From Concept to Creation: A Vision Forty Years On

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The Five Ages of Man are said to be the Golden Age, the Silver Age, the Brazen Age, the Heroic Age, and the Iron Age. Endodontics has passed through many ages as the discipline transitions to increasingly predictable clinical success. Within the Pantheon of gods and gurus, one stands alone as a beacon of the pursuit of clinical excellence. Dr. Herb Schilder, in his landmark article "Cleaning and Shaping the Root Canal System",[1] altered endodontic protocols forever with his innovative and revolutionary concepts that defined the five mechanical objectives for optimally shaping canal spaces and cleaning root canal systems. His body of work is a reminder that while technologic advances may provide newer and more valuable tools, vision is the defining component that provides the pillars of comprehensive patient care.

Dr. Schilder was one of the first endodontists to appreciate that the shape of a prepared canal was directly related to the motion of the instrument used to sculpt the space, rather than to any particular instrument design. He theorized that the dimensions of smooth flowing funneled preparations should vary relative to the anatomy of any given root (Fig. 1). He further recognized that rotational motion rather than traditional push/pull motion would produce these optimal funnel shapes (Fig. 2). His concepts pertaining to this defining **envelope of motion** begat the protocols for the crown-down instrumentation approach and forty years later fostered the design of multiple tapered nickel-titanium files. Dr. Schilder passed away at the end of January, 2006. This article is written to honour the enormity of his contribution to the art and science of endodontics.

> First there was Chaos, the vast immeasurable abyss, Outrageous as a sea; dark, wasteful and wild.
> *(Milton)*

Dr. Schilder recognized that the mainstream step-back approach to canal instrumentation, in vogue at the time, when used in concert with a push/pull filing technique augmented by circumferential movement was the harbinger of ledges, strip perforations, blockages, lack of apical patency and a multitude of ancillary iatrogenic problems. As an alternative, he developed the envelope of motion technique using K hand reamers. The fluted portion of the reamer is curved approximating a semi-circle. While holding the shaft vertically, the "envelope" is generated as the reamer is spun (Fig. 3). The size of the envelope depends on how much of a curve has been placed; the bigger the curve, the bigger the envelope (taper), the smaller the curve, the smaller the envelope (taper).

The precurved reamer is passively inserted in the canal to a

FIGURE 1—Root curvatures, external root concavities and aberrations in internal anatomy hallmark the root canal system.

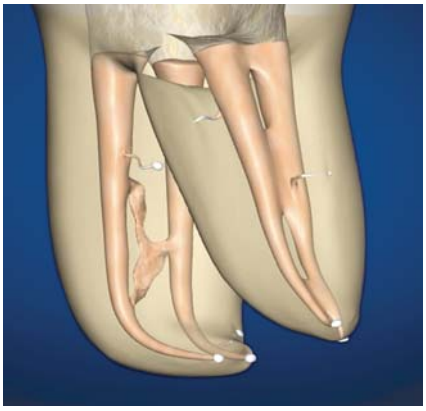

FIGURE 2—The ramifications of the root canal system when viewed three dimensionally after microstructural replication demonstrate the complex synergy of technical demands of shaping and the biologic imperative of cleaning integral to predictable clinical success.

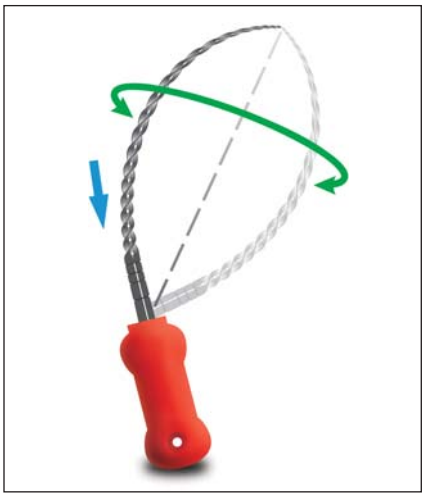

FIGURE 3—The envelope of motion is generated by precurving the reamer and rotation and withdrawal of the instrument during the working cycle. All the work is done on the outstroke, obviating the potential for ledge creation.

position just prior to binding. The reamer will then contact in two places — near the tip and at the widest part of the bend (the belly). If the reamer is positioned further down the canal, more lateral pressure is developed as the heavy curve of the reamer insinuates the belly more forcibly against the canal wall. A lesser curve means less lateral pressure, thus less work by the belly and less cutting in that area. A push/pull amplitude of motion is never used. All the work is done on the outstroke, obviating the potential for ledge creation.

