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Review Article

Entering A New Era in Endodontics with Revolutionary Single File Systems: A Comprehensive Review

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Abstract

Root canal shaping is of utmost importance in the success of root canal treatment. Numbers of systems available are effective for shaping; accounting from stainless steel hand files to nickel-titanium rotary files to the new single file system concept. Single file technique is developed for shaping vast majority of canals, regardless of their length, diameter or curvature. Therefore, single use of endodontic instruments was recommended to reduce instrument fatigue and possible cross-contamination.

Keywords: *Single file system; Waveone; Reciprocation; Reciproc; Oneshape; Self Adjusting File*

Introduction

Cleaning and shaping is a key step for successful root canal treatment. Its aim is to remove all tissue debris from the root canal space while removing the inner layers of root canal dentin. For many years, it has been a common practice to enlarge the root canal to at least three ISO sizes larger than the first file to bind at the apical part of the canal. It was assumed that such preparation will remove the inner layers of the dentin while allowing the irrigant to reach the entire length of the root canal for a thorough cleaning and disinfection of the root canal space [1,2].

Over the decade, an outstanding display of files has emerged for negotiating and shaping canals. Every new age group of files has more developed canal preparation techniques through novelty in design, movement and material [3]. Endodontists have visualized preparing canals utilizing a single-file technique. Therefore, practically all canals can now be optimally prepared using a single-file technique [4]. Newly the focus is on the idea "less is more" [5] for endodontic canal preparation, which means the whole cleaning and shaping of root canal space can be done with only one file. This article addresses the changing concepts of "Single file" endodontic instrumentation. The principle of reciprocation versus continuous rotation is being highlighted. The various single file systems available, their design, clinical feature, protocol for use and related clinical studies are discussed in detail.

Chronology of Endodontic Instruments and Changing Concepts

Endodontics has witnessed many changes within the past 20 years. The first change in the way of instrumenting a root canal came with the conversion of carbide steel hand files to stainless steel hand files. This was significant in terms of repeated use and sterilization aspects. However, techniques using stainless steel hand files have several drawbacks like it is time consuming, there is increased incidence of canal transportation and use of hand instruments in narrow canals can be very frustrating especially in teeth with difficult access [6]. The next major change was the introduction of NiTi rotary files in the early 1990s. In 1988, Walia., *et al*. [7] proposed Nitinol, a Ni-Ti alloy

for shaping canals, as it was 2 to 3 times more flexible, in the same file sizes, as compared to stainless steel files. A game-changing outcome of files manufactured from Ni-Ti was that curved canals could be mechanically prepared utilizing a continuous rotary motion. By the mid-1990s, the first commercially available Ni-Ti rotary files had come to market [8]. The first rotary file introduced was LightSpeed in 1994.

The following is a mechanical classification of each generation of rotary file systems:

1. First generation Ni-Ti files have passive cutting radial lands (encouraged a file to stay centered in canal curvatures during work) and fixed tapers of 4% and 6% over the length of their active blades [9] (Figure 1).

2. Second generation of Ni-Ti rotary files came to market in 2001 [10]. They have active cutting edges (Figure 2) and require fewer instruments to fully prepare a canal. The clinical breakthrough occurred when ProTaper (DENTSPLY Tulsa Dental Specialties) (Figure 3) came to market, utilizing multiple increasing or decreasing percentage tapers on a single file.

3. Improvements in Ni-Ti metallurgy became the hallmark of what may be identified as the third generation of mechanical shaping files. In 2007, manufacturers began to focus on utilizing heating and cooling methods to reduce cyclic fatigue and improve safety when rotary Ni-Ti instruments work in more curved canals [11]. Examples of brand lines that offer heat treatment technology are Twisted File (Axis Sybron Endo); HyFlex (Coltène); and GT, Vortex and WaveOne (DENTSPLY Tulsa Dental Specialties).

4. Fourth generation utilizes reciprocationn, which may be defined as any repetitive up-and-down or back-and-forth motion (Figure 4). Blanc, a French dentist, first introduced this technology in the late 1950s. Currently, the M4 (Axis/SybronEndo), Endo-Express (Essential Dental Systems), and Endo-Eze (Ultradent Products) are examples of fourth generation files. While reciprocation and rotation camps were busy fighting regarding the merits of instrumentation motion, a novel concept of instrumentation and file design was introduced. This was the self-adjusting file (SAF). This file consists of a hollow, collapsible cylinder made up of a very thin NiTi lattice that adapts to the canal walls and sandpapers the dentin instead of cutting it.

5. The fifth generation of shaping files has been designed such that the center of mass and/or the center of rotation are offset (Figure 5) which minimize the engagement between the file and dentin.

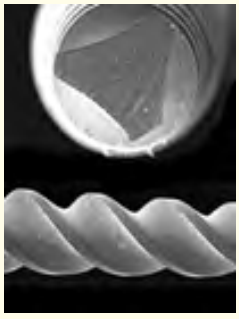

Figure 1: *SEM images showing the cross-sectional and lateral views of apassively cutting radial-landed file.*

Recent advances for endodontic canal preparation have focused on the concept "Less is More" i.e. with use of only one or two files biomechanical preparation of canal can be completed. Thus, a single-file technique has developed for shaping the vast majority of canals, regardless of their length, diameter, or curvature. Today as there are large number of single file systems available, a comparative evaluation of these systems need to be done.

