Endodontic canal preparation: New Innovations in Glide Path Management and Shaping Canals

by Drs. Clifford J. Ruddle, Pierre Machtou and John D. West

It is generally recognized that root canals can be predictably prepared when shaping files have a reproducible and sufficiently-sized pathway to follow. The secret to shaping success is glide path management (GPM), which may be thought of as procedures directed toward "securing" canals. Any portion of any canal is termed secured when a small-sized flexible hand file can reproducibly slip, slide, and glide through a catheterized canal.[1] Similar to a cardiac surgeon performing coronary angioplasty, dentists insert and slide a small-sized, flexible file through the length of a root canal to verify a smooth reproducible pathway exists for shaping files to follow.

There are a series of clinical procedural steps that comprise start-to-finish endodontic treatment. GPM is arguably the single most consequential clinical step that serves to influence the successful fulfillment of the mechanical and biological goals for shaping canals.[2] Well-shaped canals hold an effective reservoir of irrigant that, upon activation, can penetrate, circulate, and clean into the uninstrumentable portions of a root canal system. More than 40 years of rigorous scientific and clinical evidence unmistakably substantiates that canals must be well shaped in order to promote 3D disinfection and filling root canal systems ***(Figure 1, 2)***.[3]

Negotiating and securing canals with small-sized hand files requires a mechanical strategy, skillful touch, patience, and desire.[4] Once the canal can be manually reproduced, a dedicated mechanical glide path file may be used to expand the working width and *pre-shape* a canal in preparation for *shaping* procedures. This article will identify new, innovative, and clinically relevant technologies for glide path management and shaping canals. The technologies utilized to accomplish these procedures should balance the biological and mechanical goals of endodontics with a respect for the concept of minimally invasive endodontics.

Glide Path Management

The ultimate trifecta for GPM is to fully negotiate, catheterize, and manually secure any given canal to its terminus. A size 10

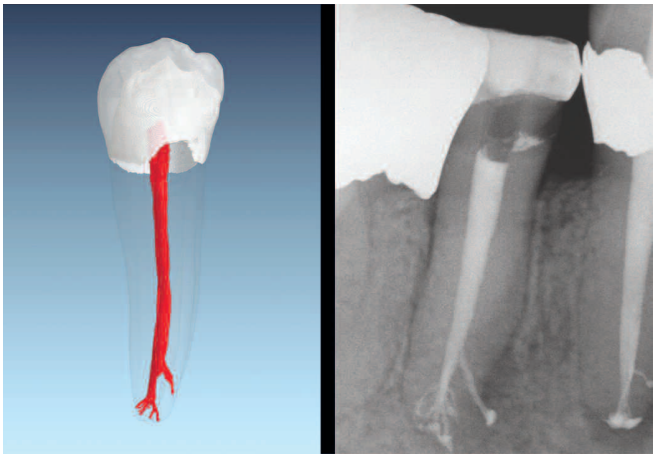

Figure 1. *Left: A µCT image of a mandibular bicuspid (Courtesy of Dr. Frank Paque; Zurich, Switzerland). Right: A post-treatment film demonstrates that a well-shaped canal promotes 3D cleaning and filling root canal systems.*

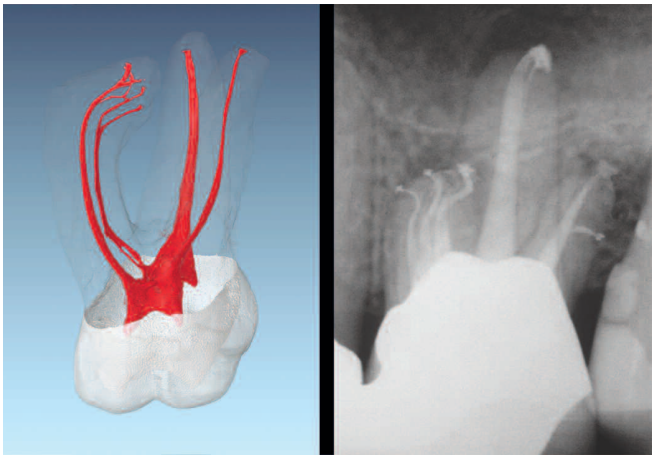

Figure 2. *Left: A µCT image of a maxillary molar (Courtesy of Dr. Frank Paque; Zurich, Switzerland). Right: This film demonstrates challenging endodontic anatomy and the clinical importance of treating root canal systems.*

