Endodontic Canal Preparation WaveOne Single-File Technique

by Clifford J. Ruddle, DDS

The mechanical objectives for endodontic canal preparation were brilliantly outlined almost 40 years ago.[1] When properly performed, these mechanical objectives promote the biological objectives for shaping canals, 3D cleaning, and filling root canal systems ***(Figure 1)***.[2] Over the following decades there has been the emergence of a staggering number of file brands, sequences, and hybrid techniques advocated for shaping canals. However, recent advances for endodontic canal preparation have focused on the concept "less is more."[3] This article will describe a single-file technique for shaping the vast majority of canals, regardless of their length, diameter, or curvature.

Rotation vs. Reciprocation

By far, the greatest number of commercially available files utilized to shape root canals are manufactured from NiTi and are mechanically driven in continuous rotation. On the other hand, reciprocation, defined as any repetitive back-and-forth motion, has been clinically utilized to drive stainless steel files since 1958. Initially, all reciprocating motors and related handpieces rotated files in large equal angles of 90º clockwise (CW) and counterclockwise (CCW) rotation. Over time, virtually all reciprocating systems in the marketplace began to utilize smaller, yet equal, angles of CW/CCW rotation. Today, the M4 *(SybronEndo)*, Endo-Eze AET *(Ultradent)*, and Endo-Express *(Essential Dental Systems)* are examples of reciprocating systems that utilize small, equal 30º angles of CW/CCW rotation. When shaping canals, it should be appreciated that there are both advantages and disadvantages associated with utilizing continuous rotating vs. a reciprocating movement. The greater tactile touch and efficiency gained when continuously rotating Niti files in smaller-diameter and more curved canals must be balanced with the inherent risks associated with torque and cyclic fatigue failures. Fortunately, these risks have been virtually eliminated due to continuous improvement in file designs, NiTi alloy, and emphasis on sequential glide path management (GPM).[4] Compared to reciprocation, continuous rotation utilizing well-designed active NiTi files requires less inward pressure and improves hauling capacity augering debris out of a canal.[5]

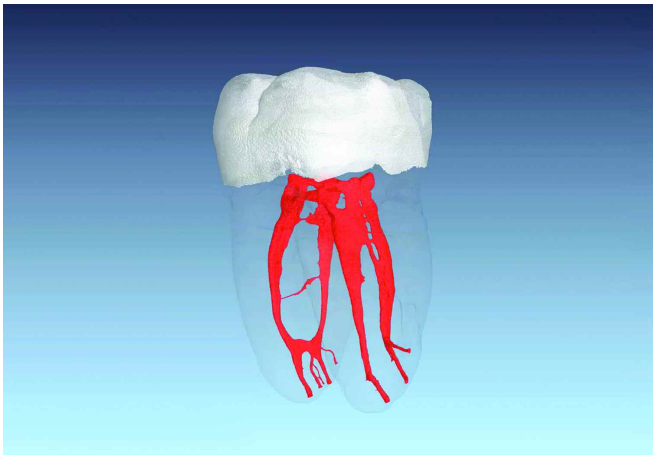

Figure 1. *A µCT image demonstrates the importance of treating root canal systems. (Courtesy of Dr. Frank Paque; Zurich, Switzerland)*

On the other hand, a mechanical reciprocating movement has merit because it somewhat mimics manual movement and reduces the various risks associated with continuously rotating a file through canal curvatures. However, current motors that drive reciprocating shaping files through equal forward and reverse angles generally require multi-file sequences to adequately prepare a canal. Further, systems that utilize small, equal CW/CCW angles have recognized limitations, including decreased cutting efficiency, more required inward pressure, and a limited capacity to auger debris out of a canal.[6] As such, there has been a genuine desire to rethink reciprocation and optimize the motors and files that utilize this concept.

