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THE SHAPING MOVEMENT
5TH GENERATION TECHNOLOGY

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Since the beginning of modern day endodontics, there have been numerous concepts, strategies, and techniques for preparing canals. Over the decades, a staggering array of files has emerged for negotiating and shaping canals. In spite of the design of the file, the number of instruments required, and the surprising multitude of techniques advocated, endodontic treatment has been typically approached with optimism for probable success.

The clinical endodontic breakthrough was progressing from utilizing a long series of stainless steel (SS) hand files and several rotary Gates Glidden drills to integrating nickel titanium (NiTi) files for shaping canals. Regardless of the methods utilized, the mechanical objectives for canal preparation were brilliantly outlined almost 40 years ago by Dr. Herbert Schilder.[1] When properly performed, these mechanical objectives promote the biological objectives for shaping canals, 3-D disinfection, and filling root canal systems ***(Figure 1)***.

The purpose of this article is to identify and compare how each new generation of endodontic NiTi shaping files served

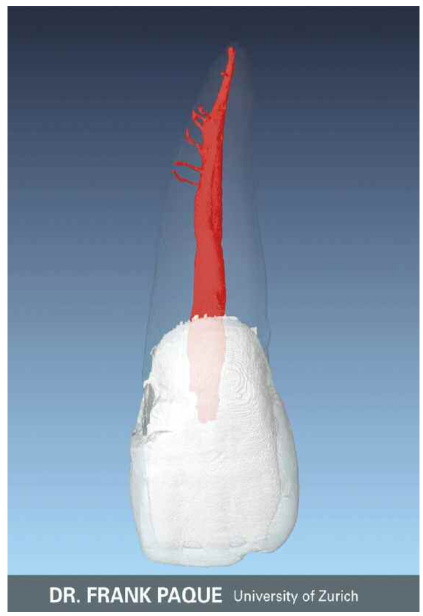


Figure 1a. *A µCT image of a maxillary central incisor tooth demonstrates a root canal system with multiple portals of exit.*

Figure 1b. *A pretreatment radiograph reveals an endodontically failing anterior bridge abutment with a draining fistula.*

Figure 1c. *This post-op retreatment image emphasizes that shaping canals promotes 3D cleaning and filling root canal systems.*

Figure 1d. *A 25-year radiographic recall image demonstrates osseous healing.*

to advance canal preparation methods. Importantly, this paper will identify a new file system and describe a clinical technique that combines the most proven design features from the past with the latest innovations presently developed.

NiTi Shaping Movement

In 1988, Walia proposed Nitinol, a NiTi alloy for shaping canals, as it is 2-3 times more flexible, in the same file sizes, compared to stainless steel.[2] A game-changing outcome of files manufactured from NiTi was that curved canals could be mechanically prepared utilizing a continuous rotary motion. By the mid-1990s, the first commercially available NiTi rotary files had come to market.[3] The following is a mechanical classification of each generation of file systems. Rather than identify the myriad of available cross-sections, files will be characterized as having either a passive vs. an active cutting action.

FIRST GENERATION

To appreciate the evolution of NiTi mechanical instruments, it is useful to know that, in general, first generation NiTi files have *passive* cutting radial lands and fixed tapers of 4% and 6% over the length of their active blades ***(Figure 2)***.[4] This generation of technology required numerous files to achieve the preparation objectives. By the mid to late 1990s, GT files *(Dentsply Tulsa Dental Specialties)* became available that provided a fixed taper on a single file of 6%, 8%, 10%, and 12%.[5] The single most important design feature of first generation NiTi rotary file was passive radial lands, which encouraged a file to stay centered in canal curvatures during work.