stainless steel (SS) hand file is typically selected to anatomically follow either a partial length or the full length of any given canal. Although a size 10 file at length is a good start, the international protocol for GPM is to further expand this pathway so that the terminus of any given canal is confirmed to be equivalent to at least 0.15 mm. Generally, when a size 15 hand file is at length, sufficient space exists to safely accommodate the tip of the first mechanically driven, reciprocating or rotary, shaping file.[5]

Many gifted clinicians work a size 10 hand file at length until it is super loose. A super loose size 10 file eliminates utilizing a considerably stiffer, significantly larger, and substantially more dangerous size 15 SS file. This strategy is particularly important when securing more anatomically complex canals that are longer, narrower, and more curved. Appreciate that the size 15 file is 50% larger in diameter at D0 than the size 10 file. Because of this large D0 discrepancy, many partially or fully negotiated canals become iatrogenically blocked, ledged, perforated, or apically transported when using a size 15 SS hand file.

The problems commonly associated with using a size 15 SS file start with failure to carry the size 10 hand file to the terminus of a canal, failure to confirm patency, and failure to work the size 10 file until it is super loose. The deficiencies of the size 15 SS file are further exacerbated by using this file in a dangerous inward cutting motion. Fortuitously, a size 15 SS hand file can be eliminated and replaced with a significantly more flexible, dedicated NiTi mechanical glide path file. It has been shown that certain mechanical glide path files more predictably follow a previously secured canal compared to utilizing a manual size 15 SS hand file.[6]

A dedicated mechanical glide path file may be used to expand or *pre-shape* any given canal prior to utilizing greater tip diameter and tapered shaping files. Fortuitously, dedicated mechanical glide path files have been shown to significantly reduce procedural chairtime while decreasing post-operative pain and flare-ups.[7] Pre-shaping secured canals with dedicated mechanical glide path files improves the safety and efficiency of all brand-lines of shaping files that have considerably larger D0 diameters and tapers along their active portions.

DEDICATED GLIDE PATH FILES

Over about the past 5 years, industry has responded and produced a variety of dedicated mechanical glide path files. Dentsply, Micro-Mega, J. Morita, FKG Dentaire, Clinicians Choice and SS White are examples of companies that distribute dedicated glide path files. Certainly, Dentsply's PathFile series has generated, by far, the most published scientific evidence supporting its use.[8] However, all the companies listed above provide either a 2 or 3 file sequence, where each file has a traditional, fixed tapered design over the length of its active portion. In general, fixed tapered files require a multi-file sequence to promote safety.

GPM BREAKTHROUGH

Years of research and development have resulted in the recent international launch of a dedicated, single-use rotary glide path file, termed ProGlider (*Dentsply Tulsa Dental Specialties* or *DTDS* and *Dentsply Maillefer*) ***(Figure 3)***. ProGlider brings what could be characterized as good news and better news. The good news is that ProGlider is one single mechanical glide path file. The better news is that one ProGlider will create a significantly larger, smoothly tapered pathway than any other dedicated multi-file sequence. In general, any given canal is first manually reproduced and secured with a size 10 hand file before using any dedicated mechanical glide path file(s) ***(Figure 4)***.

