ENDODONTIC REBOOT:  
Adaptive core debridement and disinfective finishing

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Fifty years ago, Dr. Herbert B. Schilder introduced two legacy concepts to the science of endodontics: the constricted envelope of motion for instrumentation and the use of hydraulics to enhance the rheology of the obturation material used to seal the root canal space and optimize its gravitometrics. These were radical innovations for their time and despite technological and biological shortcomings of the armamentarium available, these innovations should have been technologically iterated and shortcomings in material and manufacturing evolution obviated; however, until recently that has not proved to be the case in toto. In order to truly understand the inherent flaws, the clinician must recognize the totality of what is necessary to engender predictable clinical success in endodontics.

Studies assessing the diametric dimensions of apical anatomy have repeatedly demonstrated that the buccolingual diameter is greater than the mesiodistal diameter; canals are predominantly ovoid throughout, not round (Figs. 1a & b).1–4 The technical flaw most inherent, the use of a round file of any design conformation to clean an ovoid canal configuration, manifests as the failure to debride a substantial amount of the canal contents. A recent study showed that the mean (± standard deviation) untreated areas ranged from 59.6% (± 14.9%) to 79.9% (± 10.3%) for the total canal length and 65.2% (18.7%) to 74.7% (17.2%) for the apical canal portion, respectively (Fig. 2).5

The evolution of nickel-titanium (NiTi) instrumentation manufacture has persisted with a round core blank, regardless of whether it was ground, twisted, nanocoated, heated or metallurgically reformulated. NiTi files are superelastic and able to self-center, avoid apical ellipticization and, with appropriate taper selection, prevent thinning of the coronal and middle thirds of the root, resulting in weakening or strip perforation. They are, however, unable to cleanse most of the intracanal space effectively (Fig. 3). Moreover, regardless of design configurations with a variable tip or variable taper or multiple tapers on a single file, they were unable to adequately cleanse the isthmus confluence of many canals.6 A revolutionary design in file configuration, the Self-Adjusting File (SAF) System (ReDent Nova) was introduced to correct this deficiency by including a virtual core (Fig. 4). It showed significant promise in terms of the degree of debris removal in complicated intracanal anatomy such as the isthmus when compared with the widely accepted ProTaper system (Dentsply Maillefer); however, it failed to take hold as a true replacement for traditional “round” rotary instrumentation systems.7–9

The manipulation of the metallurgical properties of NiTi by thermomechanical processing treatments has led to significant improvement on the clinical performance of the endodontic rotary files. The transition from the martensitic phase (soft phase) to the austenitic phase (stiff phase) is dependent on temperature and metal stress. The reversible transition between these two phases increase the safety and performance of these files during rotation. Unfortunately, fracture still occurs due to cyclic fatigue and torsional failure when the elastic limit is exceeded (Fig. 5a).

The new generation of NiTi alloys have transformation temperatures much higher than those of conventional austenitic materials used in previous generations of rotary instruments and will transform at close to body temperature. A recent study of ProTaper Universal, HyFlex CM, TRUShape and Vortex Blue showed that a temperature increase to 37 °C, simulating body temperature, substantially decreased the fracture resistance of all instruments.

— Dr. Gilberto Debelian
This axial view of a mandibular molar demonstrates the ovoid eccentricity of the canals and existence of an isthmus connection between the mesiobuccal and mesiolingual canals consistent with findings of numerous studies.\(^8,9\)

The root canal space is an arborizational, anastomotic, labyrinthine complexity, morphologically comparable to the pathways of a maze. While primary canals exist, the tributaries, accessory branches and lumina of the dentinal tubules harbor extensive tissue and microflora. The existence of these vast, capacious passages has been demonstrated throughout the past century, beginning with the work of Hess and continues to this day with the use of microcomputed tomography.\(^7\)

The axial view of the obturation (microstructural replication) demonstrates the flaw in flat field film interpretation. Significant areas of the buccolingual dimensions of the root canal space remained uncleared despite the illusory appearance in the radiograph.

Dr. Herbert B. Schilder's principles included a continuously tapering shape, maintenance of the original anatomy, an apex as small as practical, and conservation of tooth structure. A continuously tapering space was acquired using precurved hand instruments, which imposed discontinuous contact with the canal walls and created an envelope of motion. Transactionally, Schilder created a virtual core.

The ideal file would produce an apical size that three-dimensionally cleaned the minor apical foramen. The SAF is a hollow file designed as an elastically compressible, thin-walled pointed cylinder that is composed of a NiTi lattice. Its hollow shape allows for the continuous flow of irrigant through its lumen. It was a beginning in the paradigm shift toward minimally invasive 3-D debridement and disinfection.
The revolution in endodontic instrumentation imparted by the first generation of NiTi instruments related to their shape memory and superelasticity. Despite the advantages, these files were susceptible to fracture due to fatigue and torsional failure.