Serendipitously, in about 1998, Dr. Ben Johnson and Professor Pierre Machtou co-discovered the unmistakable advantages of reciprocating NiTi files utilizing unequal bidirectional movements. Subsequently, in the late 1990s, Machtou and his endodontic residents extensively analyzed this novel unequal reciprocating movement using the entire series of not-yet-to-market ProTaper files. Starting with the end in mind, Dr. Ghassan Yared, a former student of Professor Machtou, performed exhaustive work to identify the precise unequal

CW/CCW angles that would enable a single reciprocating 25/08 ProTaper file to optimally shape virtually any canal.[7] Although this specific reciprocation technique stimulated considerable interest, this file was never designed to be used in this manner. Yet, Yared's work rekindled interest to take this single-file concept closer to its full potential.

WaveOne

In 2008, a team of 8 international clinicians including Drs. Ben Johnson, Sergio Kuttler, Pierre Machtou, Wilhelm Pertot, Julian Webber, John West, Ghassan Yared, and myself, in collaboration with Dentsply International, began the serious work of developing both a new reciprocating file and motor for shaping canals. In 2011, following 4 years of R&D, both WaveOne *(Dentsply Tulsa Dental Specialties and Dentsply Maillefer)* and Reciproc *(VDW)* were internationally launched as single-file shaping techniques. This paper will focus on WaveOne, as this is the system I helped develop and with which I am most familiar ***(Figure 2)***.

WHAT IT ISN'T

As expected with anything new, immediate opinions are given, frequently without knowledge, understanding, or experience. A few pundits have expressed "genuine concerns" regarding WaveOne when, in fact, their opinions are refuted by scientific evidence and the clinical experiences of a growing number of international dentists. WaveOne is not a panacea; it will not obsolete the file systems currently utilized that offer safety, efficiency, and an economy of instruments. Dentists will ultimately decide if the WaveOne concept fits into the pantheon of superb mechanical systems utilized for successfully preparing root canals.

WHAT IT IS

In most instances, the WaveOne concept provides a single-file shaping technique, regardless of the length, diameter, or curvature of any given canal. In fact, it has been shown that a single-file reciprocating shaping technique utilizing unequal CW/CCW angles is over 4 times safer and almost 3 times faster than using multiple rotary files to achieve the same final shape.[8,9]

Figure 2. *The Small, Primary and Large WaveOne files.*

Pundits should not concern themselves with whether 1 file or multiple files are utilized to prepare canals, whether the movement is continuous rotation vs. reciprocation, or if the files are manufactured from stainless steel or NiTi, as long as the final shape fulfills the mechanical and biological objectives for shaping canals. The WaveOne concept represents a solution for any dentist who has concerns with any of the following:

- Using stainless steel files for shaping canals.
- Breaking mechanically driven files.
- Ledging curved canals.
- Transporting the prepared foramen.
- Using too many shaping files.
- Mastering hybrid techniques.
- Spending too much time preparing canals.

Conveniently, the WaveOne concept is system-based. Each WaveOne file has matching paper points, gutta percha master cones, carrier-based obturators and carrier-free GuttaCore obturators. Importantly, the WaveOne single-file technique is the convergence of a unique file design, advancements in NiTi alloy, and a novel reciprocating movement.

DESIGN

Strategically, only 1 file is generally utilized to fully shape virtually any given canal. However, there are 3 WaveOne files available to effectively address a wide range of endodontic anatomy commonly encountered in everyday practice ***(Figure 2)***. The 3 WaveOne instruments are termed *Small* (yellow 21/06), *Primary* (red 25/08), and *Large* (black 40/08). The Small 21/06 file has a fixed taper of 6% over its active portion. The Primary 25/08 and the large 40/08 WaveOne files have fixed tapers of 8% from D1-D3, whereas from D4-D16, they have a unique progressively decreasing percentage tapered design. This design serves to improve flexibility and conserve remaining dentin in the coronal two-thirds of the finished preparation.

Another unique design feature of the WaveOne files is they have a *reverse* helix and 2 distinct cross-sections along the length of their active portions ***(Figure 3)***. From D1-D8, the WaveOne files have a modified convex triangular cross-section, whereas from D9-D16, these files have a convex triangular cross-section. The design of the 2 WaveOne cross-sections is further enhanced by a changing pitch and helical angle along their active portions. The WaveOne files have noncutting modified guiding tips, which enable these files to safely progress through virtually any secured canal. Together, these design features enhance safety and efficiency when shaping canals that have a confirmed, smooth, and reproducible glide path.