NiTi may be metallurgically enhanced through heat treatment pre- or post-machining. Heat treatment before machining results in what is commercially termed M-Wire. M-Wire has been shown to significantly improve flexibility and provide a 400% greater resistance to cyclic fatigue.[9] ProGlider utilizes M-Wire technology and has increasing tapers from 2% to over 8% along its active portion. These design features result

Figure 3a. *ProGlider's progressively tapered design and M-Wire technology make GPM safe, efficient, and fun.*

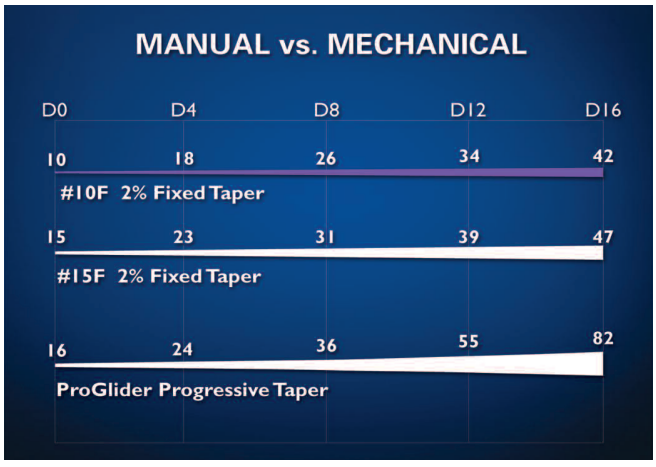

Figure 3b. *This table compares the cross-sectional diameters along the active portion of 3 files. One ProGlider can safely produce a considerable larger pre-shaped canal than a size 15 SS hand file.*

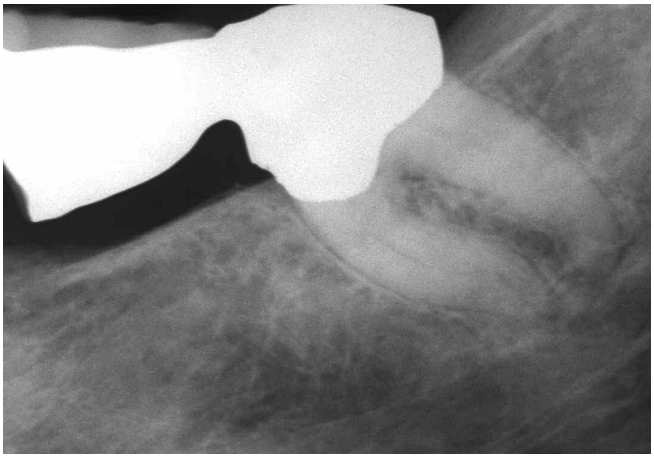

Figure 4a. *This radiographic image reveals an endodontically-involved posterior bridge abutment. Note the orientation of the prosthesis to the underlying roots.*

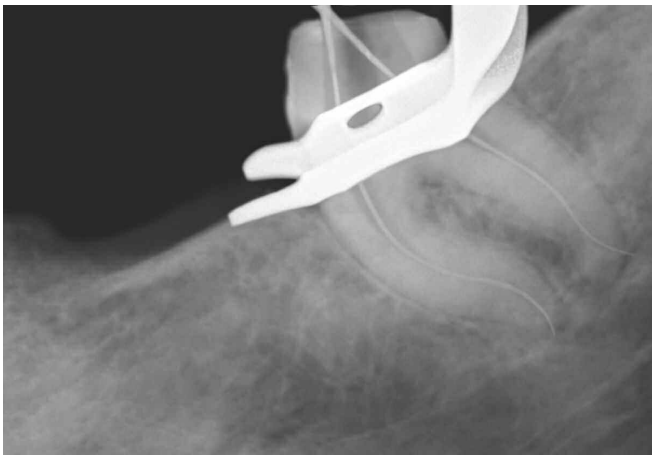

Figure 4b. *A working image reveals coronal disassembly, isolation, and size 10 files traversing through pre-enlarged canals exhibiting multi-planar recurvatures.*

