The differences in opinion are enormous regarding the best methods for shaping root canals and cleaning the root canal system. A review of the literature reveals virtually no agreement on a variety of fundamental clinical issues. Controversy is ongoing regarding the sequence of canal preparation, working length, and the use of patency files. Ignorance abounds related to the question of how large to prepare the apical foramen and what the appropriate percentage taper is of a canal to ensure that a root canal system can be both cleaned and filled 3-dimensionally. Confusion is heightened trying to identify, assimilate, and integrate the best technologies and instruments. There is no international agreement regarding the most effective strength, temperature, and volume of an irrigant, nor the potential for any given reagent to clean. Major disagreements exist pertaining to the importance of deep lateral debridement, smear layer management, and biofilm, and how these factors influence success.

In the final analysis, science and basic research can illuminate our clinical endeavors. Ultimately, however, our success as a healing profession is measured by our clinical actions. Fortuitously, Dr. Herbert Schilder described the most predictably successful concepts and strategies for shaping canals and cleaning root canal systems. Schilderian endodontics continues to serve as a powerful beacon of light to guide any clinician on the journey toward greater clinical confidence and success.

More than 30 years ago, Schilder's article, "Cleaning and Shaping the Root Canal," was published. [1] In what has become a classic article, he presents brilliant concepts and defines the 5 mechanical objectives for shaping canals and cleaning root canal systems. Schilder completely understood that, logically, the dimensions of these smooth-flowing, funneled preparations would necessarily and appropriately vary relative to the anatomy of any given root (Figures 1a and 1b). Schilder fully appreciated that well-shaped canals would exhibit "the look," improve the potential for 3-dimensionally cleaning and filling root canal systems, and fulfill the biological objectives for the retention of critically essential teeth (Figure 2).

Figure 1a. This image serves to emphasize the curvatures, external and

Figure 1b. At a higher magni

Figure 2. Sequencing the preparation for shaping canals and cleaning canals. **Figure 3.** Anatomical

Schilder's genius was the innovative motion he used with a series of instruments to carve the shape and sequence the preparation. There are strategic advantages to removing restrictive dentin from the coronal two thirds of the canal before initiating procedures in the deeper and typically more complicated apical region of the canal (Figure 3). [2] Schilder's shaping objectives are the standard against which all other preparation techniques are measured. This strategy of pre-enlargement is very different from the frequently used step-back and crown-down techniques. Each technique has been described in different ways, has something to offer, and was developed to advance canal preparation methods. Although each technique can theoretically produce the same final shape, each method is very different and has been designed to prepare a general region within the canal in a precise sequence.

The following will briefly review the step-back, crown-down, and pre-enlargement techniques.

TRADITIONAL SHAPING TECHNIQUES

In the step-back technique, small-sized ISO hand files are initially used to negotiate the full length of the canal. Larger files are then carried into the apical one third until the desired master file reaches the chosen working length. The apical one third of the preparation is deemed complete when the master file is snug at length and each consecutive larger file in the series is observed to step back uniformly from the most apical extent of the preparation. When the apical one third of the preparation has been completed, the coronal two thirds of the canal is flared, and the overall length of the preparation is smoothly blended. Although this preparation method can be successful and is performed with slight variations, the technique has regrettably resulted in countless canals that have been blocked, ledged, transported, or perforated. These iatrogenic events frequently require additional procedures, such as nonsurgical retreatments, surgeries, and extractions. [3]

In the crown-down technique, ISO instruments with varying D0 diameters are generally selected and utilized from the bigger to smaller sizes. In general, the preparation is initiated at the orifice, continued through the body of the canal, and then terminated at the canal's most apical extent. As such, dentin is sequentially removed from the coronal, then the middle, and finally from the apical one third of a canal. Although the crown-down technique overcame many of the frustrations associated with the step-back technique, the paradox is threefold. First, although

the instruments initially selected aggressively plow away dentin with their bigger, stronger, and stiffer tips, it must be recognized that a large spinning file will over-simplistically cut a round hole. Preparing a round hole through an anatomical cross-section that commonly exhibits an irregular configuration compromises debridement and disinfection. Second, the taper of the ever-expanding preparation quickly duplicates the taper of the file used, especially in longer, smaller-diameter, and more curved canals. When a file has a long engagement over its active length, dangerous taper lock results, and the potential for breakage significantly increases. 4 Third, the potential for file breakage increases, since the smaller-sized files, which are utilized in the apical one third, tend to engage and cut dentin toward their smaller, weaker, and less efficient blades.

