

## An Overview of Modern Endodontic Niti Systems



### Medical Science

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### ABSTRACT

*A wide array of nickel–titanium (NiTi) instruments has been introduced for shaping root canals. Many variables and physical properties influence the clinical performance of NiTi rotaries. It is the clinical experience, handling properties, safety, and case outcomes that decides the fate of a particular instrument design. This review article appraises the metallurgical and mechanical properties of NiTi endodontic instruments in addition to discussing their experimental and clinical evaluations of the performance in endodontic treatment.*

### INTRODUCTION

Root canal instrumentation is accomplished by the use of endodontic instruments and irrigating solutions under aseptic working conditions. Root canal instrumentation may be carried out using hand-held or engine-driven (rotary) instruments. Rotary root canal instruments manufactured out of a nickel–titanium (NiTi) alloy have proven to be a valuable adjunct for root canal therapy. NiTi instruments are highly flexible and elastic.<sup>1</sup> NiTi instruments were introduced over two decades ago. Since their first appearance, instrument design has changed considerably. Progress has been made in manufacturing as well as alloy processing. One should always bear in mind that all file systems have benefits and weaknesses. Instrument properties are derived from the type of alloy, degree of taper, and cross-sectional design. This article presents an overview of the design features, mechanical properties and instrumentation performance of the new generation of NiTi endodontic instruments.<sup>1</sup>

### DESIGN FEATURES OF EACH FILE GENERATION

Walia et al. used nitinol orthodontic wire to fabricate intracanal files, size 15.<sup>2</sup> These files had two to three times the elastic flexibility in bending and torsion, as well as superior resistance to torsional fracturing when compared to similar stainless-steel instruments. The first commercially available NiTi rotary files came to market by 1990's. Most NiTi rotary files have rounded non-cutting tips that serve as a guide in the canal.<sup>3</sup> Rather than identify the myriad of cross-sections available, files will be characterized as having either a passive or an active cutting action.<sup>2</sup>

#### First Generation files

In 1992, the first rotary 0.02 taper NiTi instrument designed by Dr. John McSpadden came to market. In 1994, Dr. Johnson introduced the ProFile 0.04 tapered series followed by the Pro-

File 0.06 tapers and the "Orifice Shapers". Their cross-sectional shapes were made by machining three equally spaced U-shaped grooves around the shaft of a tapered NiTi wire. For this "classical" design, an unground space remained next to each groove, providing the so-called "radial land" area. This flat area prevents the file from locking in the dentin, while cutting occurs through a passive planning action. Dr. Johnson broke the paradigm of ISO 0.02 tapered files by making these more highly tapered files. Soon other rotary files came afterwards, each with its purported advantages, such as the LightSpeed, the Quantec and the Greater Taper files developed by Dr. Steve Buchanan. LightSpeed was introduced as an instrument differing from all others because of its long, thin non-cutting shaft and short anterior cutting part. The same design principles apply to the recently developed LSX instrument (Discus Dental, Culver City, CA) that is manufactured not by milling but by stamping. The files are used for apical preparation and do not cut over most of the canal length because of the existence of a smooth small-diameter shaft that also enhances the flexibility of the instrument.<sup>4</sup> All the systems required a considerable number of files to achieve preparation objectives.

#### Second Generation files

By the end of the 1990s, the next generation of NiTi rotary files came to market. The critical distinctions of this generation of instruments are that they have actively cutting edges without radial lands and fewer instruments are required to fully prepare a canal. Second-generation systems were designed with positive rake angles for greater cutting efficiency. The angle between the cutting blade and the longitudinal axis of the instrument is lower than in first-generation files, which greatly reduces the tendency for a screwing effect. To discourage taper lock and the resultant screw effect associated with both passive and active

fixed tapered Ni-Ti cutting instruments, EndoSequence (Braseler USA) and BioRaCe (FKG Dentaire) provide file lines with alternating contact points. Although this feature is intended to mitigate taper lock, these file lines still have a fixed tapered design over their active portions. This generation of NiTi files includes the ProTaper (Dentsply Tulsa) rotary files which, have multiple tapers of increasing and decreasing size on a single file. The progressively tapered design limits each file's cutting action to a specific region of the canal and affords a shorter sequence of files to safely produce deep Schilderian shapes.<sup>5</sup>