ADVANCED NITI ALLOY

Technological improvements in NiTi metallurgy have generated a new supermetal, commercially termed M-wire. Engineers can identify the desired phase-transition point

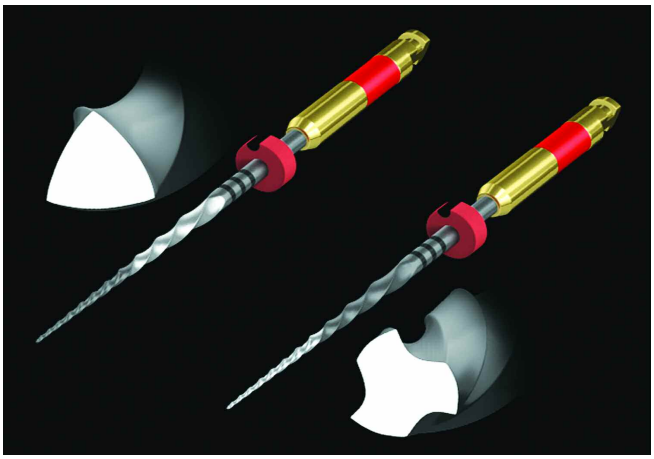

Figure 3. *This image depicts 2 different cross-sections on a single WaveOne file. The more distal cross-section improves safety and inward movement.*

between martensite and austenite and produce a more clinically optimal metal than traditional NiTi itself. Studies have shown that M-wire technology significantly improves the resistance to cyclic fatigue by almost 400% compared to commercially available 25/04 NiTi files.[10] The good news is that reducing cyclic fatigue serves to clinically decrease the potential for broken instruments.

RECIPROCATION MOVEMENT

The e3 motors *(Dentsply Tulsa Dental Specialties)* is specially engineered and programmed to drive the new WaveOne reciprocating files ***(Figure 4a)***. This motor produces a feature-specific, unequal bidirectional file movement. Because of the reverse helix design, the CCW engaging angle is 5 times the CW disengaging angle ***(Figure 4b)***. Additionally, it should be noted, this motor can drive any market version file system in full CW rotation at the desired speed and torque.

There are 3 critical distinctions with this novel, unequal bidirectional movement. One, compared to continuous rotation, there is a significant improvement in safety, as the CCW engaging angle has been designed to be smaller than the elastic metallurgical limit of the file. Two, opposed to all other reciprocating systems that utilize equal bidirectional angles, the WaveOne system utilizes an engaging angle that is 5 times the disengaging angle. Fortuitously, after three engaging/disengaging cutting cycles, the WaveOne file will have rotated 360º, or turned one CCW circle. This unique reciprocating movement enables the file to more readily advance toward the desired working length.[7] Three, compared to an equal bidirectional movement, an unequal bidirectional movement strategically enhances auguring debris out of the canal.[11] Auguring debris in a coronal direction promotes the biological objectives for preparing canals, 3D disinfection, and filling root canal systems.

SINGLE FILE / SINGLE USE CONCEPT

The WaveOne technique is both a single-file and single-use concept. As stated, it is a single-file concept given that one single file is able to transition a secured canal to a well-shaped canal, in most instances. Further, appreciate that a single WaveOne file is frequently used to prepare multiple canals in a single furcated tooth, performing a significant amount of work. The WaveOne concept must be considered a single-use concept due to the obvious stress and wear on the active portion of the file. This is in line with the growing concern in the dental community, especially in institutional settings, that all endodontic files be considered single-use. The rationale behind this legitimate concern is the documentable potential for cross-contamination between and among patients, regardless of the sterilization protocol utilized.[12]

FILE SELECTION

Although there are 3 WaveOne files, the Primary 25/08 file is invariably used first in any canal that has a confirmed,

Figure 4a. *The e3 motor has preset features designed to drive files in a continuous rotation or with the specific WaveOne reciprocating motion.*