Figure 4. An endodontically treated maxillary first bicuspid exhibits branching sy

In the pre-enlargement technique, a series of ISO instruments with varying D0 diameters are selected, appropriately precurved, and utilized from the smaller to larger sizes. Especially in longer, smaller-diameter, and more curved canals, the shaping instruments are initially restricted to the coronal two thirds of the canal. Each consecutive larger instrument will generally work short of the previously used smaller files, progressively carve away restrictive dentin, and serve to funnel the coronal and middle two thirds of the canal. However, since these instruments are used from small to big, their more flexible tips are typically loose and safely follow the secured portion of the canal. Importantly, depending on the extent of curvature, any given ISO instrument will cut a shape larger than its taper would suggest. Specifically, when the envelope of motion (EOM) technique is employed, each instrument will randomly cut dentin on the outstroke toward its larger, stronger, and more active blades.1 Properly performed, pre-enlargement procedures improve access to the typically more challenging anatomy in the apical one third of the canal. Fortuitously, following pre-enlargement procedures, finishing files are completely loose within the body of the canal and can be more predictably directed apically. In this technique, emphasis is placed on shaping and blending the apical one third of the preparation into the body of the canal. Finishing the canal is the sine qua non of preparation excellence (Figure 4).

Over many years, the pre-enlargement technique has grown in popularity, as this method for shaping canals has proven to be predictably successful. However, this method for preparing canals frequently requires many instruments and several recapitulations through a series of files and reamers. As such, it is perceived to be difficult and time-consuming. Following is a clinical technique that utilizes the principles of pre-enlargement in an efficient and less time-consuming fashion.

NI-TI FILE SELECTION

Figure 5. The canals of this maxillary molar were prepared with ProTaper files. N

The technique presented uses the ProTaper variably tapered design, which was developed to provide a 6- instrument set comprising 3 shaping and 3 finishing files that would both duplicate and simplify the Schilder technique. [5] Each shaping file would have increasing percentage tapers over the length of its cutting blades. Each finishing file would have a fixed taper in its apical extent, then, importantly, decreasing percentage tapers over the coronal two-thirds length of its blades. When sequenced and used correctly, the ProTaper files (DENTSPLY Tulsa Dental) afford flexibility, efficiency, safety, and simplicity (Figure 5). [6-8]

The ProTaper method of use precisely duplicates the Schilder technique, where precurved reamers are sequentially selected, rotated in an “envelope of motion,” and cut dentin on the withdrawal stroke. [9,10] The shaping files’ small-sized tips act as guides to follow passively the path of the canal previously secured with hand files. [11] Increasingly larger percentage tapers over the active length of each shaping file ensure that each sequential instrument works away from its apical extent. Importantly, an increasing percentage tapered file selectively cuts dentin toward its larger, stronger, and more efficient blades. [12]

PROTAPER SHAPING TECHNIQUE

Figure 6. A photograph demonstrates an access cavity through a prosthetically

Endodontic outcomes are improved when instruments pass through the access opening, effortlessly slide down smooth axial walls, and are easily inserted into the orifice (Figure 6). The potential to shape canals and clean root canal systems consistently is significantly enhanced when the coronal two thirds of the canal is first pre-enlarged followed by preparing its apical one third. [2]

Scout the Coronal Two Thirds

When straightline access is completed, the pulp chamber may be filled brimful with a viscous chelator. Based on the preoperative radiographs, ISO 0.02 tapered sizes 10 and 15 hand files are measured and precurved to match the anticipated full length and curvature of the root canal. However, in this method of canal preparation, these instruments are initially limited to the coronal two thirds of a root canal. The 10 and 15 hand files are utilized within any portion of the canal until they are loose and a smooth, reproducible glide path is confirmed. The loose depth of the 15 file is measured, and this length is transferred to the ProTaper S1 and S2 files.

