Predictable Endodontic Success: The Apical Control Zone

Kenneth S. Serota, DDS, MMSc, Yosef Nahmias, DDS, MSc, Frederick Barnett, DMD, Matthew Brock, DDS, MSD and E. Steve Senia, DDS, MS, BS

The 'Apical Control Zone' is a matrix-like region created in the apical third of the root canal space. The zone demonstrates an exaggerated taper from the clinician defined apical constriction whether this is spatially a linear or point determination. This enhanced taper in the apical control zone provides resistance form against the condensation pressures of obturation and acts to prevent the extrusion of the filling material during obturation.

The pursuit of excellence in endodontics was compromised until recently by the incompatibility of biologic demand with the technical limitations of the armamentarium available. The introduction of increasingly innovative nickel-titanium rotary instrumentation systems designed with crown down vectoring, has enhanced the architectural rendering of the anatomy, and geometrical vagaries of the root canal space.[1-3] Each portal of exit on the root face has biological significance; this includes bifurcations, trifurcations, the

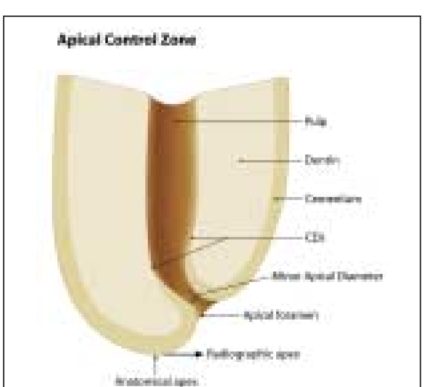


FIGURE 1—The components of the Apical Control Zone are graphically depicted.

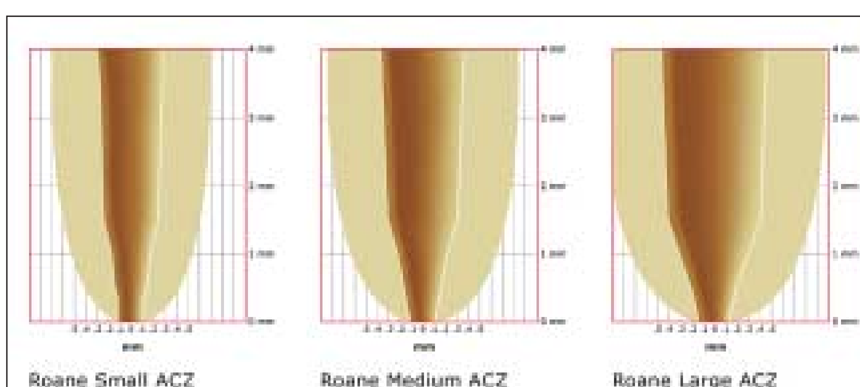


FIGURE 2—Roane defined his small, medium and large apical capture zones as #45, #60 and #80 preparations. The parameters he established were; small ACZ, #15 file to the radiographic terminus (RT), #45 file 1.5 mm back from the terminus, medium ACZ, #20 file to the RT, #60 file 1.5 mm back, large ACZ, #25 file to the RT, #80 file 1.5 mm back.

FIGURE 3—For the purposes of standardization, each ACZ image was drawn to represent the apical one-third of an "average" sized mandibular molar, 22 mm in length. Anatomical crown height being approximately 10 mm, the root length of 12 mm was then divided into thirds.

FIGURES 4A & B—The K3 NiTi rotary file system includes both .04 and .06 taper files.

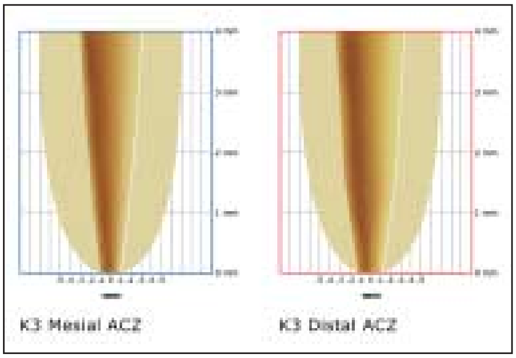


FIGURE 5—The mesial root graphic, outlined in blue, was derived from the following measurements: 0 mm — 0.20 mm, 1 mm — 0.35 mm, 2 mm — 0.41mm, 3 mm — 0.47mm, 4 mm — 0.53mm as determined by Dr. Barnett to be the optimal ACZ shape achievable with the K3 system. The distal root graphic uses 0 mm — 0.25 mm as the starting point.

FIGURE 6A—Tooth #4.6 (30) demonstrates the degree of obturation density and flow characteristics typical of the optimal rheology achievable with a well-shaped ACZ *(courtesy of Dr. Fred Barnett)*.