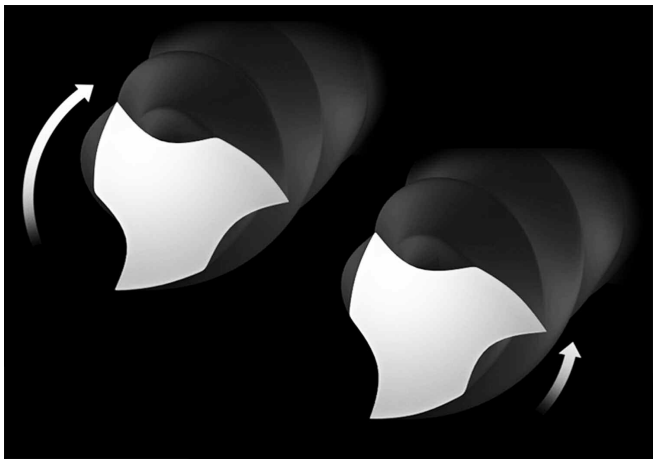

Figure 4b. *In 3 engaging/disengaging cutting cycles, the file will turn 360°, which promotes inward movement and hauling debris out of the canal.*

smooth, and reproducible glide path equivalent to at least a loose 10 file. The WaveOne development team has prepared several thousand canals over the past 4 years. From our collective experiences, our group can report that the primary 25/08 file will produce an optimal final shape in almost 90% of all canals, regardless of their length, diameter, and curvature. However, in longer, narrower, and more curved canals, even when the 10 file is loose at length, the Primary 25/08 WaveOne file will more predictably advance to the terminus of the canal when the glide path is expanded.

The Small 21/06 WaveOne file is used when the Primary 25/08 WaveOne file will not progress apically through a smooth reproducible glide path. The 21/06 is designed to work in smaller diameter, longer length, or more apically curved canals. In certain canals, when this file reaches the working length, the clinician may deem the preparation completed or, alternatively, may desire more deep shape. In these instances, the Small 21/06 is considered a "bridge file" because it promotes safety when transitioning back to the 25/08 WaveOne file. Even in these instances, the WaveOne technique is still a safe and efficient 2-file sequence compared to virtually all other mechanical shaping systems.

The Large 40/08 WaveOne file is used to complete the shape in larger diameter canals that are typically straighter. Examples include certain maxillary incisors, single-canal bicuspids, and larger diameter canals within maxillary and mandibular molar teeth. Recall, the usual WaveOne protocol is to initiate shaping procedures using the primary 25/08 file. However, after carrying the Primary 25/08 file to the working length, gauging procedures may confirm that the foramen is bigger than 0.25 mm. In these instances, the clinician will require the 40/08 WaveOne file to fully shape and finish these larger canal systems. With experience, the clinician will learn to recognize these larger and more straightforward canals and is encouraged to initiate canal preparation procedures utilizing only the 40/08 WaveOne file.

In summary, there are 3 WaveOne files. Following access and GPM procedures, the Primary 25/08 WaveOne file will generally progress to the desired working length in three or more passes. As previously mentioned, infrequently but on occasion, the clinician may require a second WaveOne file to complete a predictably successful final shape.

SHAPING TECHNIQUE

The WaveOne single-file shaping technique is beautifully safe and simplistic when attention in focused on the access preparation and GPM. As is required for any shaping technique, straightline access to each orifice is emphasized. Attention is directed to flaring, flattening, and finishing the internal axial walls.[13] Importantly, the orifice(s) should be preenlarged and all internal triangles of dentin eliminated.

Perhaps the greatest challenge performing endodontic treatment is to find, follow, and predictably secure any given canal to its terminus. Negotiating and securing canals with small-sized hand files requires a skillful touch, patience, and desire.[14] Securing a canal is an art and a critically essential element influencing predictably successful endodontic outcomes. At the end of the day, a small-sized hand file is used to either confirm existing space is available or, alternatively, to create sufficient space so mechanical files can safely follow a secured canal.[13] To clarify, a canal is secured when it has a confirmed, smooth, and reproducible glide path.

