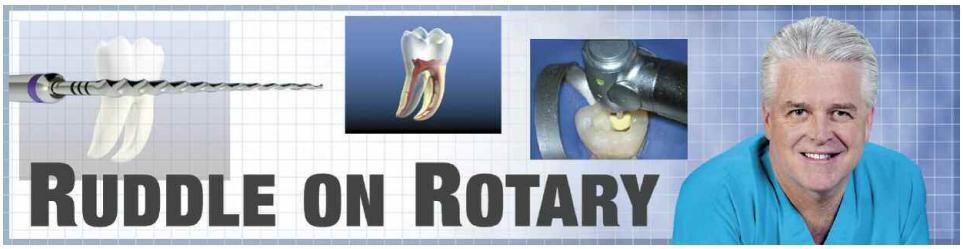

THE PROTAPER ADVANTAGE: SHAPING THE FUTURE OF ENDODONTICS*

by Clifford J. Ruddle, D.D.S.

* *Previously published in Dentistry Today under the title "The ProTaper Endodontic System: Geometries, Features, and Guidelines for Use".*

The purpose of the "RUDDLE ON ROTARY" series of articles is to provide useful information that will enable dentists to predictably shape root canals for three-dimensional obturation.[1] The information in these articles is intended to help clinicians better understand how to safely use nickel-titanium (NiTi) rotary shaping files.[2] These articles are written to enhance clinical performance for all clinicians who perform root canal preparation procedures regardless of the specific instruments chosen and the techniques employed.

INTRODUCTION

The new Progressively Tapered (ProTaper) NiTi rotary files *(Dentsply Tulsa Dental)* represent a revolutionary progression in root canal preparation procedures.[3] The ProTaper files were specifically designed to provide superior flexibility, unmatched efficiency and greater safety. The unique design features of the ProTaper files enables clinicians to more consistently create uniformly tapered shapes in anatomically difficult or significantly curved canals ***(Figures 1, 2)***. The set contains just six (6) simple-to-use files and the series is comprised of three "Shaping" and three "Finishing" instruments currently available in 21 mm and 25 mm lengths ***(Figure 3)***. The following information describes the ProTaper geometries.

PROTAPER GEOMETRIES

THE SHAPING FILES

The auxiliary shaping file, or Shaper X, is easy to recognize as there is no identification ring on its gold-colored handle.

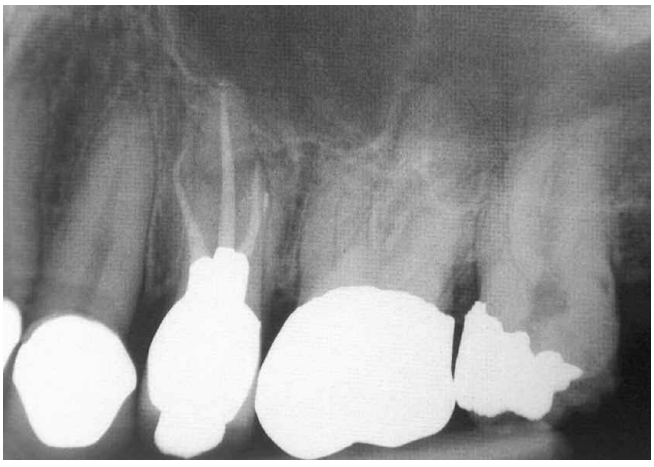

Figure 1. *An anatomically difficult maxillary second bicuspid exhibits a subcrestal pulpal floor and three systems elegantly shaped with ProTaper files. (Courtesy of Dr. Philip Lumley; Birmingham, England)*

Figure 2. *The significantly curved and dilacerated canals of this mandibular second molar were exquisitely shaped utilizing ProTaper files. (Courtesy of Dr. Elio Berutti; Torino, Italy)*

Shaper X, also referred to as SX, has an overall length of 19 mm, providing excellent access in restrictive areas. The SX file has a D_0 diameter of 0.19 mm, a modified guiding tip, and a D_{14} diameter approaching 1.20 mm. Shaper X has a much faster rate of taper from D_0 to D_9 as compared to the other two shaping files. For example, at D_6, D_7, D_8 and D_9 the instruments cross-sectional diameters are approximately equivalent to 0.50, 0.70, 0.90 and 1.10 mm, respectively ***(Figure 4)***. This file is used to optimally shape canals in shorter roots, relocate canals away from external root concavities, and to produce more shape, as desired, in the coronal aspects of canals in longer roots. The ability of Shaper X to brush and cut dentin on the outstroke is an advantage over all other rotary NiTi instruments. In summary, after establishing a smooth, reproducible glide path over any portion of the length of the canal, Shaper X may be used, at anytime, to expand the preparation and may be thought of as an ideal substitute for gates glidden drills.

Shaping File No. 1 and Shaping File No. 2, termed S1 and S2, are easy to recognize as they have purple and white identification rings on their handles, respectively. The S1 and S2 files have D_0 diameters of 0.17 mm and 0.20 mm, respectively, modified guiding tips, and their D_{14} maximal flute diameters approach 1.20 mm ***(Figure 5)***. The Shaping files have increasingly larger tapers over the length of their cutting blades allowing each instrument to engage, cut and prepare a specific area of the canal. Shaping File No. 1 is designed to prepare the coronal one-third of a canal, whereas Shaping File No. 2 enlarges and prepares the middle one-third. Although both instruments optimally prepare the coronal two-thirds of a canal, they do progressively enlarge the apical one-third.