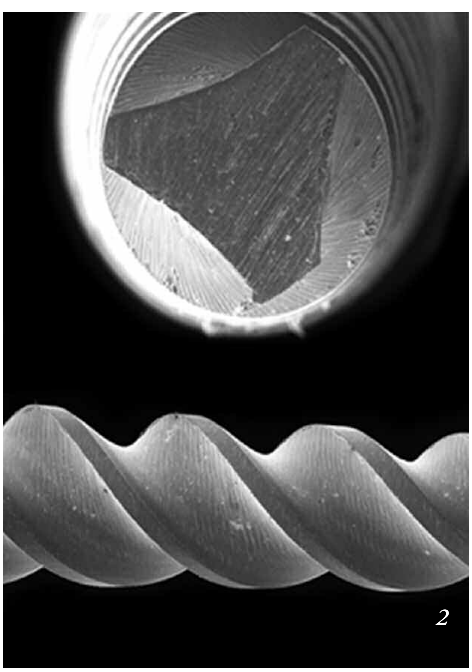
SECOND GENERATION

The second generation of NiTi rotary files came to market in 2001.[6] The critical distinction of this generation of instruments is they have *active* cutting edges and require fewer instruments to fully prepare a canal ***(Figure 3)***. To discourage taper lock and the resultant screw effect associated with both passive and active fixed tapered NiTi cutting instruments, EndoSequence *(Brassler USA)* and BioRaCe *(FKG Dentaire)* provide file lines with alternating contact points.[7] Although this feature is intended to mitigate taper lock, these file lines still have a fixed tapered design over their active portions. The clinical breakthrough occurred when ProTaper *(Dentsply Tulsa Dental Specialties)* came to market utilizing multiple *increasing* or *decreasing* percentage tapers on a single file. This revolutionary, 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 ***(Figure 4)***.[8]

During this period, manufacturers began to focus on other methods to increase the resistance to file separation. Some manufacturers electropolished their files to remove surface irregularities caused from the traditional grinding process. However, it has been clinically observed and scientifically reported that electropolishing dulls the sharp cutting edges. As such, the perceived advantages of electropolishing were offset by the more undesirable inward pressure required to advance a file to length. Excessive inward pressure, especially when utilizing fixed tapered files, invites taper lock, the screw effect, and excessive torque on a rotary file during work.[9] To offset deficiencies in general, or inefficiencies resulting from electropolishing, more cross-sectional designs have become available and increased, yet more dangerous, rotational speeds are advocated.

THIRD GENERATION

Improvements in NiTi metallurgy became the hallmark of what may be identified as the 3rd generation of mechanical shaping files. In 2007, manufacturers began to focus on utilizing heating and cooling methods to reduce cyclic fatigue



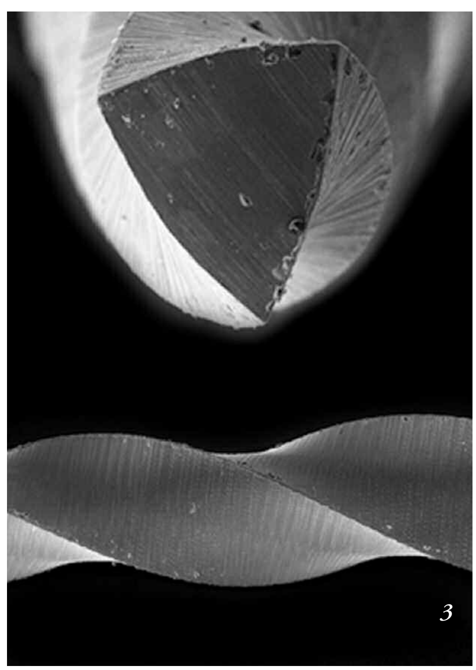


Figure 2. *These 2 SEM images reveal the cross-sectional and lateral views of a passively cutting radial-landed file.*

Figure 3. *These 2 SEM images reveal the cross-sectional and lateral views of an active file with sharp cutting edges.*

Figure 4. The ProTaper Shaping files cut dominantly in their coronal and middle one-thirds, whereas the Finishing files cut primarily in their apical one-thirds.

and improve safety when rotary NiTi instruments work in more curved canals.[10] The desired phase-transition point between martensite and austenite can be identified to produce a more clinically optimal metal than NiTi, itself. This 3rd generation of NiTi instruments significantly reduces cyclic fatigue and, hence, broken files. Examples of brand lines that offer heat treatment technology are Twisted File *(SybronEndo)*, Hyflex *(Coltene Whaledent)* and GT, Vortex, and WaveOne *(Dentsply Tulsa Dental Specialties)*.

