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Waveone and one Shape Files: Survival in Severely Curved Artificial Canals

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I. Introduction

Mechanical instrumentation and thorough debridement of root canal space are essential prerequisites for successful endodontic treatment (Schilder, 1974; Hulsmann *et al*., 2005). Stainless steel files can be used for achieving this goal but recently nickel-titanium (NiTi) rotary instruments are preferred for their excellent flexibility, superelasticity and improved cutting efficiency (Chen *et al*., 2002; Sonntag *et al.,* 2003; Peters, 2004; Schäfer *et al.,* 2004). These instruments can minimize ledging and transportation, create more centered and rounded canal preparation and for these reasons are frequently chosen for instrumentation of curved root canals (Short et al., 1997; Bonaccorso *et al*., 2009; Cheung et al., 2009). Despite their undeniably favorable qualities, NiTi rotary instruments can separate unexpectedly, especially when they are forced into the canal or are overused (Sattapan et al., 2000; Arens *et al*., 2003). Fractures of NiTi rotary instruments are result of torsional stress or cyclic flexural fatigue (Di Fiore, 2007; Wu *et al*., 2011). Root canal anatomy, instrument design, manufacturing process, preparation technique and operator skill can affect the fracture mode and the fracture rate of these instruments (Parahos *et al.,* 2004; Parashos *et al.,* 2006; Shen *et al.,* 2009; Kim *et al.,* 2010; Zhang *et al*., 2010). The chance of removing the broken file is very low in some cases and sometimes may be impossible without compromising the endodontic treatment outcome (Hulsmann *et al*., 1999).

To reduce the separation incidence, manufacturers have developed new techniques to improve the physical and mechanical properties of their instruments. One important modification of the NiTi alloy, which makes rotary systems more flexible and more resistant to cyclic fatigue, and improves their cutting efficiency, is the M-Wire alloy (Dentsply Tulsa Dental, Tulsa, OK) (Gambarini *et al*., 2008; Alapati et al., 2009; Lopes *et al*., 2013). M-Wire is a NiTi alloy prepared by a special thermal process and is used in the production of WaveOne reciprocating files (Dentsply, Tulsa Dental Specialties, Tulsa, OK).

Reciprocating mode of rotation has been introduced recently with the intent to extend the lifespan of a NiTi instrument and its resistance to fatigue in comparison with continuous rotation (De-Deus et al., 2010; Varela Patino *et al*., 2010; You et al., 2010; Franco *et al*., 2011; Pedulla *et al*., 2013). WaveOne files are used with specific motor with unchangeable settings. The engine generates different angles of rotation - 170° counterclockwise and then 50° clockwise rotation with a speed of 350 rpm – which affect the fatigue resistance (Kim *et al*., 2012). The system consists of 3 sterile single-use files with noncutting modified guiding tips: small (ISO 21 tip and 6% taper) for small canals, primary (ISO 25 tip and 8% taper) for the majority of canals, and large (ISO 40 tip and 8% taper) for large canals. The last two have fixed tapers of 8% from D1 to D3, whereas from D4 to D16, they have a unique progressively decreasing percentage tapered design. Thus, flexibility is improved and the remaining dentin in the coronal two thirds of the canal is preserved. Another unique design features of the WaveOne files are the reverse helix and the two distinct cross-sections along the length of their active portions (a modified convex triangular cross section from D1 to D8 and a convex triangular cross section from D9 to D16). The design of the two WaveOne cross sections is further enhanced by a

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changing pitch and helical angle along their active portions (Webber *et al.,* 2011).

One Shape rotary NiTi files (MicroMega) work with continuous rotation and the producers try to increase their flexibility and to reduce instrument screwing effects by a variable cross-section along the blade of the instrument. They have 3 different cross-section zones: apical (with a variable 3-cutting-edge design), transitional (progressively changing from 3 to 2 cutting edges) and coronal (with 2 cutting edges). Anti Breakage Control (ABC) increases safety and avoids separation by unwinding of the instrument. The system consists of one sterile single file for root canal shaping (ISO 25 tip and 6% taper) with variable pitch and non-working (safety) tip.