Figure 3. *The ProTaper system represents a revolutionary progression in root canal preparation procedures and is comprised of just three Shaping and three Finishing files.*

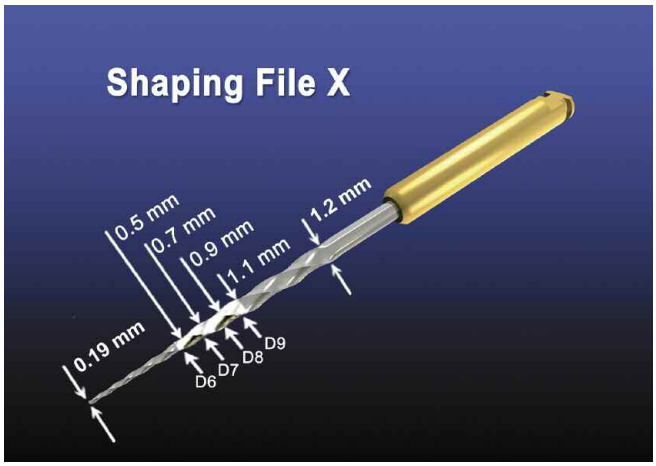

Figure 4. *Shaper X has 9 increasingly larger tapers ranging from 3.5% to 19% and is used in a brushing motion to cut dentin, between D_6 and D_9, on the outstroke.*

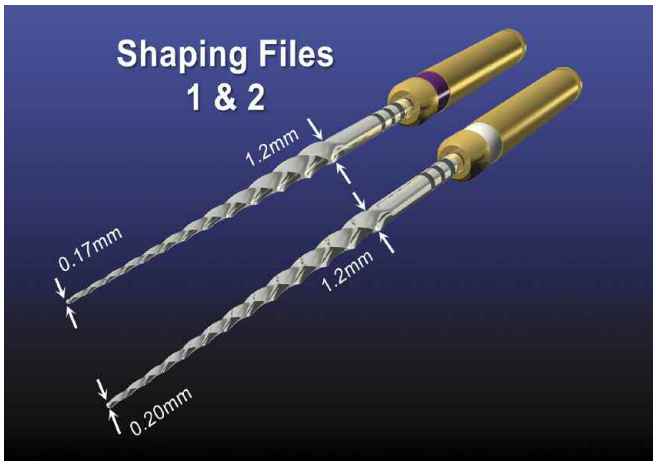

Figure 5. *S1 and S2 each have progressively larger tapers over the length of their blades allowing each instrument to perform its own crown-down work.*

THE FINISHING FILES

Three Finishing files named F1, F2 and F3 have yellow, red and blue identification rings on their handles corresponding to D_0 diameters of 0.20, 0.25 and 0.30 mm, respectively. Between D_0 and D_3, the F1, F2 and F3 have fixed tapers of 7%, 8% and 9%, respectively ***(Figure 6)***. From D_4-D_{14} each instrument has increasing cross-sectional dimensions but importantly, over this same length, each instrument has a decreasing percentage taper. Decreasing the percentage taper over a portion of a files' cutting blades serves to improve flexibility, and this feature also improves safety by reducing the potential for dangerous taper-lock. Although these instruments have been designed to optimally finish the apical one-third, they do progressively blend and expand the shape into the middle one-third of the canal. Generally, only one finishing instrument is required to prepare the apical one-third of a canal. The "finishing criteria" will be discussed in the next "Ruddle on Rotary" article.

ProTaper Features & Benefits

MULTIPLE TAPERS

A unique feature of the Shaping files is their progressively tapered design which clinically serves to significantly improve flexibility, cutting efficiency and typically reduces the number of recapitulations needed to achieve length, especially in tight or more curved canals (***Figure 7***). As an example, the SX file exhibits nine (9) increasingly larger tapers ranging from 3.5% to 19% between D_1 and D_9, and a fixed 2% taper between D_{10} and D_{14}. The S1 file exhibits twelve (12) increasingly larger tapers ranging from 2% to 11% between D_1 and D_{14}. The S2 file exhibits nine (9) increasingly larger tapers ranging from 4% to 11.5% between D_1 and D_{14}. This design feature allows each Shaping file to perform its own "crown down" work. One of the benefits of a progressively tapered Shaping file is that each instrument engages a smaller zone of dentin which reduces torsional loads, file fatigue and the potential for breakage.

CONVEX TRIANGULAR CROSS-SECTION

Another unique feature of the ProTaper instruments relates to their convex triangular cross-section ***(Figure 8)***. This feature reduces the contact area between the blade of the file and dentin, and serves to enhance the cutting action and improve safety by decreasing the torsional load. As is true with any instrument, increasing its D_0 diameter and percentage taper correspondingly increases its stiffness. To improve flexibility, Finisher No. 3 has a reduced core, as compared to the other instruments in the series.