Figure 2: *SEM images showingl the cross-sectional and lateral viewsof an active file with sharp cutting edges.*

Figure 3: *Taper Shaping files (DENTSPLY Tulsa Dental Specialties) cut dominantly in their coronal and middle one thirds, whereas the Finishing files cut primarily in their apical one thirds.*

Figure 4: *WaveOne (DENTSPLY Tulsa Dental Specialties) reciprocating file utilizes unequalcounterclockwise/clockwise angles to improve efficiency, inward progression, and auguring debris out of the canal.*

Figure 5: *Cross-section of a ProTaper Next (PTN) file (DENTSPLY Tulsa Dental Specialties). Note an offset mass desirably reduces file engagement, provides greater space debris, and improves flexibility [12].*

Concepts of Reciprocation Versus Rotary

By far, the greatest number of commercially available files utilized to shape root canals is manufactured from nickel-titanium (Ni-Ti) and are mechanically driven in continuous rotation. In continuous rotation file is rotation file rotated 360° continuously with in the root canal.

On the other hand, reciprocation, defined as any repetitive back-and-forth motion, has been clinically utilized to drive stainless steel files since 1958. In 1985, Roane., *et al.* introduced the balanced force technique using instruments in rotational reciprocation for the preparation of curved root canals [13]. They were the first to report the use of hand files with unequal clockwise and counter-clockwise movements in reciprocation. In 2008, Yared introduced engine-driven single file reciprocation for the preparation of curved canals [14]. (Figure 6).

Figure 6

Single-file reciprocating shaping technique utilizing unequal clockwise and counterclockwise angles is over four times safer and almost three times faster than using multiple rotary files to achieve the same final shape [15].

- Several studies [16-20], except for one [21], have shown that reciprocation extends the flexural cyclic fatigue life of the tested instruments in comparison with continuous rotation.
- De-Deus., *et al.* [22] showed that 80% of canals with a moderate to a severe curvature could be prepared with a Reciproc instrument without a glide path.
- Liu., *et al.* [23] showed that Reciproc and the Self Adjusting File (ReDent Nova, Ra'anana, Israel) caused less dentinal defects compared to single and multiple file rotary instruments.
- Btirklein and Schafer [24] demonstrated, *in vitro*, that multiple file rotary systems were associated with less apical extrusion of debris compared to single file reciprocating systems.
- The antibacterial activity of the single file reciprocation technique was comparable with the conventional rotary techniques and the Self Adjusting File in regular and oval shaped canals [25].

Why Single File Systems!

1. They made root canal therapy more accessible and easier for a dentist.
2. Reduces working time.

3. Lowers cross contamination.

4. Faster preparation and has added advantage of reducing the instrument fatigue i.e.minimizes separation within canal without compromising the cutting efficiency.

5. There is no need for disinfecting, cleaning, sterilizing and organizing the files.

6. Single file technique is developed for shaping vast majority of canals, regardless of their length, diameter or curvature.

Limitations

1. Cost of the file

2. Reusability

3. Need of battery operated motor

Single File Systems

WAVEONE

It is a SINGLE-use, SINGLE-file system introduced by DENTSPLY Maillefer to shape the root canal completely from start to finish.

Manufacturing: The files are manufactured using M-Wire technology, improving strength and resistance to cyclic fatigue by up to nearly four times in comparison with other brands of rotary Ni-Ti files [26].

Design: The instruments are designed to work with a reverse cutting action. All instruments have a modified convex triangular cross-section at the tip end (Figure 7, D1 to D8) and a convex triangular cross-section at the coronal end (Figure 8, D9 to D16). This design improves instrument flexibility overall and conserves remaining dentin in coronal two third of the finished preparation. The files have left handed threads [27] instead of usual right handed threads and reversed helix so CCW rotations engage the file whereas CW rotation disengages the file the tips are modified (non-cutting) to follow canal curvature accurately. The variable pitch (Figure 9) flutes along the length of the instrument considerably improve safety. At present, there are three files [Small (yellow), primary (red), and large (black) files] in the WaveOne single-file reciprocating system available in length of 21, 25 and 31 mm.

Figure 7: *(D1 to D8).*

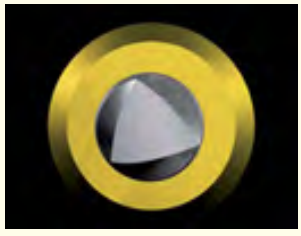

Figure 8: *(D9 to D16).*

Figure 9: *Variable pitch.*

File type	COLOR CODE	INDICATION	TIP SIZE	TAPER
Small file	Yellow	fine canals	ISO 21	6%. (continuous taper)
Primary file	Red	majority of canals	ISO 25	8% (reduces towards the coronal end)
Large file	black	large canals	ISO 40	8% (reduces towards the coronal end)

Clinical Features: Specially designed Ni-Ti files work in a reverse "balanced force" action [28] using a pre-programmed motor to move the files in a back and forth "reciprocal motion". The WaveOne motor is rechargeable battery operated with a 6:1 reducing handpiece. The pre-programmed motor is set for the angles of reciprocation and speed for WaveOne instruments. The counter clockwise (CCW) movement is greater than the clockwise (CW) movement. CCW movement advances the instrument, engaging and cutting the dentine. CW movement disengages the instrument from the dentine before it can (taper) lock into the canal. Three reciprocating cycles completes one full reverse rotation and the instrument gradually advances into the canal with little apical pressure required. WaveOne files have their own unique reverse design and can only be used with the WaveOne motor with its reverse reciprocating function.