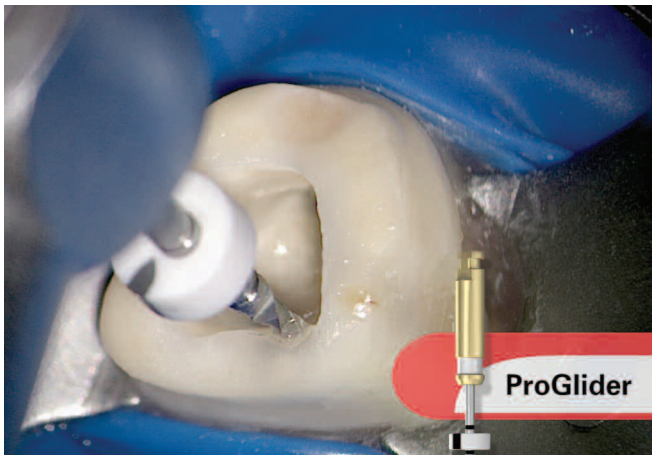

Figure 4c. *This video image shows the ProGlider following the manually secured MB canal and approaching length.*

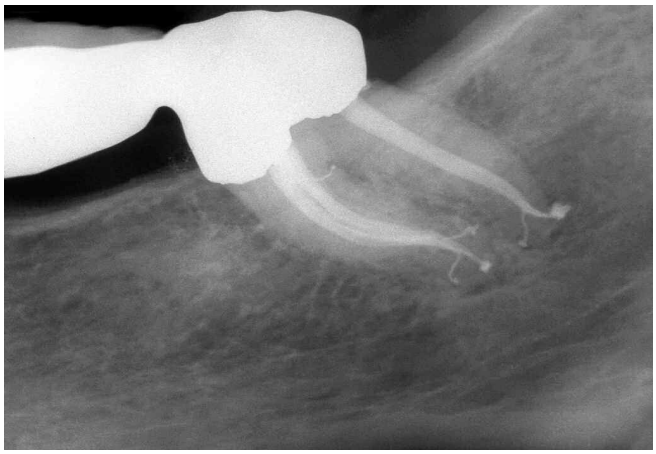

Figure 4d. *This radiographic image demonstrates provisionalization, flowing shapes, and filled multiple portals of exit.*

in a file that safely pre-enlarges the glide path in a controlled, smooth, inward cutting action ***(Figure 5)***. A progressively tapered design over the active portion of a single file reduces the potential for the dangerous screw effect.

The ProGlider file has a diameter of 0.16 mm at D0 and 0.82 mm at D16. Alternatively, fixed tapered dedicated glide path files generally have D0 tip diameters of 0.13 mm, 0.15 mm, 0.17 mm, or 0.19 mm and D16 diameters of 0.45 mm, 0.47 mm, 0.49 mm, and 0.51 mm, respectively. To mitigate the D0 percentage change between a size 10 file and ProGlider, gently slide the size 10 file to and minutely through the terminus of a canal and confirm patency. An ultrashort vertical motion is repeatedly used at length until this file is super loose. ProGlider may be used in virtually any secured canal at a speed of 300 rpm and a torque of 4.0-5.2 Ncm.

When clinically using a ProGlider, never push, peck, or force this file inward. Rather, let the ProGlider passively and progressively advance along the secured portion of a canal. If the ProGlider ceases to easily advance inward, remove the