HELICAL ANGLE & PITCH

ProTaper files have a continuously changing helical angle and pitch over their 14 mm of cutting blades ***(Figure 9)***. Balancing the pitch and helical angles of an instrument optimizes its cutting action, effectively allows its blades to auger debris out of the canal, and importantly prevents the instruments from inadvertently screwing into the canal.

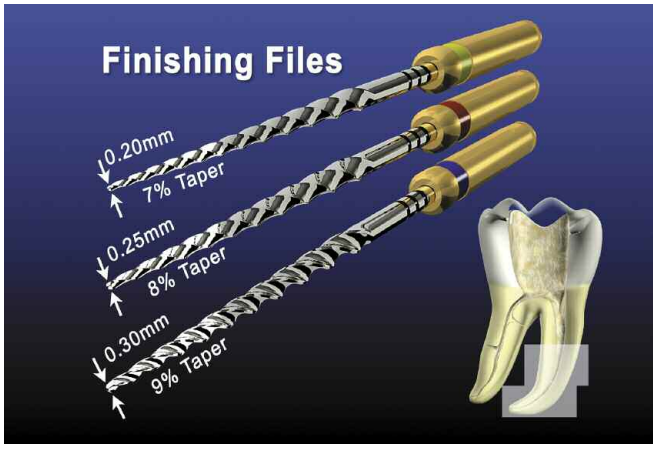

Figure 6. *The finishing files have variable D_0 diameters and tapers, and blend the deep shape into the middle one-third of the canal.*

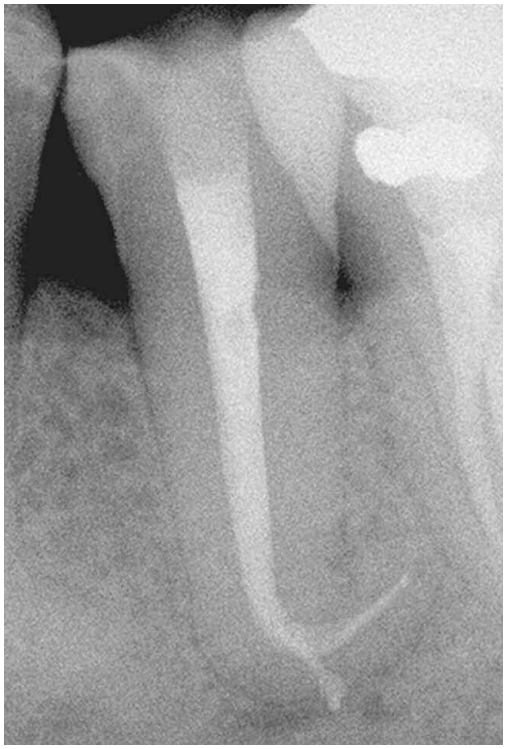

Figure 7. *This endodontically treated mandibular second bicuspid demonstrates a smooth flowing dilacerated preparation, apical bifidity and the ProTaper advantage. (Courtesy of Dr. Fabio Gorni; Milano, Italy)*

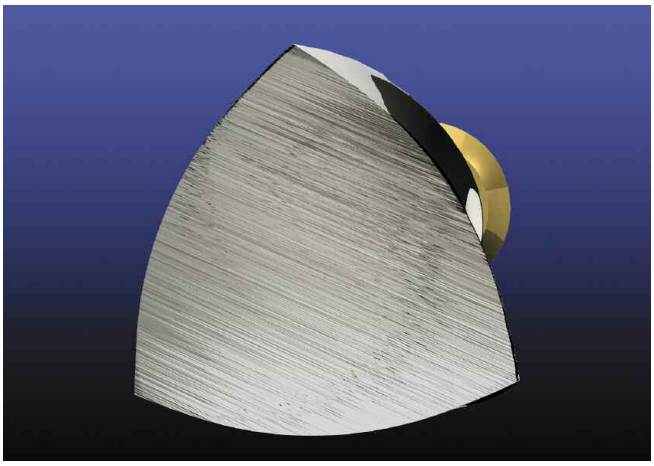

Figure 8. *The ProTaper instruments have a convex triangular cross-section which improves cutting efficiency while maximizing core strength.*

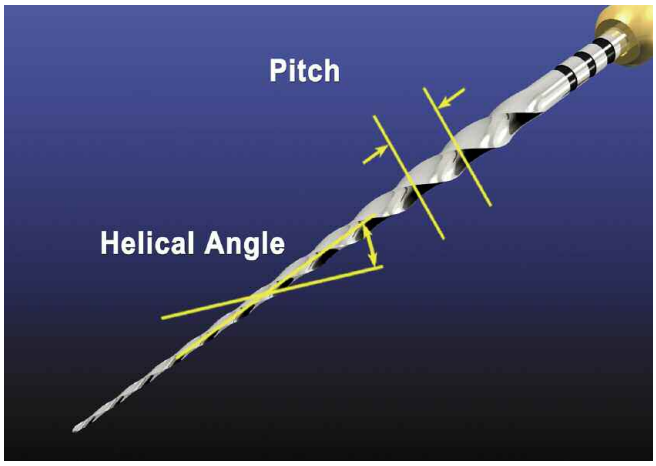

Figure 9. *ProTaper files perform smoothly, efficiently and safely as a result of their progressively tapered design and continuously changing pitch and helical angle.*