File distortion and breakage, especially in severely curved canals, can be reduced or avoided not only by improved design and mechanical properties of the instruments, but by manual preflaring of the root canal and creation of a glide path, as well. There is a strong evidence in the literature (Roland *et al*., 2002; Berruti *et al*., 2004; Varela-Patino et al., 2005; Zarrabi *et al.,* 2010) that fracture incidence might be reduced as a result of the preliminary enlargement of the root canal diameter. Thus, the size of the canal becomes bigger than or at least the same size as the tip of the first shaping rotary instrument used (Berruti et al., 2004; Varela-Patino *et al*., 2005). Hand-operated and engine-driven instruments can be used for glide path creation. Recently, two new rotary NiTi systems have been introduced for this purpose: PathFile System (Dentsply Maillefer) and G-Files (MicroMega).

The aim of the present study was to compare the survival of WaveOne and One Shape files used for the instrumentation of severely curved artificial canals, before and after the creation of a glide path.

II. Materials and Methods

Canal preparation was performed on 200 Endo-Training Block simulators (Dentsply Maillefer) with an apical diameter of 0.15 and a 0.02 taper, a 65 degree curvature and a 7.5 mm curvature radius.

The canals were divided in four equal groups: 1st group – shaped with WaveOne (Dentsply Maillefer) reciprocating files; 2nd group – shaped with One Shape (Micro Mega) files; 3rd group – preflared with PathFile System (Dentsply Maillefer) and shaped with WaveOne files; 4th group – preflared with G-Files (Micro Mega) and shaped with One Shape files.

Average lifespan and cumulative survival at the time of WaveOne and One Shape files were tested, before and after a glide path creation.

Following the instructions of the producer all files were operated using The WaveOne™ Endodontic system (Dentsply Maillefer), which is pre-programmed with settings for the WaveOne reciprocating file system. The One Shape files were used with a rotation speed of 400 rpm and torque 2.0gr/cm$^{2.}$ PathFiles and G-files worked at one and the same rotation speed (300 rpm) and torque (0.6gr/cm^2). The amount of pressure applied to all files was the pressure that could be applied to a sharp #2 pencil without breaking the lead. The files were never forced into the canal.

Initially, all canals were scouted to full working length with a #10 hand K-file. In the first group all canals were shaped with the small (ISO 21 tip and 6% taper) WaveOne file, following the instructions of the producer (a #10 hand K-file to be very resistant to movement at the initial inspection of the root canals).

In the second group shaping was performed with One Shape files (ISO 25 tip and 6% taper).

In the third group a glide path was created at the beginning with PathFile System. It consists of three instruments with a square cross section, four cutting angles, 21-25-31 mm length, a 0.02 taper and a size of the tip ISO 13, 16 and 19. Later, the canals were instrumented with the small (ISO 21 tip and 6% taper) WaveOne file.

In the fourth group G-Files were used for glide path creation. G-Files consist of two instruments 21-25-29 mm long, with a 0.03 taper, a size of the tip ISO 12 and 17 and a variable cross-section throughout the length of the instrument. The 3 cutting edges are on three different radiuses relative to the axis of the canal, leaving a large and efficient area for upward debris removal. Shaping was finished with One Shape files (ISO 25 tip and 6% taper).

WaveOne and One Shape files worked till fracture occurred.

During mechanical instrumentation each file was coated with Glyde™ (Dentsply Maillefer) to act as a lubricant, and copious irrigation with 5.25% NaOCl was carried out.

The instrumentation of all canals was performed by a single operator.

III. Results

a) Average Lifespan of Shaping Files

i. *Comparison between WaveOne and One Shape files*

Fifteen files were used in canals' preparation and fourteen of them broke: 4 WaveOne files and 10 One Shape files. The longest lifespan of a single WaveOne file was 13 canals and of a single One Shape file - 7 canals. Respectively, the shortest lifespan was 7 and 2 canals.

The average lifespan of one WaveOne file was 10.25±2.50 canals and of a single One Shape file - 4.1±1.37 canals. The difference was statistically significant ($p<0.001$) (t-test).

ii. *Comparison between WaveOne and WaveOne+PathFiles*

Eight WaveOne reciprocating files were used in canals' preparation and six of them broke: 4 files before the creation of a glide path and 2 after the initial enlargement of the artificial canals with PathFile System. The longest lifespan of a single file from the first group was 13 canals and from the second group – 19 canals. The shortest lifespan was measured in the first group and was 7 canals.

The average lifespan of one WaveOne file without a creation of a glide path was 10.25±2.50 canals and after a creation of a glide path – 17.50±2.12 canals. The difference was statistically significant ($p<0.05$) (t-test).

iii. *Comparison between One Shape and One Shape+G-Files*

Nineteen files were used during the instrumentation and 18 of them broke: 10 in the group without a glide path and 8 – after the preliminary enlargement with G-Files. The longest lifespan in the first group is 7 canals and in the second – 6 canals. Two canals were the shortest lifespan in both groups.