WaveOne instruments are a new concept in this important standard of care because there is a possibility of cross-contamination associated with the inability to completely clean and sterilise endodontic instruments [29] and the possible presence of prion in human dental pulp tissue [30] all instruments used inside root canals should be single use. The plastic colour coding in the handle becomes deformed once sterilised, preventing the file from being placed back into the handpiece.

Protocol for use

The WaveOne technique involves the following stages:

1. Straightline access.

2. WaveOne file selection:

   a. If a 10 K-file is very resistant to movement, use WaveOne Small file.

   b. If a 10 K-file moves to length easily, is loose or very loose, use WaveOne Primary file.

   c. If a 20 hand file or larger goes to length, use WaveOne Large file.

3. Single-file shaping:

   a. Take hand file into canal and watch-wind to length or resistance (approximately two-thirds of canal length).

b. Use appropriate WaveOne file to approximately two-thirds of canal length

c. Irrigate copiously.

d. Take hand file to length and confirm with an apex locator and radiograph.

e. Take WaveOne file to length.

f. Confirm foramen diameter with hand file, the same size as WaveOne file; if snug, preparation is complete.

g. If foramen diameter is larger than WaveOne file, consider the next larger WaveOne file.

h. Majority of cases will be completed with WaveOne Primary file.

4. Copious irrigation with 5% NaOCl and EDTA before, during and after single-file shaping.

RECIPROC

This new system uses single file reciprocation without prior use of hand files and was launched by VDW GmbH, Munich, Germany in 2011.

Indication

1. Preparation of the root canal system.

2. Retreatment of the root canal system (removal of gutta-percha filling material and carrier-based obturators).

Contraindication: If in rare cases, the hand file used for the working length determination (after the RECIPROC® instrument has reached 2/3 of the working length) needs to be pre-curved in order to reach the working length, it is necessary to create a glide path up to ISO size 15. If the ISO size 15 hand instrument has to be pre-curved in order to reach full working length after the creation of a glide path, there is an abrupt apical curvature in the apical region. The use of RECIPROC® instruments is contraindicated in this instance. In these cases the canal preparation has to be finished with hand files. This limitation also applies to continuous rotary instruments.

Manufacturing: Made from an M-Wire nickel-titanium that offers greater flexibility and resistance to cyclic fatigue than traditional nickel-titanium [28]. (Figure 10).

Device Description: The flexible S-shaped cross-section (Figure 11) having two cutting edges gives fine cutting ability at decreased friction. A regressive taper (Figure 12) for a preparation with no unnecessary loss of tooth substance at the coronal end. They have a continuous taper over the first 3 mm of their working part followed by a decreasing taper until the shaft. RECIPROC cleans even severely curved canals (Bürklein., *et al*. 2012). This system includes three Reciproc instruments R25, R40 and R50 (Figure 13). The stopper, in the ISO color of the specific Reciproc instrument tip size, has three points representing the several movements needed to complete 360 degrees in reciprocation. This is to support clear identification of the Reciproc instrument regarding both size (color) and specific reciprocation use (three points). Reciproc instruments have radiograph visible depth markings at 18, 19, 20 and 22 mm. Reciproc instruments have been designed with diameters and tapers which give an optimal apical preparation in most cases according to the canal anatomy, and using just one instrument. Only one Reciproc instrument is used for the canal preparation depending on the initial size of the canal.

Figure 10: *Non cutting tip.*

Figure 11: *S-shaped cross section.*

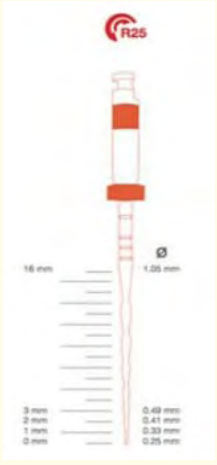

Figure 12: *Regressive taper.*

Figure 13

Clinical Features: It takes several reciprocating movements to complete just one rotation of 360° (Figure 14). The angles of alternating right and left rotations are considerably lesser than the angles at which a Reciproc instrument can cause fracture in the process of reciprocation. These angles are preserved in the Reciproc endodontic motor, which prevents these instruments from rotating past its particular angle of fracture. The centering ability of this reciprocation technique also permits the instrument to pursue the natural path of least confrontation, which is the root canal.

Figure 14

The Reciproc system is mainly designed for convenience and protection. With the single use specification of instruments, makes the work more efficient, and it declines the risk of contamination.

PROTOCOL FOR USE [29]

1. Create a straight line access to the root canal entrance
2. Select the correct RECIPROC instrument:
3. Introduce the RECIPROC® instrument into the canal. Press the motor foot pedal when orifice is reached.
4. Move the instrument in a slow in-and-out pecking motion. The amplitude of the in-and-out movements should not exceed 3 mm. Only very light pressure should be applied. The instrument will advance easily in the canal. One in-and-out movement = 1 peck. Remove the instrument from the canal after three pecks.
5. Clean the debris from the flutes in the Interim Stand.
6. Irrigate the canal.