FOURTH GENERATION

Another advancement in canal preparation procedures utilizes reciprocation, which may be defined as any repetitive up-and-down or back-and-forth motion. This technology was first introduced in the late 1950s by the French dentist, Blanc. Currently, the M4 *(SybronEndo)*, Endo Express *(Essential Dental Systems)*, and Endo-Eze *(Ultradent)* are examples of systems that use a movement where the clockwise (CW) and counterclockwise (CCW) degrees of rotation are absolutely equal. As compared to full rotation, a reciprocating file that utilizes an equal bidirectional movement requires more inward pressure to progress, will not cut as efficiently as a same-size rotary file, and is more limited in augering debris out of the canal.

From these earlier experiences, innovation in reciprocation technology led to a 4th generation of instruments for shaping canals. This generation of instruments and related technology has largely fulfilled the long hoped-for single-file technique. ReDent-Nova *(Henry Schein)* introduced the Self Adjusting File (SAF). This file has a compressible open tube design that is purported to exert uniform pressure on the dentinal walls, regardless of the cross-sectional configuration of the canal. The SAF is mechanically driven by a handpiece that produces both a short 0.4 mm vertical amplitude stroke and vibrating movement with constant irrigation.[11] Another emerging single-file technique is termed One Shape *(Micro Mega)*, to be mentioned further in 5th generation designs.

By far the most popular single-file concept is termed WaveOne *(Dentsply Tulsa Dental Specialties and Maillefer)* and Reciproc *(VDW)*. WaveOne represents a convergence of the best design features from the 2nd and 3rd generation of files, coupled with a reciprocating motor that drives any given file in *unequal* bidirectional angles. The CCW engaging angle is 5 times the CW disengaging angle and is designed to be less than the elastic limit of the file. Strategically, after 3 CCW and CW cutting cycles, the file will have rotated 360º, or one circle ***(Figure 5)***. This novel reciprocating movement allows a file to more readily progress, efficiently cut, and effectively auger debris out of the canal.[12]

FIFTH GENERATION

The 5th generation of shaping files has been designed such that the center of mass and/or the center of rotation are offset ***(Figure 6)***. In rotation, 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.[13] In addition, an offset design enhances augering debris out of a canal and improves flexibility along the active portion of a PTN file. The advantages of an offset design will be discussed later in this article.

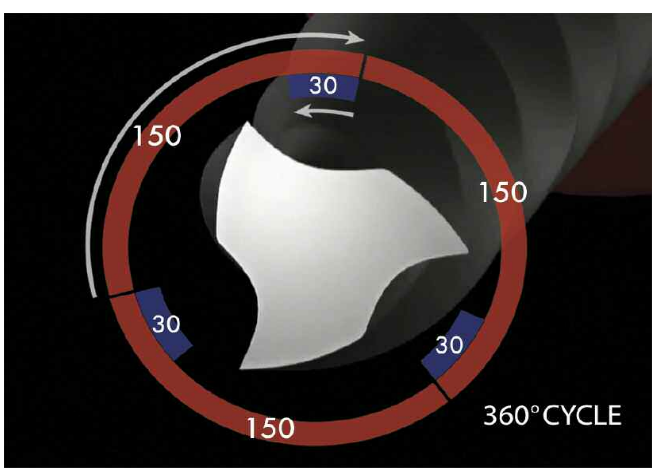


Figure 5. A WaveOne reciprocating file utilizes unequal CCW/CW angles to improve efficiency, inward progression, and augering debris out of the canal.