Heat treatment (thermal processing) is one of the most fundamental approaches to adjusting the transition temperatures of NiTi alloys and affecting the fatigue resistance of NiTi endodontic files. Newer alloys (e.g., MaxWire) transforming close to body temperature have demonstrated superior resistance to cyclic fatigue and torsional failure.

A new generation of adaptive/virtual core files, the XP-endo system (FKG Dentaire) has dramatically changed the view of endodontic instrumentation. In the absence of a solid core, this system allows the tooth to dictate the canal configuration achievable and allows cleaning of the canal with a degree of thoroughness that is unprecedented. Figure 7 details various features of the XP-endo Shaper. The Booster Tip lead section fits into the pre-established glide path, ensuring precise guidance and centering of the instrument. A traditional glide path instrument is used consistent with a #15/0.02 (size/taper) instrument. There are no cutting flutes on the lead section of the Booster Tip, and the XP-endo Shaper instrument slips into the prepared apical component of the glide path to a depth of 0.25 mm. The next 0.25 mm section of the Booster Tip is configured with six cutting flutes. Rotation of these flutes sizes the next 0.25 mm of the canal space anywhere from a #25/0.02 to #60/0.02 (size/taper) instrument; however, the apical size chosen for the XP-endo Shaper is #30. The taper of the XP-endo Shaper is 0.01; however, the MaxWire alloy of the Shaper enables the martensitic shape at room temperature to realize the memorized shape as illustrated at body temperature (Fig. 6). By repeated swaths (a motion analogous to whittling in contrast to pecking) of the file, the taper created ranges anywhere from 0.02 to 0.08. The ideal intracanal taper throughout is 0.04, which preserves dentinal girth in the coronal third and sustains maximal dentinal retention in any root curvature. Figure 7a demonstrates the difference between the ability of a standard round NiTi file to clear a less than ideal volume of intracanal debris in contrast to the more significant maximal debridement achieved by the XP-endo Shaper’s adaptive discontinuous contact of the canal walls. The desired minimally invasive shape achieved with this unique instrument is shown in Figure 7b.

The distinctions of greatest importance between the XP-endo Shaper and conventional NiTi instruments are as follows: The Shaper does not compact debris on the flutes, resulting in increased frictional resistance, as it provides substantial space in the lumen or the virtual core; nor does it force the debris apically as evidenced in instruments used with reciprocating motion. As the points of contact on the dentinal walls are discontinuous, less stress is applied and thus less cyclic fatigue created than with conventional instruments, which can be readily demonstrated in photoelastic testing models (Fig. 8a). Figure 8b demonstrates that efforts have been made with other file systems to emulate the uniqueness of the adaptive core design of the XP-endo Shaper; however, regardless of the design alterations, a solid round core remains.

Inhibition or eradication of microflora presence from the root canal spaces is a multifactorial conundrum. The bulk of the microbes reside in the primary canal in a planktonic/loose form; however, there is a vast network of labyrinthine irregularities acting as a microbial reservoir that communicate with the primary canal. While irrigation with disinfectants may be very effective against planktonic microbes, it is not sufficiently effective when the microbes are in biofilm form or in canal irregularities. The ability of organisms within the residual biofilms to create an adaptive mechanism to the environmental changes resulting from the treatment protocol can result in recrudescence of the pathosis. The biofilm must be eliminated before the disinfectants will work. This is analogous to scaling and root planing in periodontal therapy.

As already mentioned, most files produce a final round shape on any given canal cross section and as such the prac-
titioner is limited in the capacity to scrape the walls of the nonround root canal space; at best, a round file can brush the walls to facilitate an enhanced disinfection. Alternative methods must be applied to remove toxins unreachable by traditional files.

The XP-endo Finisher was designed to be adjunctive to the XP-endo Shaper. The Finisher has many properties that allow it to gain access and scrape untouched components of the canal walls, and the turbulence it produces in the canal irrigant enhances its antimicrobial properties. The file has a #25 tip diameter with a 0.00 taper. It is extremely flexible and thus has tremendous resistance to cyclic fatigue. Its primary action within the root canal is to scrape the walls that it contacts rather than debride and sculpt a shape into the wall of the canal.

When the file is cooled below 35 °C, it is in the martensitic phase. It can be bent to any other shape when in this phase. When the file is heated to body temperature (37 °C), it will change to the austenitic phase. When the file is rotated in the austenitic phase, it creates a uniquely shaped cleaning instrument: The apical 10 mm of the file transforms into a bulb shape coronally while retaining a tip in the last few millimeters. Since the depth of the spoon is 1.5 mm, the total diameter of the bulb and tip is 3.0 mm. However, if the bulb is squeezed, the tip will expand to a maximum of 6 mm; if the tip is squeezed, the bulb will likewise expand to a #300 file (Fig. 9a); however, since the instrument cannot cut, the only impact on the dentin is optimized scraping. Therefore, if moved up and down in the canal, the bulb and tip will expand or contract in concert with the natural 3-D diameter of the canal. Maximum loss of length when transforming from straight to full austenitic phase is 1 mm.