7. Make sure the canal is free to approx. 3 mm beyond the prepared canal section with an ISO size 10 C-PILOT® File.

In this way, continue with the RECIPROC® instrument until full working length has been reached.

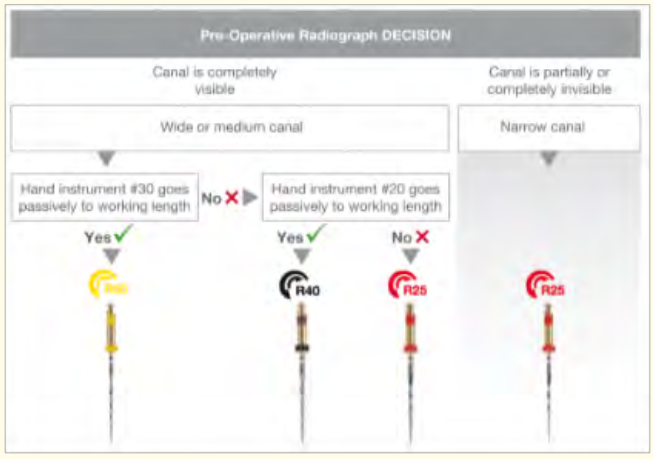

Figure 15

SELF ADJUSTING FILE

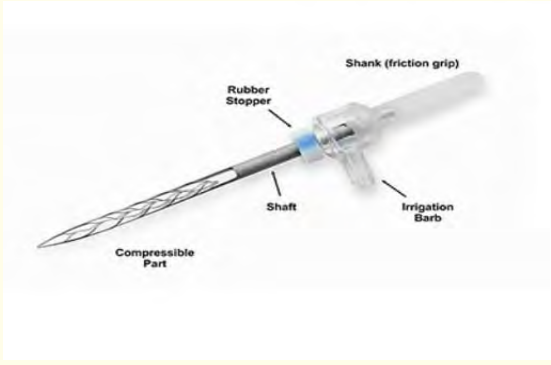

Figure 16

The SAF introduced by ReDent NOVA.

Manufacturing: The ReDent NOVA SAF is an endodontic file that is indicated for use in root canal treatment for cleaning and shaping of the root canal. The file portion of the SAF consists of a metal lattice hollow cylinder and is constructed from medical grade nickel-titanium-alloy.

Indication: The SAF is used as a single instrument to achieve complete 3D root canal shaping and cleaning.

Contraindications

1. Do not use the 1.5 mm diameter SAF if the initial diameter of the root canal allows the insertion of an ISO 045 K-file to its full working length, or on teeth that do not have fully formed roots with a mature apex.

2. The SAF is not to be used in working lengths greater than 31 mm.

Device Description

The hollow design allow SAF to be elastically compressed along its cross-section [B], when inserted into canal previously negotiated with No. 20 K file (Figure 17). It does not impose its shape on the canal but rather complies with the canal's original shape. This is true both longitudinally (A) and circumferentially (B) (Figure 18). In a round canal, it will attain a round cross-section, whereas in an oval or flat canal it will attain a flat or oval cross-section, providing a three-dimensional adaptation (Figure 18). Attempting to expand SAF applies light continuous pressure along the entire circumference of the root canal wall (Figure 19). Operated with a gentle vertical vibration (0.4 mm, 5,000 rpm), the abrasive surface of the file achieves a gradual enlargement of the root canal (Figure 20). The SAF is available in 2 diameters 1.5 mm (in lengths of 21 mm, 25 mm and 31 mm) and 2 mm (in lengths of 21 mm and 25 mm). The SAF 1.5 mm is designed for canals with initial apical size of ISO 20-40. The SAF 2 mm is designed for use in wider canals, with initial apical size of ISO 35 - 60, commonly found in retreatments, upper incisors, canines and younger patients (Figure 22). The file is attached to the hand piece via a polypropylene shank.

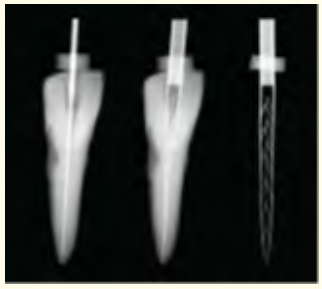

Figure 17: *(Image adapted from Metzger., et al. J Endod 2010 Apr;36(4):679-90).*

Figure 18: *(Adapting to the canal outline).*

Figure 19: *(Gradual expansion).*

Figure 20: *(Abrasive surface).*

Figure 22

Precautions

1. The law restricts this device to sale for use by or on the order of a dentist.

2. SAF files should not be used in any manner other than that detailed in Manufacturer's Instructions.

3. The SAF file is designed for a single use only. Multiple uses, disinfection and sterilization cycles may lead to increased risk of file separation.

4. Recommended working speed for all SAF files - Reciprocation of 3000-5000 OPM [oscillations per minute].

5. Irrigation should be applied while operating the SAF in the root canal.

6. When alternating between canals, inspect the instrument for any signs of wear.

Protocol for Use 1.5 mm and 2 mm diameter SAF

Root canal structure should be evaluated before treatment and the procedure should be adopted accordingly.