An arbitrary working length determination is made from a well-angulated paralleling technique radiograph at the outset. The expectation in the vast majority of cases is that initial penetration will not reach the apical aperture. Passive placement of a precurved instrument in the canal prevents inadvertent penetration through the apical foramen as the bend in the reamer makes the instrument act like a spring minimizing the depth of penetration. Thus, during initial instrumentation, the operator is always reaming short of the apical terminus. The rubber stop is set to this level, in essence the first of a series of tapers defined by the canal shape.

Very small K files (#10 and #15) or barbed broaches are used to separate the collagen fibres of the pulp and debride the residual tissue thereby enabling deeper initial irrigation. A #20/.02 reamer is used in most canals, although smaller sized reamers may be used (sizes #'s 10 or 15) at the outset when coronally calcified canals are encountered. As long as the instrument is not forcefully placed in the canal and the tip is not actively engaged, coronal enlargement or "bodywork' will occur. Early pre-enlargement of the canal body enables greater control during the apical third preparation. This precept can be seen in most of the new NiTi systems manifested as coronal shaper/enlargement files.

The instrument is withdrawn using 360 degree rotational movement. The rate of withdrawal depends on the curvature of the canal; the straighter the canal, the deeper the initial insertion; in more curved canals, there is less initial penetration. Speed of rotation can also be varied. Straighter canals can be reamed more quickly, albeit with a slower withdrawal and more rotations per individual file usage. Curved canals usually require less rotations and a more rapid withdrawal of the reamer.

The next larger sized reamer is precurved in the same manner and measured against the previous instrument by holding them side by side and adjusting the rubber stopper. After use in the canal, the stopper is reset and invariably it is short of the previous instrument by the thickness of a stopper or two. No numerical measurements are taken; the depth of penetration is ascertained by correlation measurement. Dr. Schilder taught that it was more important to let the instruments find their own depth. He wanted to emphasize that each canal had its own taper and that attempting to force an instrument to go to a predetermined length could only cause ledging. This was a radical departure from the mainstream step-back instrumentation procedure in vogue at the time.

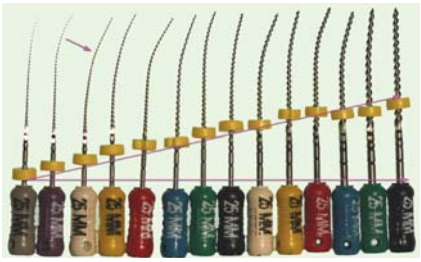

FIGURE 4—The arrow points to the belly area of the file that ideally does the "work". The curvature of the file typifies the bend desired to optimize the envelope of motion. The angle made by the position of the stops relative to the x axis indicates the degree of taper created. The flatter the angle, the less the distance between each stop... the less the taper; the greater the angle, the more the distance between instrument placement depth... the greater the taper.

FIGURE 6—The ProTaper® Universal files link concept with computer modeled design configurations that provide for an efficient and effective means of shaping the root canal space.

FIGURE 5A—Obturation density is the manifest doctrine of endodontics. Concentric diameters of decreasing size, the innate effect of the envelope of motion, maximize the rheologic potential of any thermoplastic material and ensure that replication of the canal space is paramount.

FIGURE 5B—The flow characteristics achieved by the ProTaper files regardless of the degree of dilaceration or the sinusoidal nature of the canal space ensure uninterrupted flow to the apical aperture. (courtesy of Dr. John West)

Figure 4 demonstrates the means for determining the nature of the taper that has been created and reflects graphically whether the case has been sufficiently worked to create a desirable shape. It depicts how a multitude of tapers is responsible for the final shaping. If the angle is too flat or too acute, it indicates that that a better funnel or conical shape is required. The result of this action is the limited purposeful straightening of the coronal part of the canal to allow for better negotiation of apical anatomy. If elements of the angle are not right, i.e. the stops are all at the same length in the smaller sizes, this suggests too much parallelism at the apex. Better separation is required between the stops to optimize the taper that approximates the apical aperture. The creation of a point or linear apical control zone with an exaggerated taper at the minor apical diameter is desirable.[2]

The series of reamers used can include sizes #70 and #80 depending on the diameter and curvature of the canal. Each is used in the same manner, albeit, staying slightly short of the length of the previous instrument. None should be placed into the canal in exactly the same way. The randomization of work done during withdrawal prevents stepping and ledging. It is necessary to recurve the reamer after insertion as the envelope flattens out each time it is used. It is the randomization of the belly, working against the canal wall that prevents the instrument from going to the same spot each time. The tip never binds, the only part that is in active contact is the belly, and thus the tip becomes irrelevant. Patency is verified frequently and copious irrigation is a required constant. The elimination of ruler measurements except for the working length determination establishes a regimen where the canal itself dictates shape based upon its diametral size and flow characteristics.