The average lifespan of a single One Shape file without a creation of a glide path was 4.1 (±1.37) canals and after a creation of a glide path – 4.6 (±1.30) canals. The difference was statistically insignificant ($p>0.05$) (t-test).

iv. *Comparison between WaveOne+PathFiles and One Shape+G-Files*

Twelve shaping files were used after the initial enlargement of the canals – 3 WaveOne files and 9 One Shape files. During the instrumentation ten of them broke: 2 WaveOne files and 8 One Shape files. The longest lifespan of a single file from the first group was 19 canals and from the second group – 6 canals. The shortest lifespan was measured in the second group and was only 2 canals.

After the creation of a glide path, the average lifespan of one WaveOne file was 17.50±2.12 canals and of a single One Shape file–4.63±1.30 canals. The difference was statistically significant ($p<0.001$) (t-test). The results of the average lifespan of the tested shaping files can be summarized in Table 1.

Table 1 : Average lifespan of WaveOne and One Shape rotary files

№	Preparation technique	Number of broken files	Highest number of successfully treated canals	Lowest number of successfully treated canals	Average lifespan
1	WaveOne	4	13	7	10.25±2.50
2	WaveOne+PathFile	2	19	16	17.50±2.12
3	One Shape	10	7	2	4.1 (±1.37)
4	One Shape+G-Files	8	6	2	4.63±1.30

b) Cumulative Survival at the Time of Shaping Files

The survival rate for one WaveOne files was 75% at the instrumentation of the 8th canal, 50% at the 11th one and 25% at the shaping of the twelve canal.

The cumulative proportion surviving at the time for One Shape was 90% at the instrumentation of the 3rd canal, 70% at the 4th one, 30% at the 5th and 10% at the 6th canal. All files were broken at the preparation of the 8th canal.

The cumulative survival for WaveOne files, after the creation of a glide path, was 50% at the instrumentation of the 17th canal and all files were separated at the instrumentation of the 20th canal.

The survival rate for One Shape files, after the creation of a glide path, was 88.9% at the instrumentation of the 3rd canal, 66.7% at the instrumentation of the 5th canal, 26.7% at the preparation of the 6th canal and all files were separated at the instrumentation of the 7th canal.

i. *Comparison between WaveOne and One Shape files*

The comparison between the two systems reveals significant difference ($p<0.05$). At the 6th canal the cumulative survival of one WaveOne file was 100%, while it was only 10% for a single One Shape file. At the 8th canal 75% of WaveOne files were intact but all One Shape files were broken.

ii. *Comparison between WaveOne and WaveOne+PathFiles*

After the creation of a glide path, all WaveOne Files were intact (100% survival) at the instrumentation of the 14th canal, while all of them from the first group (without a glide path) were broken. The log-rank test presented a significantly longer survival ($p<0.05$) for the instruments used after a glide path was created.

iii. *Comparison between One Shape and One Shape+G-Files*

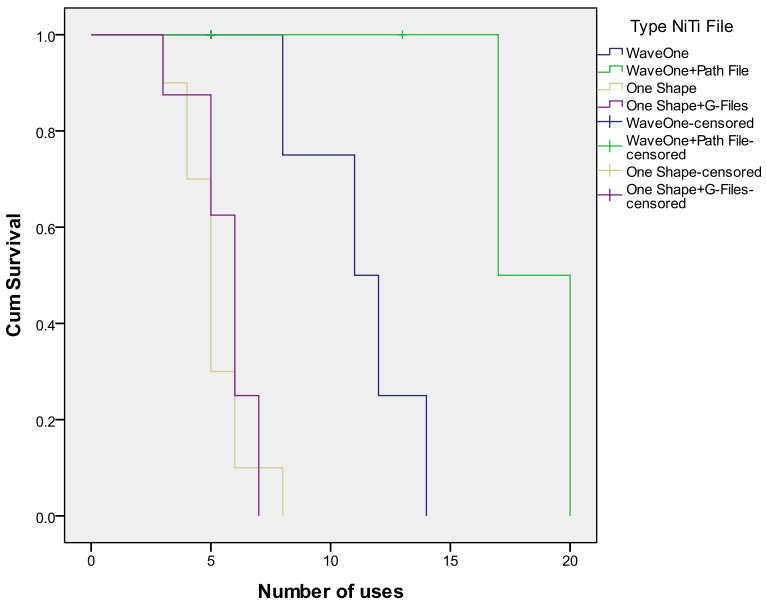
At the shaping of the 5th canal, after the creation of a glide path, the cumulative survival of a single One Shape file (66.7%) was twice as high as in the first group (30%).