Shape the Coronal Two Thirds

The secured portion of the canal can be optimally pre-enlarged by first utilizing S1 then S2. Prior to initiating shaping procedures, the pulp chamber is filled with a full- strength solution of NaOCl. Without pressure, and in one or more passes, the shaping files are allowed to “float” into the canal passively and “follow” the glide path. To optimize safety and efficiency, the shaping files are used like a “brush” to cut dentin laterally and selectively on the outstroke. A brush-cutting action creates lateral space, which will allow the shaping file’s larger, stronger, and more active cutting blades to move safely and progressively deeper into the canal. Strategically, this brush-cutting action can be used to shape more effectively into fins, isthmuses, and canal irregularities or to relocate the coronal aspect of a canal away from furcal danger. If any ProTaper file ceases to advance easily within the secured portion of a canal, withdraw it and recognize that intrablade debris has deactivated and pushed the instrument off the canal wall. Upon removing each shaping file, visualize where the debris is located along its cutting blades to appreciate better the region within the canal that is being prepared. Following the use of each shaping file, irrigate, recapitulate with a 10 file to break up debris and move it into solution, then re-irrigate. Without pressure, and in one or more passes, S1 and then S2 are used in this manner until the depth of the 15 hand file is reached.

Scout the Apical One Third

When the coronal two thirds of the canal is shaped, then attention can focus on apical one third procedures. With the pulp chamber filled brimful with a viscous chelator, the apical one third of the canal is fully negotiated and enlarged to at least a size 15 hand file, working length is confirmed, and patency is established. 13 At this time, a decision must be made as to whether rotary or hand instruments will be used to finish the apical one third. If a new and straight 15 file

can gently “slide” and passively “glide” to length, then rotary instruments will generally follow this confirmed and “reproducible glide path.”2 However, certain canals exhibit anatomical challenges that necessitate a reciprocating handle motion in order to move precurved 10 and 15 files to length. When there is an “irregular glide path,” the apical one third of a canal may be advantageously finished with precurved manual ProTaper instruments.

Shape the Apical One Third

When the apical one third of the canal has been secured, then the pulp chamber is filled brimful with NaOCl. The ProTaper sequence is to carry the S1, then the S2, to the full working length. Float, follow, and brush as previously described until the terminus of the canal is reached. S1, then S2, will typically move to length in one or more passes depending on the length, diameter, and curvature of the canal. Following each rotary file, irrigate, recapitulate with a 10 file, then re-irrigate. After using the shaping files, particularly in more curved canals, working length should be reconfirmed, as a more direct path to the terminus has been established. At this stage of treatment, the preparation can be finished using one or more of the finishing files in a “non-brushing” manner. The F1 is selected and passively allowed to move deeper into the canal, in one or more passes, until the terminus is reached. When the F1 achieves length, the instrument is removed, its apical flutes are inspected, and if they are loaded with dentin, then visual evidence supports that the shape is cut. Following the use of F1, flood the canal with irrigant, recapitulate and confirm patency, and then re-irrigate to liberate debris from the canal.

Finishing Criteria

Figure 7a. The canals of this mandibular molar were shaped with ProTaper files.