1. A pre-operative X-ray should be taken in order to estimate working length of the root canal and tooth anatomy.

2. Isolate the tooth, using a rubber dam.

3. Prepare a standard access cavity.

4. Locate root canal orifices and adjust the access cavity walls to allow clear and unobstructed access to each canal.

5. Use a Gates-glidden #3 or equivalent to prepare the coronal third of the canal to an adequately flared shape.

6. Establish the working length of the root canal using either an X-ray or an electronic apex locator.

7. Select a SAF file with the appropriate length and width to match tooth working length and width.

SAF 1.5 should be used for canals with initial width of up to ISO 035.

SAF 2 mm should be used for canals starting from size ISO 035 to ISO 060.

8. When using 1.5 mm SAF a preliminary reproducible glide path should be established using one of two methods:

a. Hand files to ISO 020 /.02 size. Funneling the coronal orifice of the root canal should be performed using an orifice shaper of your choice.

b. Create an apical ISO 020 /.04 taper glide path preparation.

9. Prior to using 2 mm SAF, use ISO 030 instruments to remove gross pulp tissue.

10. Adjust the rubber stopper on the SAF to indicate the desired working length.

11. Attach irrigation tube from any approved medical irrigation device to the SAF irrigation barb (Figure 21).

12. Continuous irrigation should be applied throughout the procedure. The choice of irrigant is at the discretion of the treating dental professional.

13. Insert the SAF gently into the canal while operating. Do not force the SAF apically. Working length will be reached while operating.

14. If resistance to insertion is noted, stop and re-establish glide path.

15. Work is performed using light pecking motions for 4 minutes in each canal.

16. Gauge the apical region of the canal using hand files to confirm that the desired root canal enlargement has been achieved. If enlargement is less than desired, another 1 minute of work may be applied.

17. Canal shaping is now complete.

18. Your preferred obturation method may be used.

Figure 21: *(Continuous irrigation).*

ONE SHAPE

This system was developed by Micro Mega, Besancon, France.

Manufacturing: The One Shape system consists of only one instrument made of a conventional austenite 55-NiTi alloy.

Device Description: One Shape is a new concept of single- file instrumentation where a single instrument is used in a full clockwise rotation.

1. The One Shape system consists of only one instrument, which has a tip size of 25 and a constant taper of 0.06 (Figure 23).
2. One Shape® Apical files are sterile and single use instruments which can be used after shaping with One Shape® to apically enlarge the root canal (Figure 24).

Figure 23

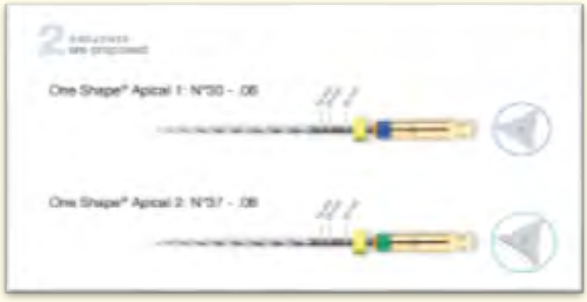

Figure 24

One Shape® principle: Innovative instrument design characterized by different 3 different cross-section zones over the entire length of the working part [30,31] (Figure 25). Asymmetrical cross-section + longer pitch- increase the available volume for upward debris elimination: high-quality shaping. More flexibility due to the longer instrument pitch. Easy progression - superior ability to negotiate curves. Improved working comfort - the longer pitch makes an easier progression of the instrument to the apex.

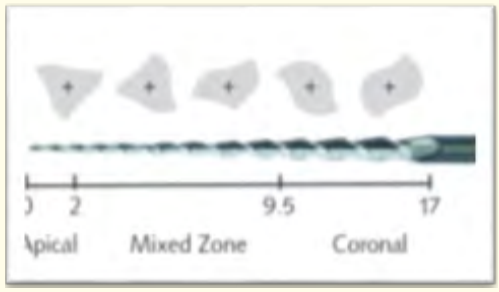

Figure 25

Clinical Features: File operates at Speed - 350 - 450 RPM and Torque- 2.5 N.cm. One Shape file is delivered in a germ-free blister, and it is recommended to use one file per tooth and then surplus. The file be supposed to not sterilized, as the cutting effectiveness decreases severely, so the file should be utilized for maximum of 3-4 canals [32]. One Shape protocol is easy to learn, safe and quick. Therefore, it might be a good alternative to existing reciprocating single file systems without the need to use a special endodontic motor generating the reciprocating motion [31].

Protocol for Use

1. Establish straight-line access preparation to expose canal orifices.
2. Remove coronal constrictions with ENDOFLARE® (or use your current flaring technique). Canal penetration of ENDOFLARE® is limited to 3 mm below the pulp chamber floor.
3. Establishing the Glide Path:

- Prepare the glide path using #10 Stainless Steel K-type hand file.
- If canal constrictions prevent the #10 K file from easily reaching the EWL, complete glide path preparation using G-Files, NiTi files for glide path development in continuous rotation.

4. Shaping the Root Canal:

Irrigate thoroughly with sodium hypochlorite. A chelating gel can also be used during the root canal shaping.

- Place One Shape® down to the 2/3 of the WL using an in and out movement without pressure. Perform an upward circumferential filing movement in order to pre-enlarge the canal. Withdraw the One Shape® instrument from the root canal and clean it. Irrigate and check canal patency with a #10 K file.
- Reintroduce the One Shape® instrument into the root canal and place it down to 3 mm from WL using an in and out movement without pressure. Withdraw the One Shape® instrument from the canal and clean it. Irrigate and re-check the canal patency with a #10 K file.