With an estimated working length and in the presence of a viscous chelator, insert a 10 file into the orifice and determine if the file will easily move toward the terminus of the canal. In shorter, wider, and straighter canals, a 10 file can usually be readily carried to the desired working length. A loose 10 file confirms sufficient existing space is available to immediately initiate mechanical shaping procedures utilizing the Primary 25/08 WaveOne file.

However, in longer, narrower, and more curved canals, oftentimes the 10 file cannot be initially and safely worked to length. In these instances, there is generally no need to select and use size 06 and/or 08 hand files in an effort to immediately reach the terminus of the canal. Simply work the size 10 hand file, within any region of the canal, until it is completely loose ***(Figure 5)***. The advantages of a sequential glide path have been previously elucidated.[4,1]

When GPM procedures have been completed, the access cavity is voluminously flushed with a 6% solution of NaOCl. Shaping can commence, starting with the Primary 25/08 WaveOne file ***(Figure 6a)***. Gentle apically directed pressure will typically allow this instrument to run 2, 3, or 4 mm inward. After every few millimeters of advancement, or if the Primary 25/08 WaveOne file will not easily progress, remove this file and clean and inspect its flutes. Upon removing any mechanical shaping file from any canal, it is wise to irrigate, recapitulate with a 10 file, then re-irrigate. Strategically, recapitulating with the 10 file moves debris into solution, con-

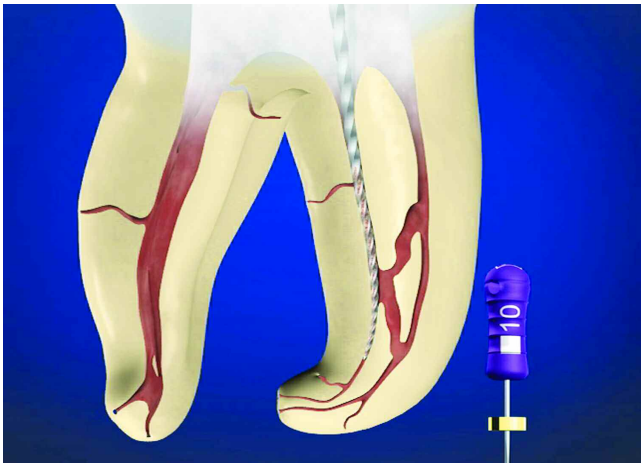

Figure 5. *This graphic image is to emphasize shaping can commence once any region of a canal has been secured with a size 10 hand file.*

firms the glide path, and provides confidence that shaping procedures can continue with the same 25/08 WaveOne file. Typically, the Primary WaveOne file will run inward, progressively advance, and incrementally move through any region of the canal that has a confirmed and reproducible glide path ***(Figure 6b)***.

A brushing motion may be utilized to eliminate interferences, remove internal triangles of dentin, or to enhance shaping results in canals which exhibit an irregular cross-section. In one or more passes, continue with the Primary 25/08 file through the body of the canal. Removing canyons of restrictive dentin from the coronal two-thirds of a canal creates a more direct path to its apical one-third, improving accuracy when determining a precise working length.

Especially in longer, narrower, and more curved canals, the apical one-third of virtually any canal can be more predictably secured when pre-enlargement procedures have been performed first. A pre-enlarged canal improves the ability to more readily direct and slide a precurved small-sized hand file to the full working length. In the endodontic vernacular, "get behind the handle, gently slide the file, and find the foramen". Regardless of the glide path sequence, once the apical one-third has been fully negotiated, establish working length, confirm patency, and verify there is a smooth reproducible glide path. The glide path is secured when a 10 file is loose at length and can "slip and slide" and "slide and glide" over the apical one-third of the canal.[13]

When the canal is secured, the Primary 25/08 WaveOne file can generally be carried to the full working length in one or more passes ***(Figure 7)***. When this Primary file will not readily advance in a secured canal, then the Small 21/06 WaveOne file may be utilized. This file will typically reach the desired working length in one or more passes. The Small 21/06 file may be the only shaping file taken to the full working length, especially in more apically or abruptly curved canals. However, with the anatomy in mind, to encourage 3D disinfection and filling root canal systems, more shape may be indicated. In these instances, the 25/08 file will generally advance through any region of a canal where the shape has been previously expanded utilizing the small 21/06 bridge file.