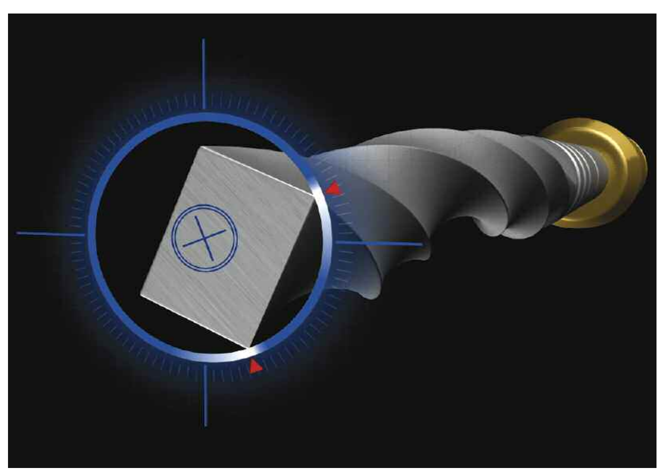


Figure 6. A cross-section of a ProTaper Next file. Note an offset mass desirably reduces file engagement, provides greater space debris, and improves flexibility.

Commercial examples of file brands that offer variations of this technology are Revo-S, One Shape *(Micro Mega)* and ProTaper Next *(Dentsply Tulsa Dental Specialties/Dentsply Maillefer)*. Today, the safest, most efficient, and simplest file systems utilize the most proven design features from the past, coupled with the most recent technological advancements currently available. The following is a brief technical description of the ProTaper Next rotary file system.

ProTaper Next

There are 5 ProTaper Next (PTN) files *(Dentsply Tulsa Dental Specialties)* available, in different lengths, for shaping canals, namely X1, X2, X3, X4, and X5 ***(Figure 7)***. In sequence, these files have yellow, red, blue, double black, and double yellow identification rings on their handles, corresponding to sizes 17/04, 25/06, 30/07, 40/06, and 50/06, respectively. The tapers just listed are NOT fixed over the active portion of any given PTN file. Appreciate the PTN X1 and X2 files have both an increasing and decreasing percentage tapered design on a single file; whereas the PTN X3, X4, and X5 files have a fixed taper from D1-D3, then a decreasing percentage tapered design over the rest of their active portions.

PTN files are the convergence of 3 significant design features, including progressive percentage tapers on a single file, M-wire technology, and the 5th generation of continuous improvement, the offset design. As a single example, the PTN X1 file has a centered mass and axis of rotation from D1-D3, whereas from D4-D16, the X1 file has an offset mass of rotation. Starting at 4%, the X1 file has 10 increasing percentage tapers from D1-D11; whereas, from D12-D16, there are decreasing percentage tapers to enhance flexibility and conserve radicular dentin during shaping procedures.

The PTN files are used at 300 rpm and a torque of 2.0-5.2 Ncm, based on the method of use. However, the authors prefer a torque of 5.2 Ncm, as this level of torque has been validated as profoundly safe if clinicians perform meticulous glide path management procedures and utilize a deliberate outward brushing motion when progressively shaping canals.[14] In the PTN technique, all files are used in exactly the same way and the sequence always follows the ISO color progression and is always the same regardless of the length, diameter, or curvature of a canal.

PROTAPER NEXT SHAPING TECHNIQUE

The ProTaper Next shaping technique is extraordinarily safe, efficient, and simplistic when attention is focused on the access preparation and glide path management (GPM). As is required for any shaping technique, straightline access to each orifice is emphasized. Attention is directed to flaring, flattening, and finishing the internal axial walls. For radicular access, the original ProTaper system offers the auxiliary Shaping file, termed SX. The SX file is used in a brushing manner on the outstroke, to pre-flare the orifice, eliminate triangles of dentin, relocate the coronal most aspect of a canal away from external root concavities, or produce more shape, as desired.

Perhaps the greatest challenge performing endodontic treatment is to find, follow, and predictably secure any given canal to its terminus. Negotiating and securing canals with small-sized manual files requires a mechanical strategy, skillful touch, patience, and desire. A small-sized hand file is initially used to scout, expand, and refine the internal walls of the canal. Once the canal can be manually reproduced, a dedicated mechanical glide path file may be used to expand the working width in preparation for shaping procedures.[15] To clarify, a canal is secured when it is empty and has a confirmed, smooth, and reproducible glide path.