- Reintroduce the One Shape® instrument into the root canal and take it down to the WL by performing the recommended in and out movement. The WL can be reached in one or more passages (file withdrawal, cleaning of the file, irrigation and patency check) depending on the complexity of the canal anatomy.

Remove and clean the instrument and irrigate the canal when apical resistance or a slight apical pull is encountered. Repeat steps until the WL is reached.

KOMET F360

F360 is a single instrument used in continuous rotation introduced by Komet Brasseler, Lemgo, Germany. This file system permits preparation of most root canals with a simplified, time-saving sequence requiring only two files.

Indications

1. Rotary preparation of straight and curved root canals in a torque limited power system.

Contraindications

1. Root canals with pronounced abrupt curves in apical region and severely calcified root canals.
2. Plastic deformation in instrument, e.g. untwisted blades, in the region of the working part (during the course of the treatment, during intermediate cleaning), discard files.

Device Description: The cross section of F360 files resembles a Double-S (S-curve design, Figure 26-28) influencing its cutting performance and cleaning capacity. Sharp cutting angles and large space ensure a remarkable cutting efficiency and removal of infected debris, which significantly reduces the time for root-canal preparation. It has a thin instrument core to deliver a high level of cutting efficiency while respecting natural root canal morphology [33].

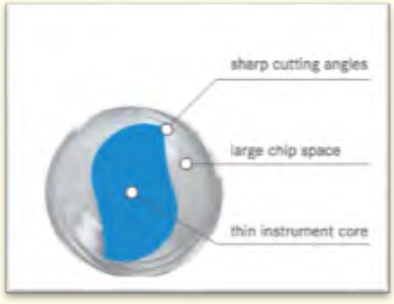

Figure 26

In addition to sizes 025 and 035 (required for most root-canal preparations), the F360 files are offered in sizes 045 (White) and 055 (Red) to meet additional clinical situations such as wide roots [34]. F360 files are available in three lengths L21, L25 and L31.

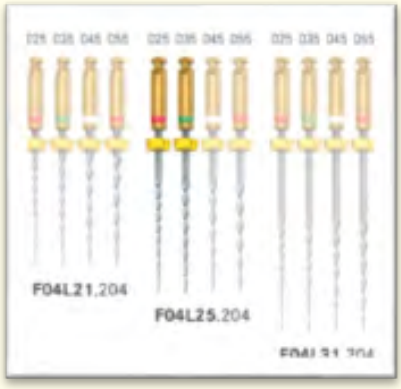

Figure 27

Figure 28

Clinical Features

1. Fast preparation [35].
2. Original anatomy of the canal is preserved [36].
3. Little over-extruded debris [37].

Protocol for Use

1. Prior to using the F360 NiTi files, an orifice opener is used to pre-enlarge the coronal part of the root-canal and to remove all infected substance.
2. Afterwards, patency of the canal should be ensured by means of suitable manual instruments up to a size #15.
3. In most cases, the root-canal can be prepared with just two files: The red F360 file in size #25, followed by the green F360 file in size #35.
4. The use of the first F360 in size #25 may be sufficient in cases of very narrow root canals.
5. The use of additional files in sizes #45 (white) and #55 (red) may be required in cases of wide canals.

6. Insert the file into canal in rotary mode in a conventional torque-limited electric handpiece or endomotor.

7. Each F360 file is used in rotary mode to full working length.

8. Files are used in a rotary picking motion, i.e., they are moved along the canal wall in a dabbing manner so the files are kept moving at all times for a period of maximum 5 - 8 seconds, according to the single- length principle.

9. Clean the instrument periodically during the treatment, for example in the interim block.

10. Rinse the root canal thoroughly in order to flush out all debris.

Critical Evaluation of Single File Systems based on Clinical Properties

Comparative evaluation of all the single file systems based on very important clinical features like cyclic fatigue, crack formation, file separation, debris removal, cutting efficiency, apical transportation /canal shaping ability and retreatment success gives us an invaluable insight into the functioning and efficacy of these files that contribute immensely towards success of endodontic therapy. Various researchers have undertaken numerous '*in vivo*' and '*in vitro*' studies comparing these systems. A critical evaluation of all the single file systems based on clinical properties is compiled under.

Cyclic Fatigue

Instrument does not bind in the canal, but it rotates freely in a curvature, generating tension/compression cycles. This repeated tension-compression cycle, caused by rotation within curved canals, increases cyclic fatigue of the instrument over time and may be an important factor in instrument fracture.