Once the Primary 25/08 WaveOne file readily moves to the working length, it is removed. The finished shape is confirmed when the apical flutes of this file are loaded with dentin. Alternatively, the size of the foramen can be gauged

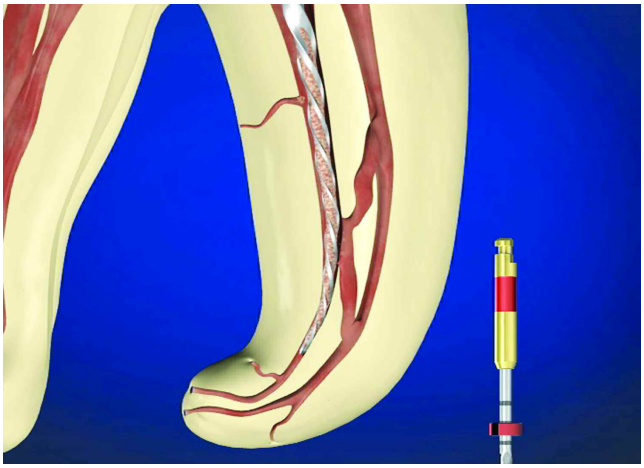

Figure 6a. *This graphic image shows the Primary 25/08 WaveOne file inside the glide path and following the secured portion of the canal.*

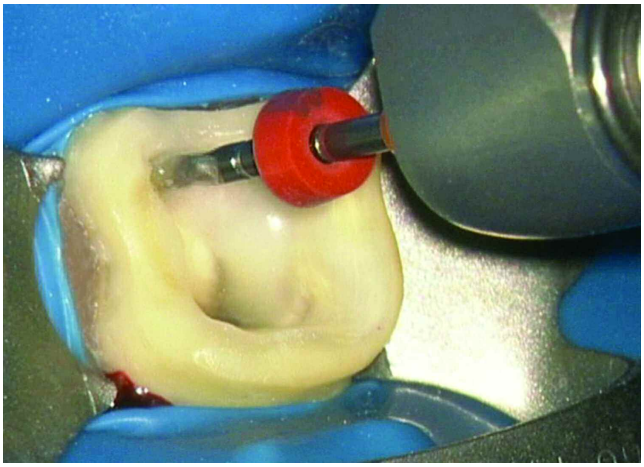

Figure 6b. *This clinical photo shows the Primary 25/08 WaveOne file progressing apically through the glide path.*

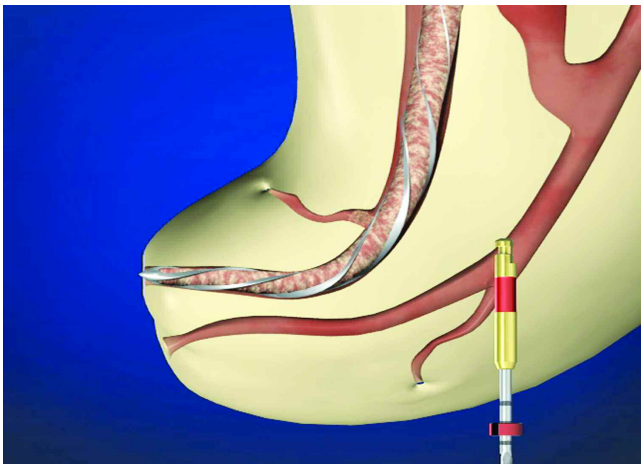

Figure 7a. *This graphic image shows the Primary 25/08 WaveOne file around the apical curve, at length, and loaded with debris.*