Figure 7b. The canals of this

Figure 7c. This maxillary bicuspid was endodontically prepared with ProTaper file

Figure 8. This chart summarizes the ProTaper shaping technique. The ProTaper sequen

Following the use of the 20/07 F1, the "finishing criteria" is to gauge the size of the foramen with a 20/02 tapered hand file to determine if this instrument is snug or loose at length. If the 20 hand file is snug at length, then the canal is fully shaped and, if irrigation protocols have been followed, ready to pack. Following the use of F1, if the 20 hand file is loose at length, then gauge the size of the foramen with a 25/02 tapered hand file. If the 25 file is snug at length, then the canal is fully shaped and ready to pack. If the 25 file is short of length, proceed to the 25/08 F2 and, when necessary, the 30/09 F3, gauging after each finisher with the appropriately sized hand files. If the 30 file is loose at length, then use an alternative Ni-Ti rotary line or manual files to finish the apical extent of these larger, easier, and more straight-forward canals. ProTaper shapes are easy to fill utilizing a ProTaper matching gutta-percha master cone in conjunction with a warm vertical condensation technique (Figures 7a to 7c). As an alternative, a well-shaped canal can be filled with a ProTaper carrier-based obturator. The ProTaper sequence is always the same regardless of the tooth or anatomical configuration of the canal being treated (Figure 8).

EVIDENCE FOR CLINICAL SUCCESS

Figure 9a. This figure shows horizontal µCT sections through the

Figure 9b.

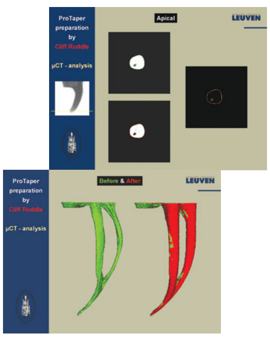

Figure 9c. This figure shows horizontal µCT sections through the

Figure 9d.

A clinical investigation of the ProTaper technique, emphasizing method of use, was conducted on mesial canals of extracted mandibular molar teeth using µCT-Analysis. 14 In this study, horizontal sections from different radicular levels were analyzed using µCT slices and volume renderings. The green color represented the anatomical contours before instrumentation, whereas the red color indicated the shape after instrumentation. The results from this investigation are clinically relevant, and a portion of the data is available for review in Figures 9a to 9d. The shaping files' ability to brush laterally and selectively cut dentin on the outstroke is summarized below:

- The shaping files were essentially loose within a canal during the majority of their work.
- The coronal aspect of the canals were safely relocated away from an external root concavity.
- A brush-cutting action achieved a centered preparation and maximized remaining dentin.
- The shaping files physically contacted more than 90% of the internal walls of the canals.

FUTURE

Figure 10. The ProTaper rotary files may be easily converted to manual files usin

ProTaper files will be relaunched this year and will be termed ProTaper Universal (Figure 10). The most noticeable change will be the addition of 2 larger ProTaper finishing files, namely F4 (40/06) and F5 (50/05). These 2 files may be used in anatomically larger canals or by those dentists who philosophically subscribe to making anatomically smaller-sized canals larger. Other modifications include removing the transition angle between the safe-end of the file and the first cutting blade, balancing the work more evenly from file to file within the series, electro-polishing, providing 31-mm lengths, and increasing the flexibility of the larger-sized finishing files. The objective is to address a greater variety of anatomical situations. Importantly, these instruments will decrease the perceived need for dentists to use hybrid file techniques.

CONCLUSION

It is an exciting time in dentistry as new technologies potentially drive new practice-building techniques and the expectation for greater clinical efficiency and success. In this time of unrelenting change, it would be wise to pause and remember the early pioneers of modern dentistry and reflect on the enormous contributions they made to create the biological and clinical foundations on which we stand. Dr. Herbert Schilder is one of these pioneers, and his innovative concepts have remained enduring and relevant over the decades. For new

technologies to be meaningful, clinical results must hold up to scientific scrutiny and complement time-honored principles.

The technique described in this article for shaping canals utilizing unique file geometries (ProTaper) has enabled both inexperienced and experienced dentists to duplicate consistently the most predictably successful concept ever described for preparing a canal. Uniting the most enduring shaping method from the past with today's technological advancements in machining fulfills the age-old adage, "Everything old is new again."

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Disclosure: Dr. Ruddle has a financial interest in products he designs and develops, which include the ProTaper System.