The small core diameter of the file maintains its flexibility and cyclic fatigue resistance, causing it to scrape, not shape, the dentinal walls. This, plus the turbulence that is created in the irrigant, results in a large surface area of the canal being touched by the file and removal of biofilm that would never be removed by round files.

Figure 9b shows the action of the XP-endo Finisher. In the martensitic phase, the Finisher is placed in the canal before it changes to full austenitic phase. The middle illustration demonstrates full austenitic phase at canal temperature; the file will expand to the extent that is determined by the canal anatomy. By moving the Finisher up and down in a 7–8 mm swath, it expands and contracts according to the anatomy of the canal. A recent study demonstrated the efficacy of the Finisher in comparison with traditional modes regarding hard-tissue debris removal; the results are reflected in Figure 10. A more recent study showed that the Finisher had the greatest bacterial reduction compared with standard needle irrigation, sonic agitation with the EndoActivator and PIPS (photon-initiated photoactivated acoustic streaming). Figure 11 is an example of the unique action of the Finisher. The irregularity in...
A traditional NiTi file from a round blank is represented in red and XP-endo Shaper in blue. The sinusoidal motion of the XP-endo Shaper in contrast to the round file, which augers, demonstrates the benefit of adaptive debridement. In conjunction with the XP-endo Finisher, unprecedented levels of debris removal and disinfection are possible.

Minimally invasive endodontics, preservation of coronal dentinal girth and optimal apical size (courtesy of Dr. G. Debelian).

Photoelasticity is an experimental technique for stress and strain analysis useful for conditions of complicated geometry or loading. As evidenced by the accompanying images, the XP-endo Shaper demonstrates the least stress in the apical third.

ProTaper NEXT was the first example of an attempt to migrate away from the augering peck and pull motion of most NiTi files. Its swaggering motion was an improvement with regard to emulating the constricted envelope of motion; however, its foundation remained a round blank with all the attendant issues related to cyclic fatigue and torsional failure.
the canal is in the mesiodistal dimension owing to internal resorption. The Finisher enabled removal of debris and tissue in the irregularity while retaining the original shape of the canal and preventing further weakening of the root.

There is a third file in the XP-endo system, the XP-endo Finisher R designed for retreatments. This file is a #30/0.00 making it slightly stiffer and more efficient in removing root filling material adhering to the canal walls, especially in the curvature or oval areas. The residual amount of filling material when a tooth is retreated is difficult to calculate; however, studies using histological evaluation of teeth with post-treatment periapical periodontitis show evidence that bacterial colonization is associated with the canal remnants. A new supplementary strategy using a finishing instrument was evaluated for its ability to improve filling material removal in a recent study, and the results showed substantial reduction in residual contents when the Mtwo system and RECIPROC system were used for retreatment. The results using the XP-endo Finisher R instrument were encouraging because the remaining filling volume showed a 69% reduction in volume contents. In canals with residual filling material, an adjunctive approach with the XP-endo Finisher R instrument significantly enhanced removal (Fig. 12).16

**Conclusion**

Preliminary studies on XP-endo files have shown remarkable removal of soft tissue, fewer dentinal chips residual in the isthmus and canal walls after instrumentation, and low dentinal stress (fewer microcracks). The minimally invasive conservative instrumentation engenders a low amount of dentin removal coronally and efficient debridement and disinfection of the apical third area. Have we achieved the ideal fusion of technology and biology for long-term positive treatment outcomes? Perhaps. What has been achieved is a redress of a design flaw that has persisted for much too long.

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Fig. 10
The image reflects the distal views of 3-D reconstructions of the mesial root canal systems of four mandibular molars prior to (green) and after (red) canal preparation with reciprocating instruments. Final irrigation was done with conventional irrigation, passive ultrasonic irrigation, the SAF and the XP-endo Finisher. The figures demonstrate the effectiveness of the Finisher in the apical region.

Fig. 11
The pre-op periapical radiograph shows a mesiodistal resorptive defect. The cone beam computed tomography images show that this was internal resorption and that it extended buccolingually as well. The post-op radiograph shows that, at the second visit, the canal was filled completely, which is an indication that the tissue and debris had been removed. Also, and just as importantly, the original shape of the canal was maintained so that the tooth was not further weakened by the cleaning procedure.

Fig. 12
Microcomputed tomography (μ-CT) images of representative specimens subjected to retreatment procedures. Only the apical segment of roots was reconstructed. (A) The initial μ-CT scan taken after root canal filling. (B) A post-preparation μ-CT scan taken after retreatment procedures with both systems: left canals with RECIPROC and right canals with Mtwo. (C) The final μ-CT scan after using the XP-endo Finisher.