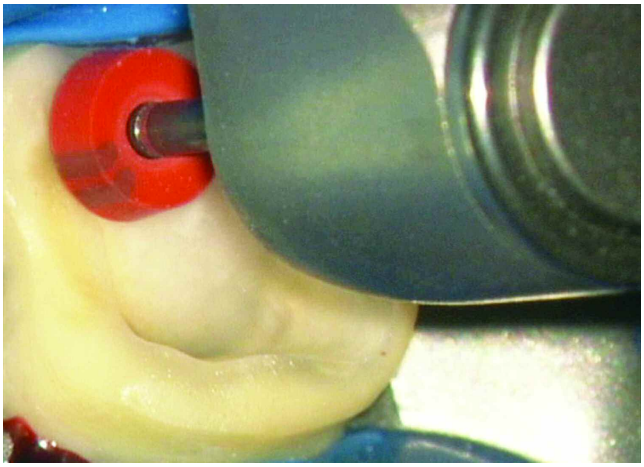

Figure 7b. *This clinical photo demonstrates the Primary 25/08 WaveOne file has reached the desired working length.*

with a size 25/02 hand file ***(Figure 8)***. When the size 25 hand file is snug at length, the shape is done. If the size 25/02 hand file is loose at length, it simply means the foramen is larger than 0.25 mm. In this instance, gauge the foramen with a size 30/02 hand file. If the size 30 hand file is snug at length, the shape is done. If the size 30 hand file is loose at length, proceed to the Large 40/08 WaveOne file to more optimally prepare and finish these larger canals.

Upon reaching the working length, remove the 40/08 WaveOne file and inspect its apical cutting flutes. If the flutes are loaded with dentine mud, there is visual confirmation that this file has cut its shape in the apical one-third. Alternatively, the terminal size of the preparation can be gauged using a size 40/02 hand file. When the size 40/02 hand file is snug at length, the shape is done and the foramen is confirmed to be 0.40 mm. When the 40/02 hand file is loose at length, it simply means the foramen is larger than 0.40 mm. In these instances, other methods may be utilized to finish these larger, typically less curved, and more straightforward canals.

There are differing opinions regarding the optimal size and taper to prepare the apical one-third of any given canal. Importantly, clinicians should not be trying to mechanically prepare "round" foramens; rather, clinicians should be trying to "clean" foramens. Cleaning is readily accomplished in a preparation that has a sufficiently tapered resistance form. Well-shaped canals promote the exchange of irrigants into all aspects of the root canal system.[15] Evidence is available that clearly shows a 40/06 preparation is no cleaner than a 20/10 preparation.[16]

Articles have been accepted for publication that demonstrate the WaveOne shapes preserve and maximize remaining dentin, accurately follow and shape the original pathway of the canal, and maintain the position of the foramen ***(Figure 9)***.[17] The WaveOne shapes of 25/08 and 40/08, in combination with active irrigation, have been shown to produce consistently clean root canal systems that any dentist can effectively fill in three dimensions ***(Figure 10)***.[15]

Conclusion

Although a single-file technique has been conceptualized for decades, it has been, at best, illusive and only sporadically possible in straighter and more wide-open canals. Today, this long-sought-after objective has become a clinical reality. Whether you choose to prepare canals using continuous rotation vs. a reciprocating method, the 3 sacred tenets for shaping canals are safety, efficiency, and simplicity. William James had it right when he said, "A new idea is first condemned as ridiculous and then dismissed as trivial, until finally, it becomes what everybody knows." Dentists will find that when they have a smooth reproducible glide path, the WaveOne technique is safe, efficient, and generally requires only one file to optimally shape most canals. ▲

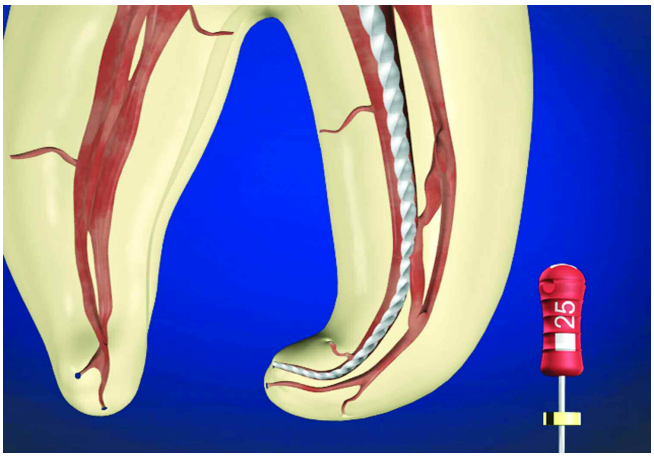

Figure 8. *This graphic image shows the size 25/02 hand file loose along its length and gauging the prepared foramen.*