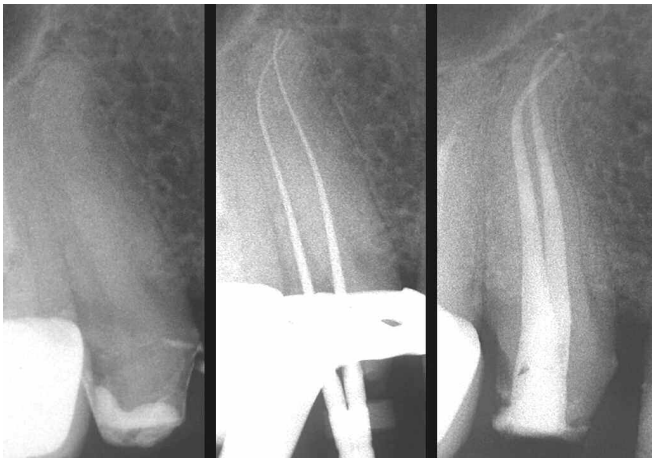

Figure 5. *A pre-treatment image shows an endodontically-involved maxillary bicuspid. The working film shows ProGliders following apical curvatures and at length. The post-treatment image demonstrates that pre-shaped canals guide the case to successful conclusion (Courtesy of Dr. Filippo Santarcangelo; Bari, Italy).*

file and irrigate with NaOCl, recapitulate with a size 10 file to move debris into solution and reconfirm the glide path, then re-irrigate to liberate this loose debris. In longer, narrower, and more curved canals, it may require one or more passes for the ProGlider to safely follow the glide path, reach length, and pre-shape any given canal ***(Figure 6)***. With a *pre-shaped* canal, let's look at a new innovation in shaping canals.

Shaping Canals

The necessity for shaping canals has long been recognized as an essential step in endodontic treatment. In 1974, Prof. Herb Schilder precisely described the mechanical objectives for shaping canals that, when fulfilled, would ensure the biological goals for longterm success.[10] Based on the current state of endodontic development, we only shape canals in order to 3D clean and fill root canal systems. Recently, there has been renewed interest in the concept of minimally invasive endodontics (MIE). Yet, virtually no evidence exists to validate that minimally prepared canals and related root canal systems can actually be 3D cleaned or filled.[11]

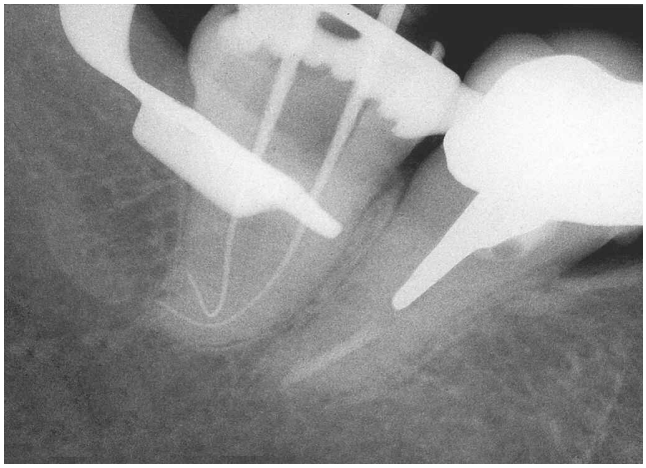

Figure 6a. *This working film demonstrates ProGliders safely following and pre-shaping significant apical canal curvatures.*

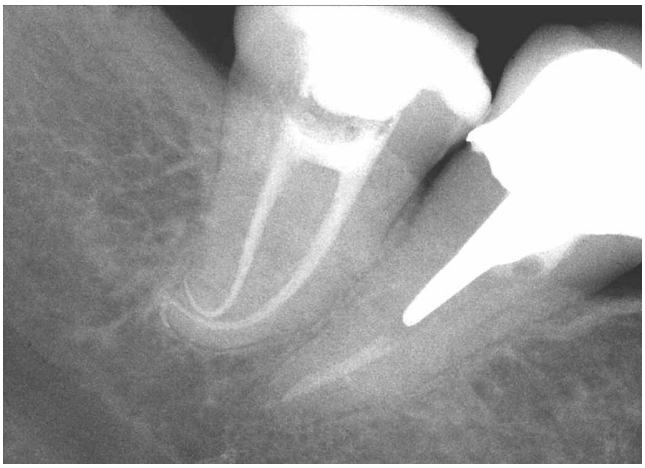

Figure 6b. *This post-treatment film demonstrates that an expanded glide path enables larger-sized shaping files to precisely follow these canal curvatures (Figures 6a-6b courtesy of Dr. Giuseppe Cantatore; Rome, Italy).*

In 2001, the ProTaper NiTi rotary file system (*DTDS* and *Dentsply Maillefer*) came to market utilizing a progressively tapered design on a single file.[12] Unlike fixed tapered shaping systems, the ProTaper system strategically allows clinicians to increase the terminal diameter of a canal and expand the deep shape without further enlarging the body of the canal.[5] ProTaper's success is dominantly linked to reproducible final shapes in all situations, which, in turn, has led to this 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.[13] Let's review the ProTaper success story.