VARIABLE TIP DIAMETERS

The three Shaping files have variable D_0 diameters to allow clinicians to safely and efficiently follow the canal while allowing each instruments' more coronal cutting blades to pre-enlarge specific zones of the canal. Shaper No. 1 has a diameter of 0.17 mm at D_0. Shaper X has a diameter of 0.19 mm at D_0 and Shaper No. 2 has a D_0 diameter of 0.20 mm. The finishing files have variable D_0 diameters of 0.20, 0.25 and 0.30 mm to address the obvious variations in cross-sectional diameters that canals exhibit in their apical one-thirds. Generally, only one finishing file is necessary to optimally finish the apical one-third of an anatomically difficult or significantly curved canal ***(Figure 10)***.

MODIFIED GUIDING TIP

Another specific feature of the ProTaper files is each instrument has a modified guiding tip. This design feature allows each instrument to better follow the canal and enhances its ability to find its way through soft tissue and loose debris without damaging the root canal walls.

SHORT HANDLES

ProTaper files have short, 12.5 mm handles as compared to the more standard file handle length of 15 mm. This feature serves to improve access into the posterior regions of the mouth, especially when there is a narrow interocclusal space ***(Figure 11)***.

SIX (6) INSTRUMENT SERIES

The ProTaper system features just six NiTi files which is the fewest number of instruments as compared to all other brand lines or series of files. In fact, in anatomically difficult or significantly curved canals, generally only three instruments are required to produce a fully tapered canal that exhibits uniform shape over length ***(Figure 12)***. Canals that have foramens larger than 0.30 mm are generally easy to prepare and may be accomplished utilizing a variety of different, currently available instruments.

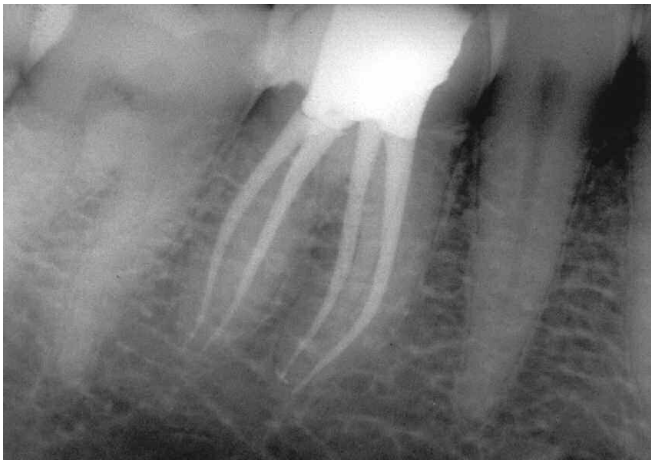

Figure 10. *ProTaper files were utilized in the endodontic treatment of this mandibular first molar. Note four optimally prepared systems exhibiting multiplanar curvatures. (Courtesy of Dr. Pierre Machtou; Paris, France)*

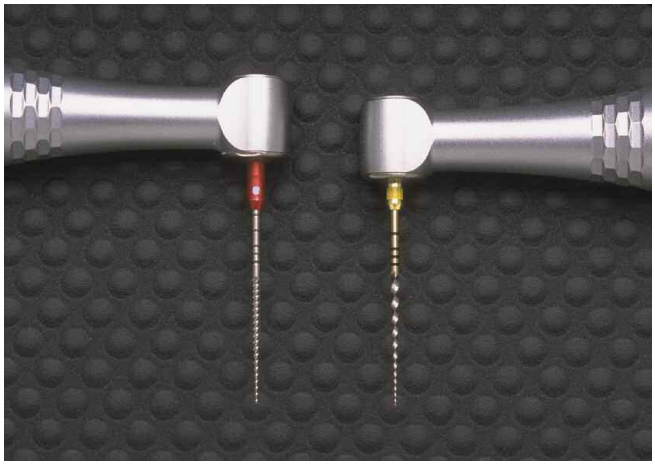

Figure 11. *When ProTaper files are inserted into a handpiece, their shorter handles provide improved access.*

ProTaper: Guidelines for Use

When the "guidelines for use" are followed, the ProTaper NiTi rotary instruments will provide high performance and excellent safety. It is essential to prepare the access cavity so that there is a straightline pathway to the orifice(s). The pulp chamber should be filled brimful with either sodium hypochlorite (NaOCl) or a viscous chelator. Rotary instruments should only be placed in portions of the canal that have a confirmed, smooth and reproducible glide path. To fulfill this objective, small, flexible stainless steel 0.02 tapered hand files are used to create or confirm the glide path. Additionally, small, flexible hand files provide information regarding straightline access, cross-sectional diameter and root canal system anatomy. Further, rotary NiTi instruments should only be used in the apical one-third of a canal that is patent and has a known, accurate working length. Finally, when incorporating the ProTaper instruments, clinicians should follow the specific "method of use", observe the recommended sequencing of files, and adhere to the correct range of speed and prescribed torque suggested for each file. The following summarizes the ProTaper rotary shaping file guidelines:

STRAIGHTLINE ACCESS

The access preparation is an essential element for successful endodontics.[4] Preparing the endodontic access cavity is a critical step in a series of procedures that potentially leads to the three-dimensional obturation of the root canal system. Access cavities should be cut so the pulpal roof, including all overlying dentin, is removed. The size of the access cavity is dictated by the position of the orifice(s). The axial walls are extended laterally such that the orifice(s) is just within this outline form. The internal walls are flared and smoothed to provide easy, straightline access into the orifice and the root canal system ***(Figure 13)***. Additionally, access preparations are expanded to eliminate any coronal interference during subsequent instrumentation. Access objectives are confirmed when all the orifices can be visualized without moving the mouth mirror. Ideally, endodontic access cavities should parallel the principle of restorative dentistry where the axial walls of a "finished" preparation taper and provide draw for a wax pattern. Cleaning and shaping potentials are dramatically improved when instruments conveniently pass through the occlusal opening, effortlessly slide down smooth axial walls and are easily inserted into the orifice. Spacious access cavities are an opening for canal preparation.[5-7]

IRRIGATION & LUBRICATION

No instrument should be introduced into the root canal space until the appropriate irrigant is introduced into the pulp chamber. When straightline access has been completed and all the orifices have been identified, the choice of irrigant may be determined as follows: If the pulp is vital and bleeding, it is desirable to fill the chamber brimful with a viscous chelator. In the instance where the pulp is necrotic, the chamber may be completely filled with a 5.25% solution of warm NaOCl. The importance of irrigants, their methods of use and their role in cleaning the root canal system has been described in several clinical articles.[2,8,9] To optimize safety, rotary shaping instruments are always used in the presence of a lubricating irrigant. Pulp chambers should be filled brimful with sodium hypochlorite or a chelator to reduce friction between the instrument and the wall of the canal and promote the preparation objectives.

REPRODUCIBLE GLIDE PATH

Cleaning and shaping outcomes are significantly improved when stainless steel 0.02 tapered sizes 10 and 15 hand files *(Dentsply Maillefer)* are utilized to scout a portion of the overall length of a canal and create or confirm a smooth, reproducible glide path before introducing any rotary NiTi instruments. With the onset of NiTi rotary instrumentation, the role of "hand" instruments has diminished and been redefined. For many rotary file users, small hand instruments are primarily used to gather reconnaissance information, to confirm available space, or when necessary, to create sufficient space prior to using more efficient rotary NiTi instruments. The 10 and 15 "scouter files" should not be thought of as just measuring wires, rather they can additionally provide feedback regarding:[10]

1. *Cross-Sectional Diameter*
   Scouter files immediately reveal the cross-sectional diameter of a canal and provide information as to whether the canal is open, restricted, or significantly calcified. Before

Figure 12. *This endodontically treated mandibular bicuspid demonstrates a corkscrewing and spiraling system that has been optimally treated.*

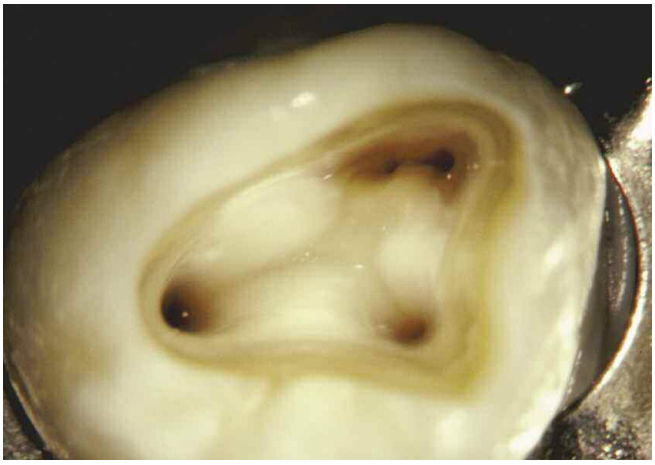

Figure 13. *A photograph at 15x shows straightline access, divergent axial walls and the orifices just within this outline form.*

any rotary instrument can be safely introduced into the canal, sufficient space must exist to accommodate and guide their tips. In other words, there must be a pilot hole of circumferential dentin and a smooth glide path for NiTi rotary instruments to follow. As an example, if a canal has been scouted to within 2-3 mm of anticipated working length with 10 and 15 hand files, then more space exists than the files' numerical names suggest. Recall the 10 and 15 hand files taper 0.02 mm/mm, have 16 mm of cutting flutes and their D_{16} diameters are 0.42 and 0.47 mm, respectively. These small instruments provide an opening for the implementation of rotary instruments.

2. *Straightline Access*
   Scouter files confirm the presence or absence of straight-line access. Clinicians can observe the handle position of the smaller sized instruments to see if they are upright and paralleling the long axis of the tooth or skewed off-axis. In the instance where the roots are under the circumferential dimensions of the clinical crown and the file handle is upright, or "On" the long axis of the tooth, then the clinician is able to confirm both coronal and radicular straightline access. In instances where the handle of the initial scouting instrument is "Off" the long axis of the tooth, then pre-enlargement procedures should be directed towards uprighting the file handle ***(Figure 14).***[10,11] To upright the handle of the small scouter files oftentimes requires refining and expanding the access preparation and selectively removing the triangle of dentin from the coronal one-third of the canal. This procedural distinction is critical and simplifies all subsequent instrumentation procedures while virtually eliminating many cleaning and shaping frustrations.