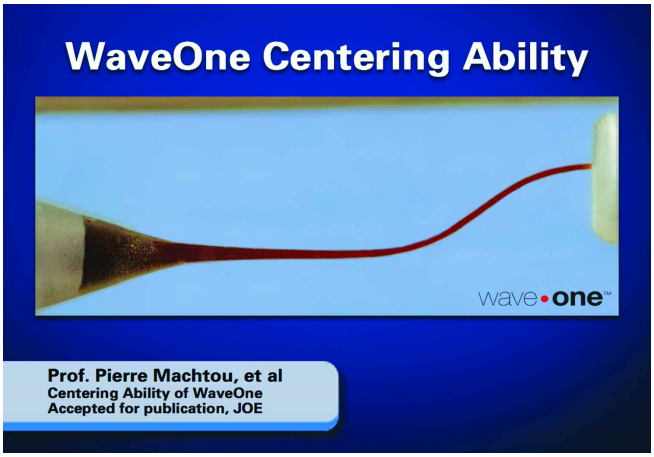

Figure 9a. *This image shows a red dye visually mapping the original, unprepared S-curved canal in the Maillefer Training-Bloc.*

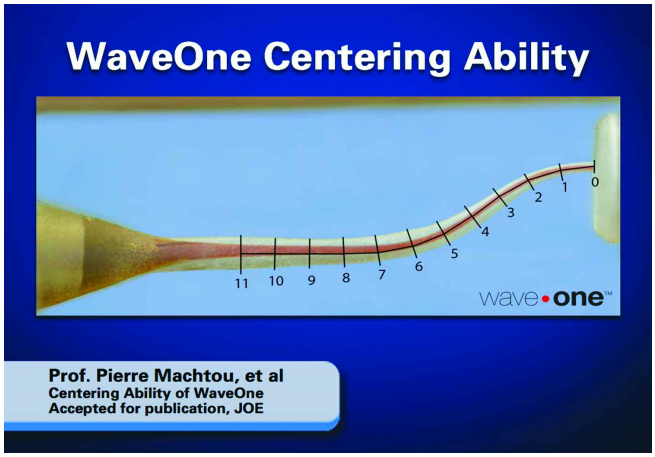

Figure 9b. *This image is a superimposition of the shaped canal over the original canal. Note the 25/08 WaveOne file precisely followed the original pathway. (Figures 9a-9b courtesy of Dr. Pierre Machtou; Paris, France)*

Figure 10a. *A post-op radiograph demonstrates the WaveOne single-file shapes accurately follow the apical anatomy. Shaping canals facilitates 3D treatment.*

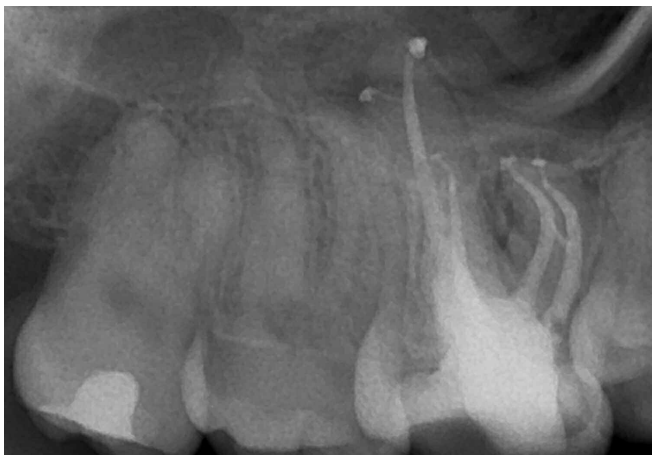

Figure 10b. *A post-op radiograph demonstrates the ability of WaveOne to precisely follow and shape apical curvatures. Shaping canals promotes complete endodontics. (Courtesy of Dr. Yosef Nahmias; Toronto, Canada)*

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