With an estimated working length and in the presence of a viscous chelator, insert a #10 file into the orifice and determine if the file will easily move toward the terminus of the canal. In shorter, wider, and straighter canals, a #10 file can usually be readily carried to the desired working length. Once a #10 file is confirmed loose at length, the glide path may be further enlarged with either a #15 hand file or dedicated mechanical glide path files, such as PathFiles *(Dentsply Tulsa Dental Specialties)*. The glide path just described confirms sufficient existing space is available to initiate mechanical shaping procedures with the PTN X1 file.

In other instances, certain endodontically involved teeth have roots that harbor longer, narrower, and more curved canals ***(Figure 8a)***. In these situations, a #10 file will oftentimes not initially go to length. Generally, there is no need to select and use size #06 and/or #08 hand files in an effort to immediately reach the terminus of the canal. Simply and gently work the size #10 hand file, within any region of the canal, until it is completely loose. PTN files can be utilized to shape any region of a canal that has a smooth and reproducible glide path. Regardless of the glide path and shaping sequence, the endgame is to negotiate the entire length of the canal, establish working length, and confirm apical patency ***(Figure 8b)***. The canal is secured and a glide path is verified when a #10 file is loose at length and can reproducibly slip, slide, and glide over the apical one-third of the canal.

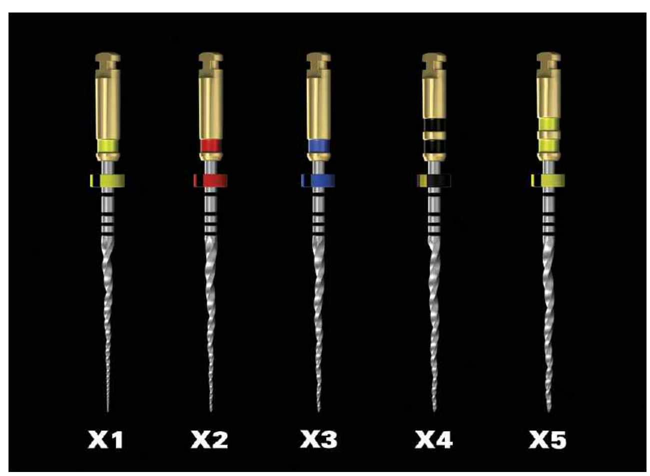


Figure 7. *This image depicts the 5 ProTaper Next files. Most canals in posterior teeth can be optimally shaped using 2 or 3 instruments.*

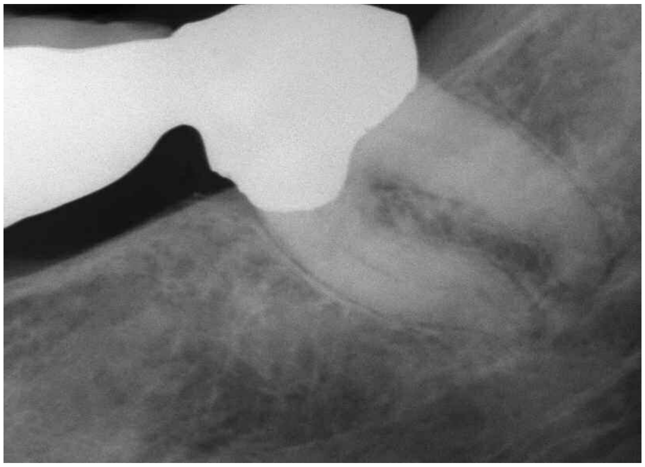


Figure 8a. This radiographic image reveals an endodontically involved posterior bridge abutment. Note the orientation of the prosthesis to the underlying roots.