During this period, manufacturers began to focus on other methods to increase the resistance to file separation. Some manufacturer's electropolished their files to remove surface irregularities caused from the traditional grinding process. It has been suggested that the surface condition of the NiTi instrument contributes to fatigue resistance because most fatigue failures nucleate from the surface, especially in the presence of high stress amplitude or surface defects.

### Third Generation files

In the third generation there was improvement in NiTi metallurgy. Heat treatment is one of the most fundamental approaches toward adjusting the transition temperatures of NiTi alloys and affecting the fatigue resistance of NiTi endodontic 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.<sup>10</sup> The desired phase transition point between martensite and austenite can be identified to produce a more clinically optimal metal than Ni-Ti itself. Examples are Twisted File (Axis Sybron Endo); HyFlex (Coltène); and GT, Vortex, and WaveOne (DENTSPLY Tulsa Dental Specialties).

M-wire (SportsWire, Langley, OK) was introduced in 2007. It is produced by applying a series of heat treatments to NiTi wire blanks. M-wire instruments include Dentsply's ProFile GT Series X, ProFile Vortex, and Vortex Blue.<sup>6</sup>

CM Wire (DS Dental, Johnson City, TN) was introduced to endodontics in 2010. CM NiTi files are manufactured using a special thermo mechanical process that controls the memory of the material, making the files extremely flexible but without the shape memory of other NiTi files. Both the HyFlex and TYPHOON CM instruments are made out of CM Wire. They exhibit a lower percent by weight of nickel (52 Ni %wt) than the common 54.5–57 Ni %wt.

In 2008, Sybron Endo presented the first fluted NiTi file manufactured by plastic deformation. According to the manufacturer, a thermal process allows twisting during a phase transformation into the so-called R-phase of NiTi.<sup>7</sup>

### Fourth Generation files

Another advancement in canal preparation procedures utilizes reciprocation, which may be defined as any repetitive up-and-down or back-and-forth motion. All reciprocating systems in the market utilize smaller, yet equal, angles of CW/CCW rotation. Examples of reciprocating systems that utilize small, equal 30° angles of CW/CCW rotation are: the M4 (SybronEndo), Endo-Eze AET (Ultradent), and Endo-Express (Essential Dental Systems).

In 2011, both WaveOne (Dentsply Tulsa Dental Specialties and DentsplyMaillefer) and Reciproc (VDW) were launched as single-file shaping techniques.

WaveOne represents a convergence of the design features from the second and third generation of files, coupled with a reciprocating motor. The CCW engaging angle is five times the CW dis-

engaging angle and is designed to be less than the elastic limit of the file. Strategically, after three CCW and CW cutting cycles, the file will have rotated 360°, or one complete circle.

Reciproc instruments have a short shaft of 11 mm, enabling better access to molars compared to many other instruments which have a shaft of 13 mm or longer. The design of the cross-section is S-shaped. The three Reciproc files have a regressive taper: R25 (25/0.08) for narrow canals; R40 (40/0.06) for medium canals, and R50 (50/0.05) for wide canals.

The self-adjusting file (SAF; ReDent-Nova, Raanana, Israel) is a hollow device, designed as a cylinder of thin-walled, delicate NiTi lattice with a lightly abrasive surface different from the traditional nickel-titanium (NiTi) rotary files, the SAF system uses a hollow reciprocating instrument that allows for simultaneous irrigation throughout the mechanical preparation. When inserted into the root canal, the manufacturer claims that the SAF is capable of adapting itself to the canal shape three-dimensionally<sup>8</sup>.