Although the survival rate increased after the preliminary enlargement of the canal diameter, the difference between the two groups remained insignificant ($p>0.05$).

iv. *Comparison between WaveOne+PathFiles and One Shape+G-Files*

When comparing the results from both groups, it is found that at the instrumentation of the 7th canal all WaveOne files were intact (100% survival), while all One Shape files were broken. After the creation of a glide path, the log-rank test presented a significantly longer survival for the WaveOne instruments when compared with the One Shape files ($p<0.05$).

The survival curves of the tested instruments are presented on Fig. 1.



Figurer 1 : Survival curves of WaveOne and One Shape files

IV. Discussion

Our study was carried out on standardized artificial canals, which are expected to minimize the influence of other variables (Yao et al., 2006). We used Endo-Training Block simulators with high degree curvature in the apical 1/3 because we wanted to trace out and to compare the survival of WaveOne and One Shape rotary files under the conditions of greater stress. It is well documented in *in vitro* investigations that a stronger curvature and a smaller radius of the root canal increase the risk of rotary instrument fracture (Pruett et al., 1997; Zelada *et al.,* 2002; Martin *et al*., 2003). Despite the proven beneficial characteristics of the nickel-titanium rotary instruments, the risk of their separation, especially during the instrumentation of severely curved canals is higher (Iqbal *et al*., 2006; You et al., 2010; Setzer *et al.,* 2013). Fracture of NiTi files is a result of flexural and torsional failure. Flexural fracture is due to repeated compression and tension in curved canals that lead to cyclic flexural fatigue of the metal and the initiation of cracks from the outer surface of the instrument (Berutti *et al.,* 2006). In majority of cases, torsional fracture occurs in the last millimeters of the file when the tip or any other part of the instrument binds to the canal walls whereas the handpiece keeps turning (Sattapan *et al*., B 2000; Arens *et al*., 2003; Di Fiore, 2007; Varela Patino *et al.,* 2010). Consequently, NiTi files exposed to torsional stress are more susceptible to fracture and can break at a lower cyclic fatigue (Cheung *et al.,* 2005), and at the same time, torsional resistance decreases in used files (Parashos *et al*., 2006).

The observations in our study are similar to the findings in the works of Pruett et al., Varela Patino *et al*. and Tygesen *et al*. (Pruett *et al*., 1997; Tygesen *et al*., 2001; Varela Patino *et al*., 2005). Instrument breakage occurred in the apical portion of the canal, a few millimeters from the tip of the file, at the point of maximum flexure within the canal, where the stress is greatest.

The choice of the instruments compared in our investigation was not accidental. Our attention was directed to WaveOne and One Shape NiTi rotary files because they are sterile single-file systems and have non-working (safety) tip and variable cross-sections along the blade of the instrument. At the same time, they work with different mode of rotation – reciprocating (WaveOne) and continuous (One Shape). Both producers claim their products are safe and ensure an effective apical progression with low risk of fractures and obstructions. In fact, the incidence of their separation in clinical practice can increase as s result of overusage due to their high cost.

The examined files have different size of the tip because of two reasons: firstly, the One Shape files are offered only in one size and secondly, the tip size of the WaveOne file was chosen strictly following the instructions of the manufacturer - to use the small

WaveOne file, if #10 hand K-file doesn't easily move toward the terminus of the canal.

Sometimes, shaping of severely curved canals is a big challenge. That is the reason most clinical guidelines and manufacturers' recommendations for instrumentation with rotary NiTi instruments to claim reduction of canal curvature. It can be achieved either by creating straight-line access, which is not always possible, or by initial enlargement of the canal. The preliminary creation of a glide path can be regarded as a crucial step during chemomechanical endodontic procedures which reduces the interference of the shaping instrument with canal walls and makes the subsequent use of the larger rotary NiTi instruments safer and more effective (Roland *et al*., DD, 2002; Ruddle, 2005; Di Fiore, 2007; Peters e*t al.,* 2010). The probability of canal modifications and aberrations seems to be significantly reduced (Berruti *et al.,* 2004; Varela Patino *et al.,* 2005; Berruti *et al.,* 2012).