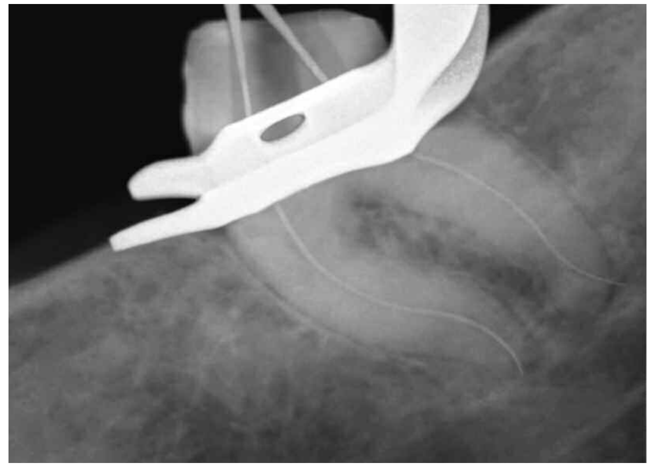


Figure 8b. A working image reveals coronal disassembly, isolation, and #10 files traversing through canals that exhibit curvatures and recurvatures.

When any given canal is secured, the access cavity is voluminously flushed with a 6% solution of NaOCl. Shaping can commence, starting with the PTN X1 file. It should be emphasized that PTN files are never utilized with an inward pumping or pecking motion; rather, PTN files are utilized with an outward brushing motion. Importantly, this method of use will enable any given PTN file to passively move inward, follow the glide path, and progress toward the working length. The X1 file is carried through the access and passively inserted into a pre-flared orifice and secured canal. Before resistance, immediately begin to deliberately brush on the outstroke ***(Figure 8c)***. Brushing creates lateral space and enables this file to progress a few millimeters inward. A brushing action serves to improve contact between the file and dentin, especially in canals that exhibit irregular cross-sections or eccentricities off their rounder parts.

Continue with the PTN X1 file through the body of the canal. After every few millimeters of file progression, remove this mechanical shaping file to inspect and clean its flutes. Before reinserting the X1 file, it is critical to irrigate and flush out gross debris, recapitulate with a #10 file to break up residual debris and move it into solution, then re-irrigate to liberate this debris. In one or more passes, continue with the X1 file until the full working length is reached. To promote the mechanical objectives, always irrigate, recapitulate, and then re-irrigate after removing any mechanical shaping file.

Select the PTN X2 file and let it begin to run inward. Before resistance, laterally brush against the dentinal walls, which, in turn will enable the X2 file to passively and progressively advance inward. The X2 file will easily follow the path of the X1 file, progressively shape, and incrementally advance toward length. If this file bogs down and ceases to move inward, remove the file and clean and inspect its flutes. Again, irrigate, recapitulate, and re-irrigate to promote the mechanical objectives for shaping canals. Continue with the X2 file until the working length is reached; appreciate it may require one or more passes, depending on the length, width, and curvature of any given canal ***(Figure 8d)***.

Once the PTN X2 file has reached the working length, it is removed. The shape may be confirmed as finished when the apical flutes of this file are visibly loaded with dentin. Alternatively, the size of the foramen may be gauged with a size 25/02 NiTi hand file. When the size #25 hand file is snug

Figure 8c. This video grab image shows a mechanical wave of motion traveling along the active portion of a PTN X1 Shaping file.

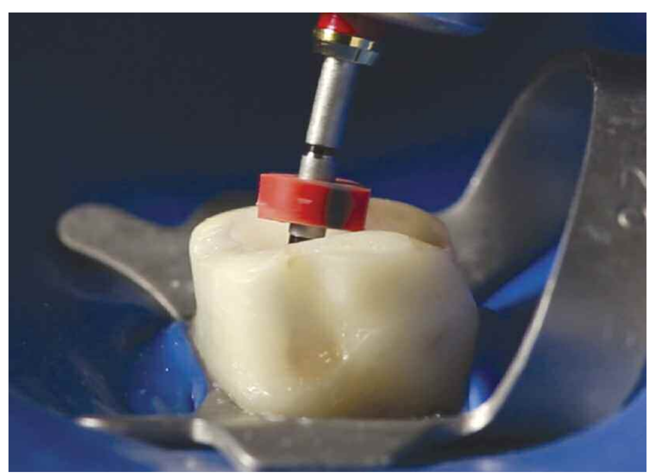


Figure 8d. This video grab image reveals a PTN X2 file at length in the MB system.

at length, the shape is finished. If the size 25/02 hand file is loose at length, it simply means the foramen is larger than 0.25 mm. In this instance, the foramen may be gauged with a size 30/02 NiTi hand file. If the size #30 hand file is snug at length, the shape is done. However, if the size #30 hand file is short of the working length, proceed to the PTN X3 file, following the exact method just described for the PTN X1 and X2 files.