PROTAPER GEOMETRIES

In the ProTaper Universal (PTU) system, there are 2 Shaping files and 1 Auxiliary Shaping file. Shaping File No. 1 and Shaping File No. 2, termed S1 and S2, have D0 diameters of 0.17 mm and 0.20 mm, respectively, modified guiding tips, and 9 and 12 increasing percentage tapers over their active portions, respectively ***(Figure 7)***. As a result of this design, the S1 file primarily prepares the coronal one-third, whereas the S2 file dominantly prepares the middle one-third of a canal. The S1 and S2 files only minimally enlarge the apical one-third of any given canal.

The Auxiliary Shaping file, termed SX, has an overall length of 19 mm and provides excellent access when interocclusal space is limited. The SX file is 0.19 mm at D0 and has diameters of about 0.5 mm, 0.7 mm, 0.9 mm, and 1.1 mm at D6, D7, D8, and D9, respectively ***(Figure 8a)***. When there is sufficient working width, the SX file is used to brush and cut dentin on the outstroke. The SX file is an industry leader for gaining radicular access. Specifically, the SX may be utilized to eliminate triangles of dentin, intentionally relocate the coronal-most aspect of a canal away from furcal danger, or to produce more shape, as desired ***(Figure 8b)***.

Five ProTaper Finishing files, named F1, F2, F3, F4, and F5, have D0 diameters of 0.20, 0.25, 0.30, 0.40, and 0.50 mm,

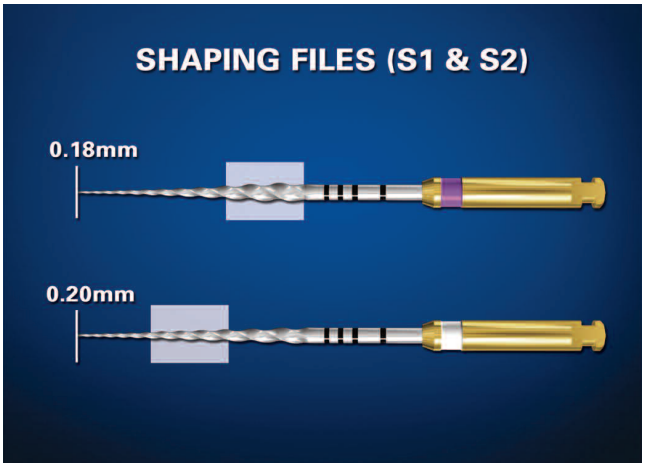

Figure 7. *The S1 and S2 files have a progressively increasing percentage tapered design over their active portions. The S1 dominantly prepares the coronal one-third, whereas the S2 prepares the middle one-third of a canal.*

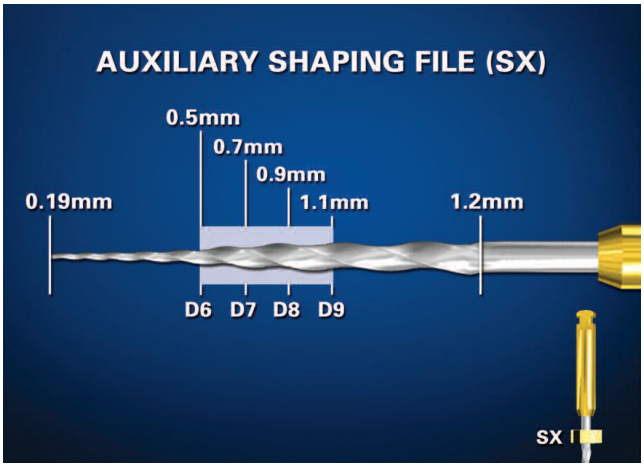

Figure 8a. *The SX is used in a brushing motion to cut dentin, between D_6 and D_9, on the outstroke.*