The role of the initial creation of glide path is clearly demonstrated in our investigation, as well. After the preliminary enlargement of the artificial canals the average lifespan and the cumulative survival of WaveOne and One Shape files were increased.

In the couple WaveOne-WaveOne+PathFiles the difference between the average lifespan in the two groups was statistically significant ($p<0.05$). From 10.25±2.50 canals it raised to 17.50±2.12 canals, the number of broken files in the second group decreased twice and the highest lifespan values were found here – 16 and 19 canals. The log-rank test presented a significantly longer survival ($p<0.05$) for the instruments used after a glide path was created. In this group all WaveOne files were intact at the instrumentation of the 14th canal while all the files from the first group were broken; 50% of the instruments remained safe at the shaping of the 17th canal and the files didn't break until the preparation of the 20th canal.

The couple One Shape-One Shape+G-Files reveals the same tendency. The average lifespan was increased from 4.1 (±1.37) to 4.6 (±1.30) canals after the creation of a glide path but the difference was insignificant ($p>0.05$). We found the greatest number of fractures in the study – 10 and 8 files, respectively and the shortest lifespan of only two uses. At the instrumentation of the 5th canal in the second group the cumulative survival of a single One Shape file (66.7%) was twice as high as in the first group (30%) but the difference between the two groups remained insignificant ($p>0.05$).

The great difference in the results obtained for WaveOne and One Shape files can be explained to some extent with the characteristics of the two NiTi rotary systems used for glide path creation. They are claimed by the producers to create a good combination of flexibility, strength and efficacy that allows a safe and fast use even in severely curved and/or calcified canals. The last files used from the two systems have different tip size (PathFile – ISO 19 and G-Files – ISO 17) and create different apical size of the canal. For the WaveOne group it is closer to the size (ISO 21) of the shaping file used when compared with the One Shape group (ISO 25). Consequently, under one and the same conditions, the stress accumulated on One Shape files is greater and the separation incidence increases.

The great number of uses of WaveOne files can be attributed not only to the creation of a glide path but to the specific reciprocal way of rotation and their design, as well. It is well documented that the reciprocating rotation decreases the impact of cyclic fatigue on nickel-titanium rotary instrument life and the incidence of instrument fractures (in resin blocks and natural teeth) is lower (Varela-Patino *et al*., 2008; Varela-Patino *et al*., 2010; You et al., 2010; Pedulla et al., 2103). The survival of an instrument is directly proportional to the stress accumulated during work in the root canal (Berutti *et al*., 2003).

In the couple WaveOne-One Shape a statistically significant difference between the average lifespan of the two groups was found out. For one WaveOne file it was 10.25±2.50 canals and for a single One Shape file – only 4.1±1.37 canals. The tendency is preserved when the comparison was made after the creation of a glide path. The average lifespan of one WaveOne file was 17.50±2.12 canals and of a single One Shape file –4.63±1.30 canals and again the difference was statistically significant ($p<0.001$).

The results from the cumulative survival are similar. The comparison between the two systems reveals a huge difference. In the couple WaveOne-One Shape 75% of WaveOne files were intact at the shaping of the 8th canal while all One Shape files were broken. When a glide path was created, all One Shape files were separated at the instrumentation of the 7th canal but 100% of WaveOne files survived.

The findings from our study undoubtedly demonstrate that reciprocating motion reduces torsional stress and avoids taper-lock due to the unsymmetrical repeating of the clockwise and counterclockwise rotations (Yared et al., 2001; You *et al.,* 2010). Our results are in agreement with the findings of the work of Varela Patino *et al.* (Varela Patino *et al*., 2010) in which the incidence of instrument fracture in blocks of resin was lower with alternating rotation than with continuous rotation. The mean number of uses in their study was 10 with alternating movement compared with 4-5 uses with continuous rotation. Torsional stress is additionally decreased when a glide path is initially created because the area on which the stress is exerted on is shifted from the tip of the file to its body. Reciprocating motion raises our expectations for longer survival of the files and gives us more comfort and safety, especially during shaping of severely curved root canals.

V. Conclusion

In conclusion, within the limitations of this study, WaveOne files showed significantly higher resistance to fracture compared with One Shape files. Instrumentation with files with reciprocal motion increases significantly instruments life and makes them safer during shaping of root canals. NiTi rotary instruments can be used for creation of a glide path as a result of which the lifespan and survival rate of WaveOne and One Shape files increase.

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