The vast majority of canals will be optimally shaped after using either the PTN X2 or X3 files ***(Figure 8e)***. The PTN X4 and X5 files are primarily used to prepare and finish larger diameter canals. When the apical foramen is determined to be larger than a PTN 50/06 X5 file, recognize other shaping methods may be utilized to finish these larger, typically less curved, and more straightforward canals. What is important is to appreciate that meticulously secured canals promote shaping, 3-D cleaning, and filling root canals systems ***(Figure 8f)***.

DISCUSSION

From a clinical standpoint, the PTN rotary system is a convergence of the most proven and successful generational designs from the past, coupled with the most recent advances in critical path technology. This brief discussion will describe how design influences performance.

The most successful generational design of the past is the mechanical concept of utilizing a progressively percentage tapered design on a single file. The patent protected ProTaper Universal NiTi rotary file system utilizes both an increasing or decreasing percentage tapered design on a single file. This design feature serves to minimize the contact between a file and dentin, which decreases dangerous taper lock and the screw effect, while increasing efficiency.[8] Compared to a similarly-sized fixed tapered file, a decreasing percentage tapered file design, strategically improves flexibility, limits shaping in the body of the canal, and conserves coronal two-thirds dentin. Taking advantage of this mechanical design, PTN also utilizes progressive tapers on a single file. This design has contributed to the ProTaper system becoming the #1 selling file in the world, the #1 file choice of endodontists, and the #1 system taught in international dental schools to undergraduate students.[16]

Another critical design feature that is intended to benefit certain brand lines of mechanical shaping files is metallurgy. Although NiTi files have been shown to be 2-3 times more flexible than same-sized SS files, additional metallurgical benefits have been identified using heat treatment. R&D has focused on heating and cooling traditional NiTi, either pre- or post-machining. Heat treatment serves to create a more optimal phase transition point between martensite and austenite. It should be appreciated that the best transition point is dependent on the cross-section of the file. Research has shown that M-wire, a metallurgically improved version of NiTi, reduces cyclic fatigue by 400% when comparing files of the same D0 diameter, cross-section, and taper.[17] This 3rd generational advancement is a strategic improvement to the overall clinical safety and performance of the PTN rotary file system.

The third design feature of PTN is related to its offset cross-sectional design. There are 3 major advantages when a continuously rotating file is designed so its mass of rotation is offset.[13]

1. 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 compared to the action of a fixed tapered file with a centered mass of rotation ***(Figure 9)***. Reduced engagement limits undesirable taper lock, the screw effect, and the torque on any given file.

2. A file with an offset design affords more cross-sectional space for enhanced cutting, loading, and augering debris out of a canal compared to a file with a centered mass and axis of rotation ***(Figure 10)***. Many instruments break as a result of excessive intrablade debris packed between the cutting flutes over the active portion of a file. Importantly, an offset file design decreases the probability for laterally compacting debris and blocking root canal system anatomy ***(Figure 6)***.

Figure 8e. *This video grab image shows a PTN X3 file at length in the D system.*

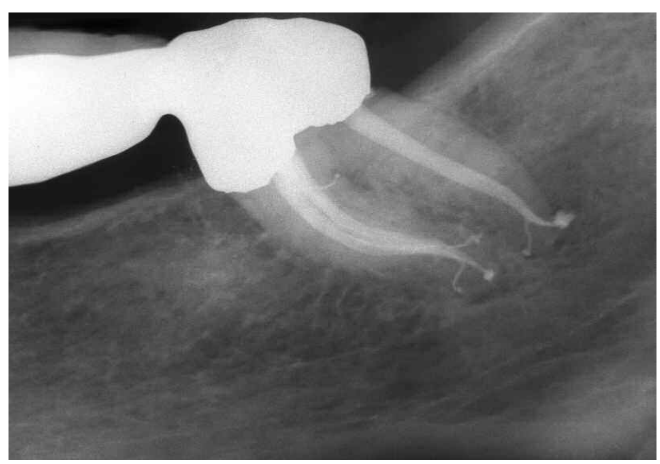


Figure 8f. *This radiographic image demonstrates the bridge provisionalized, flowing shapes, and the importance of treating root canal systems.*