   Traditionally, a series of gates glidden drills, used like "brushes", were needed to upright the file so it would parallel the long-axis of the tooth. With just a single instrument, the ProTaper SX file may be used to rapidly, effectively and safely remove the triangle of dentin ***(Figure 15)***. Once this restrictive dentin has been eliminated, the handles of the scouter files will be uprighted and "stand-up" straight and tall. This important procedural step serves to relocate the coronal aspect of the canal towards the greatest bulk of dentin, simplifies the use of any subsequently placed instrument, and promotes safety.

3. *Root Canal System Anatomy*
   Scouter files can provide information regarding root canal system anatomy. Clinicians need to appreciate the five commonly encountered anatomical forms which include canals that merge, curve, recurve, dilacerate or divide. Scouter files provide information regarding the anatomy and give important feedback regarding the canal's degree of curvature, recurvature, or if there is a dilaceration. Further, before introducing rotary instruments, clinicians need to know if a single canal coronally subsequently divides or if two or more systems within a root merge along their length. It must be recognized that certain root canals exhibit anatomical configurations which preclude the safe use of NiTi rotary files.

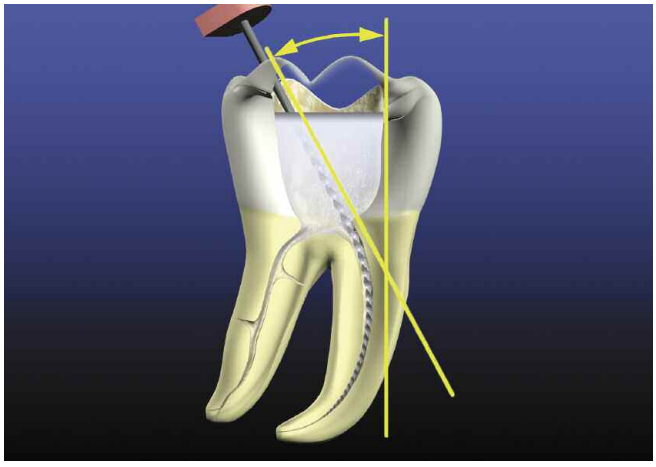

Figure 14. *The handles of small hand files are frequently "Off" axis in furcated teeth due to internal triangles of dentin.*

PATENCY & WORKING LENGTH

The breakthrough to apical one-third finishing procedures is canal "patency" and is performed by gently directing small, highly flexible files to the radiographic terminus (RT).[5] To ensure patency, the file tip is intentionally inserted minutely through the foramen to discourage the accumulation of debris ***(Figure 16)***. Importantly, working a small, flexible file to the RT will encourage the elimination of dental pulp, related irritants, and dentinal mud. Keeping the canal terminus patent discourages blocks, ledges and perforations.[12] It is illogical to assume that passing a small file passively and minutely through the apical foramen is going to prejudice the result or predispose to any irreversible conditions when one reflects on the rich collateral circulation and healing capacity available in the attachment apparatus.

Researchers, academicians and clinicians are well aware that when a file is passed through the entire length of a canal and its most apical extent is observed to be at the radiographic terminus, then, in actuality, the instrument is minutely long. Traditional wisdom advocates that since the apical extent of a canal terminates at the cementodentinal junction (CDJ) then working length should extend to this anatomical landmark.[13] Although the CDJ exists in a non-pulpally involved tooth, its position can never be precisely located clinically as this histological landmark varies significantly from tooth to tooth, from root to root, and from wall to wall within each canal. Working arbitrarily short of the radiographic terminus based on statistical averages encourages the accumulation and retention of debris, which may result in apical blocks that predispose to ledges and perforations. Working short has led to many frustrations, interappointment flare-ups, "unexplained" failures, surgical procedures and extractions.[12]

Electronic apex locators represent an improvement over radiographs for more accurately identifying the position of the foramen.[14] Technological advancements in specific apex locators provide greater accuracy in length determination even in canals that contain exudates or electrolytes. It should be understood that apex locators do not replace films but are used intelligently and in conjunction with radiographs. When a predictable and smooth glide path is established to the RT and working length is confirmed, then the apical one-third of the canal can be "finished" in a variety of ways.[10]

METHOD OF USE

Rotary instruments should be used passively within the canal and their use may be continued as long as they move easily in an apical direction. To optimize ProTaper safety, the *"pencil lead analogy"* is used to qualify the specific recommended pressure. The desired pressure on an instrument should be equivalent to the pressure used when writing with a pencil without breaking the lead. Let the instruments "float like a feather" into the canal and allow them to travel apically until they meet light resistance. If any ProTaper instrument ceases to advance, withdraw it, and recognize the four factors that typically prevent a rotary file from passively moving in an apical direction:

1. *Insufficient Canal Diameter*: Insufficient canal diameter will prevent a rotary NiTi instrument from passively moving deeper into the canal. Recognize that the working end of a rotary file may be too big or stiff to follow the canal due to calcification. Additionally, appreciate NiTi rotary instruments may not be able to follow a canal that abruptly curves, divides, or whose walls exhibit resorptive or iatrogenic defects. When calcification exists, use a viscous chelator, the 10 and 15 hand files, and if necessary, a few larger hand instruments to create or confirm that the diameter of the canal has been sufficiently enlarged to guide the tip of a NiTi rotary instrument.
2. *Intracanal Debris*: Intracanal debris may accumulate in a canal that previously exhibited a confirmed and reproducible glide path. To eliminate intracanal debris, voluminously irrigate the root canal space, recapitulate with a #10 file to break-up debris and move it into solution, then re-irrigate to flush-out this loosened debris. Use a 10 or 15 file to confirm a smooth, reproducible glide path before commencing with rotary shaping procedures.
3. *Intrablade Debris*: Another possibility that limits the apical movement of an instrument is the accumulation of debris within the depth between the cutting blades. Intrablade debris tends to deactivate an instrument as it pushes the active part of the file off the wall of the canal. In this latter case, withdraw the instrument and clear its blades, irrigate the canal, recapitulate with a small hand file to confirm the existence of the previously established glide path, then re-irrigate to flush out debris.

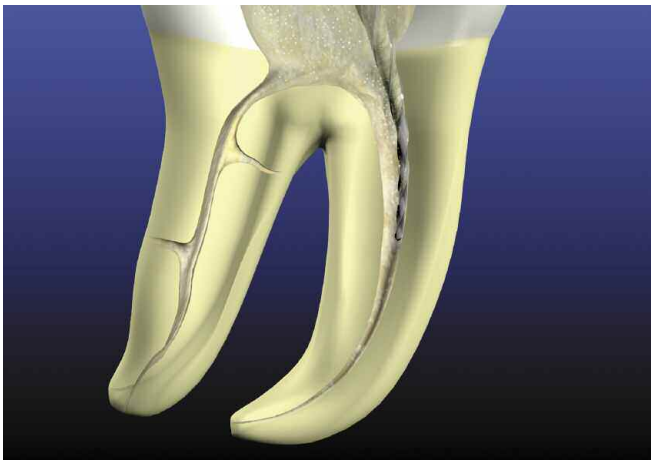

Figure 15a. *SX is used in a brushing motion to cut dentin and safely relocate canals away from external root concavities.*

Figure 15b. *SX is used initially to brush away dentin and create lateral space so its rapidly tapering blades can progressively shape deeper into the canal.*

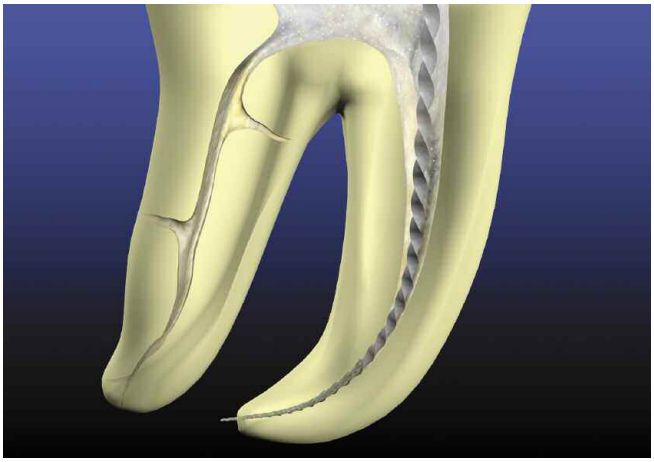

Figure 16. *Vital and necrotic teeth are negotiated to length and patency established and maintained to promote the preparation objectives.*

4. *Root Canal Anatomy*: Certain systems exhibit difficult anatomical configurations that discourage or prevent the tip of a rotary instrument to passively, accurately and safely follow the canal ***(Figure 17)***. In these instances, irrigate and recapitulate with small hand files to improve the diameter of the glide path of the canal to facilitate the use of rotary instruments. It should be recognized that certain anatomical configurations are best shaped with hand files; however, the ProTaper Shaping File No. 1 has a D_0 diameter of 0.17 mm, modified guiding tip and can follow a smooth glide path that has been confirmed with the 10 and 15 hand files. With a smooth, reproducible glide path, the ProTaper rotary instruments will progressively produce a fully shaped canal that exhibits uniform taper over length.

MULTIPLE VS. SINGLE USE

During use, any given ProTaper file should be inspected for wear and its cutting blades frequently cleaned to optimize efficiency and reduce the potential for breakage. Other causes that contribute to NiTi rotary instrument breakage are "method of use" and "multiple use" of files. In the author's opinion, all NiTi rotary instruments should be discarded after each case due to metal fatigue, loss of cutting efficiency, and the great variation in length, diameter and curvature of any given canal. When the guidelines for use are carefully followed then the ProTaper files' unique geometries afford unsurpassed *safety, flexibility and efficiency*.[15]

MOTORS

The ProTaper instruments may be utilized in gear reduction, high torque electric handpieces at speeds ranging from 250-300 RPM. Specifically, the ATR Tecnika electric motor (Dentsply Tulsa Dental) is programmed so that the optimal torque for each ProTaper file can be selected using the "touch-mode" feature ***(Figure 18)***. Advancements in electric motors promise to improve clinical performance and safety for NiTi users.