### Fifth-generation files

The fifth generation of shaping files has been designed such that the center of mass and/or the center of rotation are offset. In rotation, the files that have an offset design produce a mechanical wave of motion that travels along the active length of the file. Like the progressively percentage tapered design of any given ProTaper file, this offset design serves to further minimize the engagement between the file and dentin (24). Commercial examples of file brands that offer variations of this technology are Revo-S, One Shape° (Micro-Mega°, Besançon, France), and ProTaper Next (PTN; Dentsply Tulsa Dental Specialties/ DentsplyMaillefer).

ProTaper Next is the successor to the ProTaper Universal system. There are five PTN files available, in different lengths, for shaping canals: X1 (17/0.04), X2 (25/0.06), X3 (30/0.07), X4 (40/0.06), and X5 (50/ 0.06). The tapers shown above indicate the taper of the tip region of each file and are not fixed over the active portion of any given PTN file. An offset design generates a traveling mechanical wave of motion along the active portion of a file. This swaggering effect serves to minimize the engagement between the file and dentin. Reduced engagement limits any undesirable taper lock, the screw effect, and the torque on any given file. An offset file design may also decrease the probability of laterally compacting the debris and blocking the root canal system anatomy.

The Revo-S NiTi instrument system includes three shaping instruments: the shaping and cleaning instrument (SC) number 1 (SC1) (#25/0.06), SC2 (#25/0.04), and the universal shaper (#25/0.06). The One Shape file from Micro-Mega (Besançon, France) is the only single-file NiTi instrument in continuous rotation for root canal preparations. The One Shape instrument presents a variable cross-section along the blade which has an optimal cutting action in three zones of the canal<sup>9</sup>.

### Metallurgical and mechanical properties

NiTi "shape memory metal alloy" can exist in two different temperature-dependent crystal structures called martensite and austenite. The crystal lattice structure can be altered by either temperature or stress. This is important because several properties of the two forms are notably different. Near equiatomic NiTi alloys contain three microstructural phases (i.e. austenite, martensite, and R-phase), the character and relative proportions of which determine the mechanical properties of the metal. When the material is in its martensite form, it is soft and ductile and can easily be deformed, while austenitic NiTi is quite strong and hard<sup>10</sup>.

The conventional SE NiTi file (1<sup>st</sup> and 2<sup>nd</sup> generation) has an austenite structure at room and body temperatures. It is well known that the nature of the alloy and the manufacturing process greatly affect the mechanical behavior of the instrument<sup>1</sup>. To improve the fracture resistance of NiTi files, manufacturers have either introduced new alloys to manufacture NiTi files or developed new manufacturing processes<sup>3</sup>. Recently, a series of proprietary thermomechanical processing procedures has been developed with the objective of producing SE NiTi wire blanks that contain the substantially stable martensite phase under clinical conditions. Enhancements in these areas of material management have led to the development of the new generation (3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> generation) of endodontic NiTi instruments. NiTi files with thermal processing (e.g. CM Wire and M-wire) contain a mixture of austenite and martensite conditions at body temperature. The martensitic phase transformation has excellent damping characteristics because of the energy absorption characteristics of its twinned phase structure. In addition, the martensitic form of NiTi has an excellent fatigue resistance<sup>1</sup>.

The TF is a NiTi rotary file manufactured by twisting when the metal is in the so-called R-phase. The R-phase shows good superelasticity and shape memory effects; its Young's modulus is typically lower than that of austenite. Thus, an instrument made out of R-phase wire would be more flexible.

## DISCUSSION

Instrument fracture is a potentially serious mishap that can complicate and compromise the endodontic treatment outcome<sup>9</sup>. NiTi rotary files are available in a variety of designs, each with features that affect the manner in which they engage and cut dentin<sup>10</sup>. The incidence of instrument fracture in clinical practice for files used multiple times has varied from 0.05% to 39%. The reasons for the fracture of NiTi instruments may be complex and multifactorial; the most important reasons may be operator-related, instrument design, bulk material properties, and root canal anatomy<sup>5</sup>. Judgment error or inadvertent misuse by the operator may be more important than the number of uses in causing the breakage of the instrument in the canal.