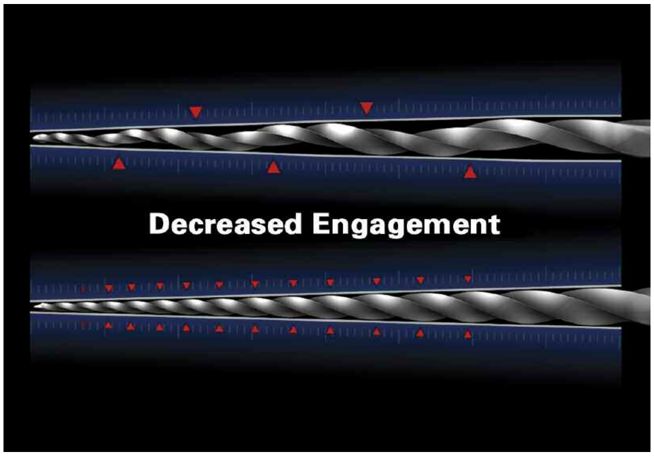


Figure 9. *A PTN file has a progressively tapered and offset design. These features minimize engagement, maximize debris removal, and improve flexibility. By contrast, the bottom image shows a fixed tapered file with a centered mass and axis of rotation.*

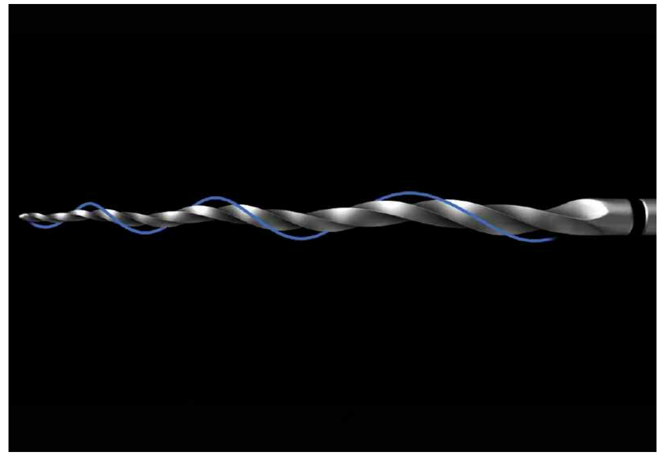


Figure 10. *Similar to a sinusoidal wave, a rotating PTN file produces a mechanical wave of motion, or swaggering effect, along its active portion.*

3. A shaping file with an offset mass of rotation will generate a mechanical wave of motion analogous to the oscillation noted along a sinusoidal wave ***(Figure 10)***. As a result of this design, any given PTN file can cut a bigger envelope of motion compared to a similarly-sized file with a symmetrical mass and axis of rotation ***(Figure 6)***. The clinical advantage of this is a smaller-sized and more flexible PTN file can cut the same-size preparation as a larger and stiffer file with a centered mass and axis of rotation ***(Figure 9)***.

CONCLUSION

Each new generation of shaping files has had something to offer, has been described in different ways, and has been intended to improve on previous generations. PTN has emerged as a 5th generation system designed to bring the most proven performance features from the past together with the most recent technological advancements. This system should simplify rotary shaping procedures by eliminating the number of files typically used to shape canals and the so-called hybrid techniques. Clinically, the PTN shapes fulfill the 3 sacred tenets for shaping canals, which are safety, efficiency, and simplicity. Scientifically, evidence-based research will be needed to validate the potential benefits of this system. ▲

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