Figure 8b *The SX may be used to safely relocate canals away from external root concavities, resulting in more centered preparations.*

respectively ***(Figure 9)***. Between D1 and D3 , the most commonly used Finishers, namely the F1, F2 and F3, have fixed tapers of 7%, 8% and 9%, respectively. Strategically, from D14 - D16, each file has a decreasing percentage tapered design. This means F1, F2, and F3 files have a maximum flute diameter at D16 of about 1.0 mm vs. 1.32 mm, 1.53 mm, and 1.74 mm, respectively, if each file had a fixed taper over its active portion. This design occurred more than 10 years before the concept of minimally invasive endodontics was first reported.

ProTaper Universal was the first file line to offer both Shaping and Finishing files. Together, they produce a smoothly tapered and well-shaped canal while using an economy of files. Importantly, these shapes have been repeatedly shown to promote 3D disinfection and filling root canal systems, while maximizing remaining dentin in the coronal two-thirds of any given canal ***(Figure 10)***. Yet, with this success story, PTU has not truly changed since R&D begun in 1995 and the system was launched in 2001. After more than 12 years, it became time to take advantage of technological advancements in metallurgy that did not exist in earlier years.

PROTAPER GOLD

Improvements in NiTi metallurgy have been a hallmark in improving both flexibility and the resistance to cyclic fatigue. Through heating and cooling cycles, the desired phase-transition point between martensite and austenite can be identified to produce a more clinically optimal metal than NiTi, itself. Dentsply International was the first company to offer heat treatment technology on their mechanical files.[9] In order of market launch progression, DTDS first released file brands using M-Wire, then Blue Wire,[14] and now Gold Wire. Gold Wire technology is a post-machining process that makes files significantly more flexible and resistant to fracture.

After years of testing all the available metallurgically enhanced technologies, PTU evolved, has been validated in Gold Wire, and is termed ProTaper Gold (PTG) ***(Figure 11)***. Of clinical significance, PTG has the exact same geometries as PTU, which will continue to be available. The PTG Finishing files set a new standard in safety by significantly improving flexibility and the resistance to cyclic fatigue, when compar-

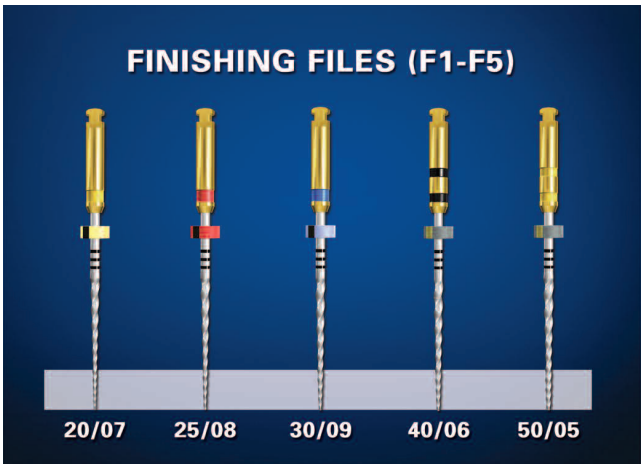

Figure 9. *The PTU Finishing files can increase the terminal canal diameter and expand the deep shape without further preparing the coronal two-thirds of a canal.*

Figure 10. *The canals of this maxillary molar were prepared with ProTaper Universal files. Note that these files precisely follow significant mid-root and apical curvatures (Courtesy of Dr. John West; Tacoma, Washington).*

Figure 11. *PTG has been shown to significantly increase flexibility and provide more than twice the resistance to cyclic fatigue compared to PTU (Internal Dentsply testing, data on file).*

ing PTG against PTU or any other brand-line of files of like sizes. Together, PTG Shaping and Finishing files precisely maintain canal centering, especially when preparing longer, more restrictive, and curved canals ***(Figure 12)***.