- *Higuera., et al*. compared cyclic fatigue resistance between two systems i.e Waveone and Protaper. They found no statistically significant differences between the instruments tested except for WaveOne Primary, which showed the lowest resistance to cyclic fatigue. *(J Endod 2015; 41:913-915).*

- *Gustavo De-Deus., et al*. studied the bending resistance, the dynamic and static cyclic fatigue life of Reciproc and Waveone. They observed that Reciproc R40 instruments resisted dynamic and static cyclic fatigue significantly more than WaveOne large instruments. Furthermore, WaveOne instruments presented significantly less flexibility than Reciproc*. (J Endod 2014; 40:575-579).*

- *Hyeon-Cheol Kim., et al.* investigated cyclic fatigue and torsional resistance in reciprocating motion of Reciproc versus Waveone. They observed that Reciproc had the best fatigue resistance between groups and WaveOne had significantly higher NCF than ProTaper. The ultimate torsional strength was the highest for WaveOne, then Reciproc and followed by ProTaper r*. (J Endod 2012; 38:541-544).*

- *Ana Arias., et al*. examined cyclic fatigue resistance at apical and coronal Levels in two systems i.e Reciproc and Waveone. They found that Reciproc files were more resistant to cyclic fatigue than WaveOne files at both distances from the tip. *(J Endod 2012; 38:1244-1248).*

Crack Formation

Instrumentation with rotary NiTi instruments having active cutting edges & larger taper produce significant forces on root dentin during instrumentation and leads to root dentinal defects or apical root microcracks which have potential to develop into root fracture, thus deteriorating the root integrity and reducing long term prognosis of endodontically treated teeth.

- *Ertugrul Karatas., et al.* determined root cracks formation after root canal instrumentation with three different systems i.e Pro Taper Next, Pro Taper Universal and Waveone. ProTaper Next and Twisted File produced significantly fewer cracks than the ProTaper Universal and WaveOne systems only in the apical section. *(J Endod 2015; 41:261-264).*

- *Sebastian Burklein* tested the dentinal defects produced with reciprocating single-file systems (Reciproc and WaveOne) and the 2 full-sequence rotary Mtwo and ProTaper. Under the conditions of study, root canal preparation with both rotary and reciprocating instruments resulted in dentinal defects. At the apical level of the canals, reciprocating files (reciproc and wave one) produced significantly more incomplete dentinal cracks than full-sequence rotary systems. *(J Endod 2013; 39:501-504).*

- *Oguz Yoldas* assessed microcrack formation with Hand filling system, HERO Shaper, Revo-S, Twisted File, ProTaper and SAF. All rotary files created microcracks in the root dentin, whereas the SAF file and hand instrumentation presented with satisfactory results with no dentinal microcracks. *(J Endod 2012; 38:232–235).*

- Rui Liu., *et al*. measured the root microcracks formation with ProTaper, OneShape, Reciproc or the Self-Adjusting File. Nickel-titanium instruments may cause cracks on the apical root surface or in the canal wall. The Self-Adjusting File and Reciproc files caused less cracks than the ProTaper and OneShape files. *(J Endod 2013; 39:1054-1056).*

File Separation

When used in root canal, an instrument can bind in the canal. Following these, the instrument will be subjected to stress which will increase with the rotation of the instrument when bound; ultimately, the instrument will fracture. Also, an instrument will repeatedly engage the root canal walls to cut dentine; the instrument will be subjected to stress in torsion from the cutting procedure. This repeated stress can cause torsional fatigue which can also result in instrument fracture.

- *Rodrigo Sanches Cunha., et al.* evaluated file separation with Wave one files. They found that Incidence of endodontic instrument separation using the WaveOne reciprocating file was considerably low. *(J Endod 2014; 40:922-924).*

Debris Removal

Debris was defined as dentin chips, pulp remnants and particles loosely attached to the root canal wall. Effective cleaning (i.e. removal of debris) and shaping of the root canal system is essential for achieving the biological and mechanical objectives of root canal treatment.

- *Wael H. Kamel., et al*. analysed the smear layer and debris removal with Wave one and Reciproc. They found that Wave One produced the cleanest canal walls, and the Wave One system gave superior results compared with the ProTaper system. *(J Endod 2014; 40:446-450).*

- *Matthew A. Dietrich., et al*. measured canal and isthmus debris removal with Self adjusting file, K3 and waveone. They witnessed that there was no significant difference in canal cleanliness between the 3 file systems. However, SAF and K3 files performed significantly better than the WaveOne with respect to isthmus cleanliness *(J Endod 2012; 38:1140-1144).*

Apical extrusion of debris

When the endodontic retreatment is performed, various irritants may be extruded through the foramen. Filling materials, necrotic tissues, bacteria's or irrigants may be undesirably introduced into the periapical tissues. The extrusion of these materials may potentially cause problems, such as: post-operative pain, flare-ups, foreign-body reaction, and even failure in the lesion repair.

- Sebastian Burklein investigated the apical extrusion of debris with reciprocating single-file systems (Reciproc and WaveOne) and the 2 full-sequence rotary Mtwo and ProTaper. Under the condition of this study, all systems caused apical debris extrusion. Full-

sequence rotary instrumentation was associated with less debris extrusion compared with the use of reciprocating single-file systems. *(J Endod 2012; 38:850-852).*

- Sibel Koc¸Ak carried out a study to check the apical extrusion of debris with Self adjusting file, Pro Taper F2, Revo SSU or Reciproc. They observed that all instrumentation techniques were associated with extruded debris*. (J Endod 2013;39:1278-1280).*

- *Alison Luıs Kirchhoff., et al.* compared apical extrusion of debris with Waveone, ProTaper Next, Twisted File Adaptive and Self adjusting file. They observed that SAF was associated with the highest amount of debris extrusion compared with PTN, WO, and TFA*. (J Endod 2015;41:237-241).*

Cutting Efficiency

Cutting dentin is an important step during root canal preparation, as it is necessary to remove contaminated dentin and shape the canal to create conditions for it to be filled.

