportation is reportedly highest at the curved part of the canal as the file tries to straighten against the curve to return to its original position (Hasheminia, et al., 2018; Silva, et al., 2016; Vallabhaneni, et al., 2017), WOG and M3-L have larger diameter than TRN files which made them less flexible (Donnermeyer, et al., 2020), this could explain the increased amount of transportation at the biggening of the curved section of the canal in them compared to TRN files. TRN files have smaller maximum flute diameter (0.8mm) (Amr M. Elnaghy, et al., 2020), which gives them the ability to negotiate the curved section better, since the single files system is designed to work on the entire length of the canal, the files try to straighten back while negotiating the curved part, as it doing that, it contacts the opposite side of the curve causing wear, which explains the large amount of canal transportation at the coronal part.

Previous studies have stated that there was an increase in canal transportation as the diameter of the file increased due to increased stiffness of the file (Chole, et al., 2016; Yoo and Cho, 2012). The current study has exhibited similar results as the amount of canal transportation have increased with the larger file sizes. Although the difference in canal transportation is significant at some levels in the canal, it should be noted that all three systems tested in the three sizes produced a relatively small amount of canal transportation. Wu et al. (Wu, et al., 2000) and Peters OA et al. (Peters, 2004) have reported that apical transportation between 0.15 to 0.3 is acceptable and apical canal transportation more than

0.3mm negatively affects the sealing ability of root filling materials, and since none of the files have produced canal transportation more than 0.3 mm, the centering ability for these systems is proven to be sufficient.

The lowest amount of area removed was reported with the use of TRN single file system followed by WOG, and the largest amount of area removed was reported with M3-L system ($p < 0.05$). this can be attributed to the design and diameter of each file system, TRN files were designed on the bases of minimally invasive endodontics in which a regressive instead of consistent taper was adapted in order to create a preparation without unnecessary enlargement of the coronal section, these files have a smaller maximum flute diameter (0.8mm) compared to the generic variable tapered NiTi files (up to 1.2mm), With a parallelogram cross-section slip design (Amr M. Elnaghy, et al., 2020).

Although the taper of the M3-L files is similar to that of WOG files, M3-L reported the most amount of area removed, this could be attributed the difference in flexibility between WOG and M3-L files, WOG NiTi alloy is made with gold wire post -manufacturing heat treatment procedure (Özyürek, et al., 2017) that increases the file's elasticity and increase the cyclic fatigue resistance compared to M- wire instruments like M3-L (Adıgüzel and Capar, 2017; Fangli, et al., 2019).

The result of this study states a significant difference between the three single file systems in regards to the amount of canal transportation and amount of removed area, and so the null hypothesis of this study is rejected.

Researching endodontic instrument's performance is usually done by ether using extracted natural teeth or resin simulated blocks, although the use of natural extracted teeth can offer conditions close to the clinical situation, the differences of each individual tooth in case of length, angle of curvature, diameter of the canal and differences in hardness and abrasion (Alrahabi and Zafar, 2018) for each tooth can affect the results of the study, so for proper standardization and for elimination of any outer influences other than the type of file being used, J -shaped Endo-Training Blocks (Dentsply Sirona, Ballaigues, Switzerland) are used in this study. In addition to standardized study conditions, the use of these clear resin blocks can provide visual comparison of the shape of the canals after instrumentation with different file systems by superimposing pre- and post-operative photos taken with a stereomicroscope with a build in camera (Franco, et al., 2011; Silva, et al., 2015; Yoo and Cho, 2012).

One of the drawbacks of using resin blocks is softening of the resin due to heat generated from instrumentation which can in turn cause clenching of the cutting blades (Gu, et al., 2017) the hardness of resin blocks and dentine is not the same so, a standardized study of these file systems using resin blocks is necessary, and the efficacy and the reliability of the research results done on resin blocks in well noted in literature (Khalilak, et al., 2008; Silva, et al., 2016; Yoo and Cho, 2012) however, further study of these systems should be conducted on naturel extracted teeth and a comparison of both results should be done for proper comprehensive representation of the shaping and centering ability of these single

file systems. So, the results of this study should be translated with care onto the clinical situation.

V. Conclusion

Despite the differences between the systems, canal transportation was in general minimal, and so the shaping ability of these systems is proven to be satisfactory, some suggestions for the clinical use of these files are as follows; the use of TRN files is recommended when minimally invasive endodontics is needed and in narrow canals, and if used with severely curved canals care must be taken. WOG files can be used safely in curved canals while M3-L files are better suited to be used with less curved ones.

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Abstract (In Korean)

한 종류의 왕복 및 2 종류의 회전식 니켈-타이타늄 single file 시스템을 이용한 근관변위 및 삭제된 영역의 실험실적 평가

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이번 연구의 목적은 세 가지 서로 다른 니켈 타이타늄 (Ni-Ti) 단일 파일 시스템을 사용하여 인공 근관 블록에서 근관 변위량 및 제거된 면적을 평가하는 것이었다.

90 개의 J 형태의 근관치료 실습 블록 (0.02 경사도, 16mm 길이)을 무작위로 3 개 그룹 (n = 30)으로 나눈 뒤, 각 그룹에 WaveOne Gold (Dentsply Sirona, Ballaigues, Switzerland), Trunatomy (Dentsply Sirona) 및 M3-L Platinum (United Dental Changzhou, Shanghai, China) 단일 나이타이 파일 시스템을 배정하였다. 이후, 각 그룹 내에 파일 크기 (small, primary, medium)에 따른 3 개의 하위 그룹에 각

10 개의 블록을 배정하였다. 카메라가 내장된 광학 현미경을 사용하여 근관 성형 전 (염료 포함) 및 근관 성형 후 사진을 촬영한 뒤 Adobe Photoshop CC (Adobe Systems Inc, San Jose, CA, USA)를 이용하여 사진을 중첩하였다. 근관 내측, 외측에서 제거된 레진의 양과 근관 변위량은 근첨에서 1, 3, 5, 7mm 떨어진 위치에서 측정하였고 ImageJ 프로그램을 사용하여 분석하였다. 측정된 데이터는 일원배치 분산분석 및 터키 검증을 통하여 통계적으로 분석하였다.

M3-L Platinum 은 근관 변위량이 가장 많았고, Trunatomy 는 가장 적었으며 일부 지점에서 통계적으로 유의미한 차이를 보였다. TRN, WOG, M3-L 순으로 제거된 면적의 양이 증가하였다. Medium 크기의 파일을 제외하고 WOG 와 M3-L 간에 모든 군에서 유의한 차이를 보였다 ($p < 0.05$).

결론적으로, 이번 연구에 사용된 세 가지 서로 다른 파일 시스템 모두에서 근관 변위량은 일반적으로 최소로 측정되었고, 근관 성형 능력은 만족스러웠다. 이번 연구를 통한 파일의 임상적 사용에 대한 제안은 다음과 같다. 좁은 근관에서 최소 침습적 근관 치료가 필요한 경우 Trunatomy 파일의 사용이 권장되고, 만곡이 심한 근관에서 사용하는 경우 주의를 기울여야 한다. WaveOne Gold 파일은 만곡이 있는 근관에서 안전하게 사용할 수 있으며, M3-L 파일은 비교적 만곡이 심하지 않은 근관에서 사용하는 것이 더 적합하다.

핵심 되는 말 : 성형 능력, 근관 변위량, 니켈-타이타늄 파일, single-file 시스템, 인공 근관 블록