Because PTG has considerably less shape memory than NiTi, the Finishing files safely follow and produce effective deep shapes that can be 3D cleaned and filled ***(Figure 13)***. From a practical standpoint, less shape memory means a new, unopened package of files may exhibit a slight degree of curvature. Further, upon removing a PTG file from a curved canal, the file will be noted to have a similar curvature as the canal being shaped. To facilitate re-inserting a curved file into a canal, place its apical extent against the line-angle of the finished access cavity to guide it back into the canal, or alternatively, use cotton pliers to straighten the file.

EVIDENCE FOR CLINICAL SUCCESS

Some years ago, a clinical investigation of the PTU technique, emphasizing method of use, was conducted on highly curved mesial canals of extracted mandibular molar teeth using μCT-Analysis. Prof. Paul Lambrecht and Dr. Lars Bergmans, at the Catholic University of Leuven, analyzed horizontal sections from different radicular levels using μCT slices and volume renderings. From an MIE viewpoint, the results from this investigation are clinically relevant. The advantages of the ProTaper files to brush laterally and selectively cut dentin on the outstroke are summarized below.[15]

1. The Shaping files were essentially loose within a canal during the majority of their work.
2. The coronal aspects of canals were safely relocated away from external root concavities.
3. A brush-cutting action achieved a centered preparation and maximized remaining dentin.
4. The Shaping and Finishing files contacted over 90% of the internal walls of the canals.

The PTG system, and in particular the Finishing files, will serve to improve these results ***(Figure 14)***. PTG are single-use files and have been shown to be safely and optimally utilized at 300 rpm and a torque of 4.0-5.2 Ncm.

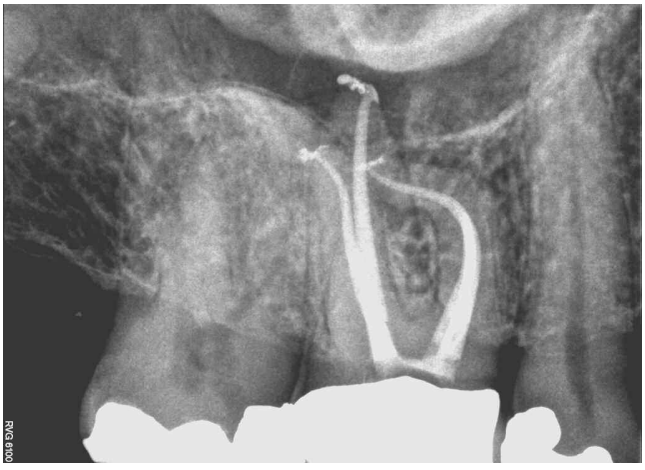

Figure 12. *This post-treatment result demonstrates 4 exquisitely shaped systems utilizing PTG (Courtesy of Dr. Jordan West; Tacoma, Washington).*

Figure 13. *PTG was used to prepare these flowing tapered shapes, encouraging 3D cleaning and filling root canal systems (Courtesy of Dr. Jason West; Tacoma, Washington).*

Figure 14. *PTG files have the flexibility and resistance to cyclic fatigue to safely follow and shape complex curvatures (Courtesy of Dr. Jacob Amor; Paris, France).*

Future

In the present state of endodontic development, glide path management and shaping canals are still required to promote 3D disinfection, and filling root canal systems. ProGlider represents a significant advancement in GPM procedures by improving safety, efficiency, and simplicity. PTG continues the ProTaper legacy of excellence by uniting the most successful shaping method from the past with the most recent advances in metallurgical technology. ProGlider and PTG will allow virtually any dentist who desires to improve their canal preparation results to consistently achieve a gold medal performance. ▲

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