Figure 17a. *Small hand files should be used to verify if the apical one-third of a pre-enlarged canal has either a smooth or irregular glide path.*

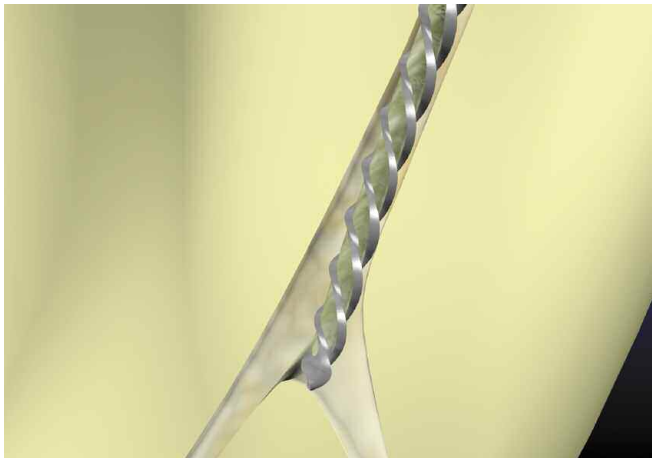

Figure 17b. *When small hand files can not easily slide along a canal, then NiTi rotary shaping instruments should not be used.*

Figure 18. *The ATR Tecnika electric motor offers many programmable features including torque control.*

CONCLUSION

This article has identified the ProTaper geometries, features and benefits. Additionally, the ProTaper guidelines for use have been discussed. The purpose of this article is to help clinicians understand and appreciate the advantages of this innovative, simple to use, set of six instruments. The next "RUDDLE ON ROTARY" article will describe the ProTaper technique and finishing criteria. ▲

AUTHOR NOTE:

The ProTaper rotary file system evolved over the past several years and represented a collaborative effort from Drs. Ben Johnson, Pierre Machtou, Clifford Ruddle and John West, and the engineers, Francois Aeby and Gilbert Rota, at Dentsply Maillefer in Ballaigues, Switzerland. Dr. Ruddle would like to thank everyone involved for their perseverance, creativity and effort.

REFERENCES

1. Ruddle CJ: Nickel-titanium rotary systems: Review of existing instruments and geometries, *Dentistry Today* 19:10, pp. 86-95, 2000.
2. Ruddle CJ: Current concepts for preparing the root canal system, *Dentistry Today* 20:2, pp.76-83, 2001.
3. West JD: Introduction of a new rotary endodontic system: progressively tapered files, *Dentistry Today* 20:5, pp. 50-57, 2001.
4. Levin H: Access cavities, *Dent Clin North Am* pp. 701-710, November, 1967.
5. Schilder H: Cleaning and shaping the root canal system, *Dent Clin North Am*, 18:2, pp.269-296, 1974.
6. Ruddle CJ: Endodontic canal preparation: breakthrough cleaning and shaping strategies, *Dentistry Today* 13:2, pp. 44-49, 1994.
7. Machtou P: Ch. 8, La cavité d'accès. In Machtou P, editor: *Endodontie - guide clinique*, pp. 125-137, Editions CdP, Paris, 1993.
8. Berutti E, Marini R: A scanning electron microscopic evaluation of the debridement capability of sodium hypochlorite at different temperatures, *J Endod* 22:9, pp. 467-470, 1996.
9. Berutti E, Marini R, Angeretti A: Penetration ability of different irrigants into dentinal tubules, *J Endod* 23:12, pp. 725-727, 1997.
10. Ruddle CJ: Ch. 8, Cleaning and shaping root canal systems. In Cohen S, Burns RC, editors: *Pathways of the Pulp*, pp. 231-291, 8th ed., Mosby, St. Louis, 2002.
11. Scianamblo MJ: Ch. 15, La preparazione della cavitá endodontica. In Castellucci A, editor: *Endodonzia*, pp. 374-391, 1st ed., Edizioni Odontoiatriche Il Tridente, Prato, Italy, 1993.
12. Ruddle CJ: Ch. 25, Nonsurgical endodontic retreatment. In Cohen S, Burns RC, editors: *Pathways of the Pulp*, pp. 875-929, 8th ed., Mosby, St. Louis, 2002.
13. Pineda F, Kuttler Y: Mesiodistal and buccolingual roentgenographic investigation of 7275 root canals, *Oral Surg* 33:101, 1972.
14. Shabahang S, Goon WWY, Gluskin AH: An in vitro evaluation of Root ZX electronic apex locator, *J Endod* 22:11, pp. 616-618, 1996.
15. Survey results from the North American, Asian and Western European endodontic opinion leaders: "Clinician evaluation: protaper endodontic file system," 2000 Endodontic Opinion Leaders Forum, Shangri-La, Oklahoma; 2001 European Endodontic Opinion Leader Meeting, Les Diablerets, Switzerland; 2001 Asian Endodontic Opinion Leader Meeting, Macao, China.