- *Gianluca Plotino., et al.* reviewed cutting efficiency of Reciproc and Waveone. They conclude that Reciproc instruments demonstrated statistically higher cutting efficiency than WaveOne instruments. *(J Endod 2014; 40:1228–1230).*

Apical transportation /Canal shaping ability

In curved root canals, their preparation is limited as it is difficult to control the instrument inside the endodontic space. Due to their curvature, force components tend to displace the instrument in the opposite direction, which may cause apical transportation, as well as root perforations.

- *Dan Zhao., et al.* assessed canal shaping properties of Pro Taper Next, Pro Taper Universal and Waveone. They observed that the WaveOne instruments shaped root canals in mandibular first molars in vitro without significant shaping errors. The curved canals prepared using PTN had less apical transportation than the canals prepared using WaveOne and PTU. *(J Endod 2014;40: 1860-1864).*

- *Elio Berutti., et al.* compared the canal curvature and axis modification after instrumentation with Wave One Primary reciprocating files and Rotary ProTaper. They concluded that canal modifications are reduced when the new WaveOne NiTi single-file system is used*. (J Endod 2012;38: 505–509).*

- *Abdulrahman Mohammed Saleh* researched the shaping ability in S-shaped Canals with Reciproc , WaveOne, OneShape and F360. Under the conditions of this study, all single-file instrumentsssss (Reciproc, wave one, one shape, F360) were safe to use and were able to prepare the canals efficiently. However, single-file systems that are less tapered seem to be more favourable when preparing S-shaped canals. *(J Endod 2015;41: 548–552).*

- *Ove A. Peters* evaluated the property of dentine removal with Self adjusting file. He observed that preparation of straight root canals in maxillary anterior teeth left little canal surface instrumented after shaping with the SAF. *(J Endod 2010;36: 1068-1072).*

- *Michael Solomonov* studied the efficacy of shaping C-shaped Canals between Self adjusting file and ProTaper. The SAF was more effective than the ProTaper file system in shaping the walls of C-shaped root canals*. (J Endod 2012;38: 209-214).*

- *Sebastian Burklein., et al.* measured the shaping ability of different rotary (HyflexCM, F360 & OneShape) and reciprocating (Reciproc & WaveOne) nickel-titanium file systems with and without previous glide path preparation in simulated S-shaped canals. Canals prepared with F360, OneShape, and HyflexCM remained better centered compared with those enlarged with WaveOne and Reciproc. *(J Endod 2014;40: 1231-1234).*

- *Tambe VH., et al*. disscused the canal transportation and centering ability of Rotary ProTaper, One Shape and Wave One systems using cone beam computed tomography. They observed canal preparation with Wave One files showed lesser transportation and better centering ability than One Shape and ProTaper. *(Journal of Conservative Dentistry, Nov-Dec 2014,Vol 17 , Issue 6)*

Canal Centring Ability

During instrumentation of the root canal, it is important to develop a continuously tapered form and to maintain the original shape and position of the apical foramen. However, the presence of curvatures may cause difficulty in root canal instrumentation. The ability to keep the instruments cantered is essential to provide a correct enlargement, without excessive weakening of the root structure.

- *Nazari Moghadam K., et al*. evaluated the canal transportation and centering ability of Twisted File (TF) to that of Reciproc system. They observed that Both file systems were able keep the original curvature of the canal and thus can be considered safe for clinical application. *(Iran Endod J. 2014 Summer;9(3): 174-9. Epub 2014 Jul 5)*

- *Hikmet A. Sh. Al-Gharrawi and Farah Salahalden Abbas* assessed the canal transportation and centering ability at different levels of root canals prepared by self-adjusting file using computed tomography. They found that Self Adjusting File group showed less canal transportation than ProTaper group. There was a comparable value of canal centering ability among different levels in each group except in BioRaCe group. *(J Bagh Coll Dentistry 2014; 26(1): 16-23).*

Retreatment

After a root canal procedure, a tooth may require retreatment because of a persistent infection or reinfection of the root canal. Retreatment requires complete removal of the root canal filling material, followed by further shaping, cleaning and re obturation.

- *Marcos de Azevedo Rios* studied the Gutta-percha removal with 2 reciprocating systems i.e Reciproc and WaveOne compared with a nickel-titanium (NiTi) rotary system (ProTaper Universal Retreatment). The Reciproc and WaveOne reciprocating systems were as effective as the ProTaper Universal retreatment system for gutta-percha and sealer removal. *(J Endod 2014; 40: 543-546).*

- *Kathelijn C. Voet* evaluated the removal of Gutta-percha with Pro Taper retreatment files and Self adjusting file. They detected that the complete removal of gutta-percha from the apical portion of curved canals remains a challenge. The additional use of SAF removed more gutta-percha than ProTaper alone. *(J Endod 2012;38: 1004-1006).*

Conclusion

It is concluded that Single file systems, are the new asset in endodontic armamentarium. Only single rotary file is used for complete endodontic treatments. A root canal treatment is approximately 3-4 times quicker than a conventional therapy. Thus, the general period of treatment is shortened, and it's easy for patients to accept the treatment due to less follow-ups. However further long-term studied with longer follow-ups are required to access the best file in this group.

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