A clinical study on HyFlexNiTi instruments found that none of the 468 HyFlex instruments fractured during instrumentation of three teeth by each file. Only 3.4% of the instruments revealed plastic deformation. However, multiple clinical uses caused significant changes in the microstructural phases of HyFlex instruments. Previous studies<sup>7-10</sup> also confirmed this trend toward a high incidence of instrument distortion in smaller conventional superelasticNiTi instruments. Given the same torque, smaller instruments would be more susceptible to torsional failure than larger instruments. Therefore, caution should be exercised regarding the reuse of small HyFlex rotary instruments. In conclusion, it seems that HyFlex instruments, subjected to a proprietary manufacturing process, are safe to use in endodontic treatment.

Although multiple clinical uses of NiTi rotary files may be one of the causes of instrument breakages and deformations, some studies<sup>1</sup> have found that a brand-new SE NiTi instrument may also fail at first use. Recently, a study<sup>7</sup> showed that only one Pro-

File Vortex file out of a total of 2,203 files used fractured during a single clinical use over a 2-year period in an undergraduate clinic. The cause of the fracture was shear stress. Although detailed information about the thermomechanical treatment history of the Vortex file made out of M-wire is not available, it seems that this processing is a promising way to achieve substantial improvements in the safety of endodontic instruments.

## CONCLUSION

Older systems are being updated continually and new endo files are added. Since then the focus has shifted to new manufacturing processes and different unique features such as a variable cross-section along the length of the active portion of the file. Many variables and physical properties influence the clinical performance of NiTi rotaries. Ultimately, clinical experience, handling properties, safety, and case outcomes will decide the fate of a particular design. In the future, new instruments should fulfill the three sacred tenets for shaping canals: safety, effectiveness, and simplicity. Research will be needed to validate the performance and benefits of each new system.

## REFERENCE

1. Thompson SA. An overview of nickel-titanium alloys used in dentistry. *Int Endod J* 2000; 33: 297-310. | 2. Walia H, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. *J Endod* 1988; 14: 346-351. | 3. Andreasen GF, Morrow RE. Laboratory and clinical analyses of nitinol wire. *Am J Orthod* 1978; 73: 142-145. | 4. Peters OA, Barbakow F, Peters CI. An analysis of endodontic treatment with three nickel-titanium rotary root canal preparation techniques. *Int Endod J* 2004; 37: 849-859. | 5. Liu Y, McCormick PG. Thermodynamic analysis of the martensitic transformation in NiTi—II. Effect of transformation cycling. *Acta Metall Mater* 1994; 7: 2407-2413. | 6. Frick C, Ortega A, Tyber J, Maksound A, Maier H, Liu Y, Gall K. Thermal processing of polycrystalline NiTi shape memory alloys. *Mater Sci Eng A* 2005; 405: 34-49. | 7. Gutmann JL, Gao Y. Alteration in the inherent metallic and surface properties of nickel-titanium root canal instruments to enhance performance, durability and safety: a focused review. *Int Endod J* 2012; 45: 113-128. | 8. Metzger Z, Teperovich E, Zary R, Cohen R, Hof R. The self-adjusting file (SAF). Part 1: respecting the root canal anatomy—a new concept of endodontic files and its implementation. *J Endod* 2010; 36: 679-690. | 9. Parashos P, Gordon I, Messer HH. Factors influencing defects of rotary nickel-titanium endodontic instruments after clinical use. *J Endod* 2004; 30: 722-725. | 10. Di Fiore PM, Genov KA, Komaroff E, Li Y, Lin L. Nickel-titanium rotary instrument fracture: a clinical practice assessment. *Int Endod J* 2006; 39: 700-708.