Recapitulation as defined by Dr. Schilder is "the sequential reintroduction of a previously placed series of reamers into the root canal space". The term has often been confused with the idea of recapitulation meaning "repeated patency checks with previously placed files". Recapitulation is not merely a patency check. Control of the shape being created is a function of the number

of recapitulations performed. Recapitulation moves the belly of the previously placed reamers further down the canal. As such, the canal is directing the formulation of its native shape and the developing taper moves toward the apex creating deep shape and ultimately enhanced density of the obturation.

Small scouting files (#'s 10 and 15) are used to determine the working length prior to initiating the reamer series. An accurate working length determination ensures that the canal dictates its spatial configuration with the envelope of motion approach. When the technique was first introduced, apex locators were in their infancy. Dr. Schilder relied

upon a "first instrument to the apex radiograph" and a "last instrument to the apex radiograph" to verify the accuracy of the shaping. The most apical reference point was the radiographic terminus. While it is understood that the instrument at the RT is actually outside the canal space, nonetheless the technique enabled retention of the apical aperture position as canal patency ensured that the foramen would not transition from its native location.

The coronal aspect of the body is "married" to the access with Gates Glidden drills of sizes #3, 4 (depending on the canal size). These drills are placed passively in the canal orifice and only activated on the outstroke in a "brushing" manner. The refinement of the apical third is done with precurved hand files once the recapitulation has achieved the desired shape in the body of the canal.

The objective of this technique is to keep the apical size as small as practical (approximately a #20 or #25 file) to ensure density of the apical seal during obturation. Each succeeding reamer will be within a few mm of the target file during the initial penetration, thus there will be fewer recapitulations required to create the desired shape. Reaming at the apical terminus is not part of the protocol. The apical third is explored for multiple foramena and subsequently shaped and gauged with hand files in a push/pull amplitude which dramatically lessens the possibility of apical aperture transportation (Figs. 5a & b)

In theory, the envelope of motion technique "creates" a multiple tapered instrument from within a fixed instrument application. Dr. Schilder's concept is a de facto rotary motion approach with a multiple taper construct. The operator can readily achieve 300 rpm speeds with hand reaming and yet engender a lesser risk of instrument breakage. Even if a reamer is over-torqued by engaging too much dentin, the clinician will feel the sensation should the instrument unwind.

The multiple taper design of some rotary NiTi instruments has been modeled from what has been described above. The myriad of design configurations of the files of all NiTi systems move the taper apically along the canal in a crown down rotary motion. It really is the logical extension of the principles Dr. Schilder introduced decades ago and reflects that in architecture and design, "everything old is new again".

The pre-enlargement technique Dr. Schilder advocated has grown in popularity over the years and become the standard for most systems in the endodontic armamentarium. The technique as originally conceived however, required many instruments, several recapitulations through a series of files, and as such, was perceived to be both difficult and time-consuming. With the introduction of nickel-titanium, it seemed wise to design a set of files with innovative geometries that would both duplicate and simplify the Schilder technique. The geometries of the ProTaper® (Dentsply/Tulsa Dental, Tulsa OK) NiTi files unite this shaping method from the past using fixed instrument design with the technological advancements in machining and metallurgy available todayto produce multitaper NiTi instruments.

In the pre-enlargement technique, once the coronal two-thirds of the preparation has been optimally shaped, then the apical one-third of the canal is negotiated, working length established, and patency confirmed. In essence, once a reproducible glide path to the apical aperture can be demonstrated, the ProTaper S1 and S2 shaping files are carried to length, in one or more passes, prior to using the ProTaper finishing files. The finishing files have fixed tapers from D1 to D3, and then decreasing percentage tapers from D4 to D16. This design feature improves flexibility, decreases the engagement zone, and limits the finishing files to working in their apical extents. Importantly, a decreasing percentage tapered design respects external root concavities, reduces the possibility of over-preparing the coronal two-thirds of a canal, and maximizes remaining dentin.[3] The addition of two larger finishing files, namely F4 (40/06) and F5 (50/05) will occur sometime during 2006 (Figure 6).

Thomas Carlyle wrote: "Today is not yesterday: we ourselves change; how can our works and thoughts, if they are always to be the fittest, continue always the same? Change, indeed, is painful; yet ever needful; and if memory has its force and worth, so also has hope." We must be ever mindful that technology effects change, but vision energizes everything. The vistas and horizons that wait in the corridors of the future are invariably the result of unrelenting passion and dogged pursuit, an altogether solitary, albeit noble quest. Thank you Dr. Schilder. **OH**

Dr. Serota is a contributing consultant to Oral Health and maintains an endodontic specialty practice in Mississauga, ON.

Ruddle bio here

Kaufmann bio here

Oral Health welcomes this original article.

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