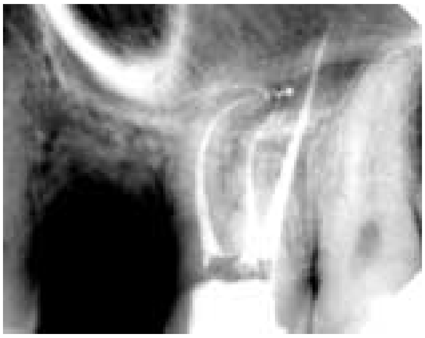


FIGURE 6B—The purposes of maintaining patency and the ability to retain the intricacies of the curvature of the root canal space by using a crown down technique are demonstrated in this radiograph *(courtesy of Dr. Fred Barnett)*.

base of infrabony pockets and apical termini. Increased irrigant volume can now access the full complexity of the root canal system resulting in an optimized cleaning phase, thereby enhancing the degrees of success achievable.

Revision of the shaping and cleaning paradigm has followed a long and tortuous evolutionary process. A chronology of recent technical protocols demonstrates the extended timeline: Serial Instrumentation—Schilder 1974,[9] Step-Back—Mullaney 1979,[10] CrownDown—Marshall 1980,[4] StepDown—Goerig 1982,[5] Balanced Force—Roane, 1985.[11,12] There is an imperative that has driven this evolution; the elastic memory of all metal instruments drives them to a single wall as they navigate curvature. In the pre-NiTi era, the self-centering characteristic of the instrument was not a component of a computer-modeled design. As a result, canal shapes were "larger" to compensate for the presence of the curve.[13]

The root forms in a crown down manner and the root canal system calcifies coronal-apically. Consistent with the morphogenesis of the root canal system, the new millennium endodontic canal preparation has shifted emphasis in achieving apical shape through a "crown down" approach. In order to affect a thorough shaping and cleaning of the entire root canal system and sealing it permanently with a biologically inert obturating material, the operator's focus has shifted toward first preparing the coronal aspects of canals in order to most effectively approach com-

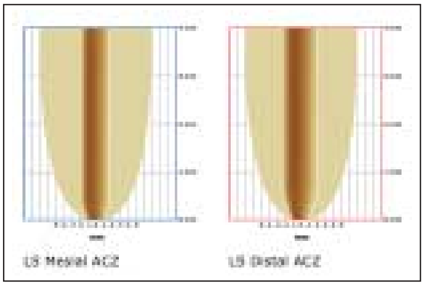


FIGURE 7—To create the ACZ, begin with the suggested First LightSpeed Size to Bind. Using moderate force, advance the FLSB to WL. If it goes to WL it means the canal is larger than this size. Try sequentially larger sizes until one binds. If the suggested FLSB doesn't go to WL (binds) try sequentially smaller instruments until one does go to WL.

FIGURE 8A—Sizes #20 to #60; the cutting edge diameter of the LightSpeed instrument varies sequentially by an increase of .025 mm. From size #60 to #70, the variability is .05 mm, from 70 to 100 the sizes increase by 0.10 mm.

FIGURE 8B—The short cutting blade of the LightSpeed instrument provides more accurate tactile feedback which helps determine when the canal has been properly cleaned.

FIGURE 9A—The LightSpeed system ensures that the integrity of the tooth structure is not compromised regardless of the degree of curvature of the root canal system *(courtesy of Dr. William Wildey)*.

FIGURE 9B—The canals were instrumented with LightSpeed and obturated with SimpliFill and sealer as follows: MB1 and MB2 = size 55; DB = size 55; P = size 55 *(courtesy of Dr. William Wildey)*.

plex apical anatomies. By enlarging the most accessible coronal portion of the canal system first while conserving the original canal pathway, access to the apical portion is facilitated. Less resistance is encountered and endodontic files undergo less stress.[4-8]

It is important to this discussion to note that, the original descriptions of "crown down" merely meant progression from larger diameters or tapers to smaller diameters and tapers. This approach can be significantly different from a systematic approach which minimizes file engagement and stress while focusing on enlarging and cleaning of the canal in portions from the coronal to the apical.

The elimination of constrictions in the coronal region of the canal with the crown down approach reduces the effect of canal curvatures and providing better tactile awareness during apical cleaning and shaping.[4-7] It enables irrigation to be effective to the depth that instruments reach. Furthermore, the majority of pulp tissue and microflora are removed before the apical third is negotiated thereby minimizing the risk of toxic extrusion into the periapical regions.[16,17] In addition, the working length is less likely to change during apical instrumentation because canal curvature has been reduced before working length is established.

It should be evident in the NiTi era, that we are just now beginning to truly respect the pulp canal space as the defining parameter of shaping and cleaning; we are 'listening to its voice' for the first time.[14,15] For much of the hand instrumentation era, the defining shape for obturation procedures was the creation of a "collar-like" apical resistance and retention morphology.[13] In the absence of variable taper instruments, with the preponderance of gates-glidden usage for coronal opening, and in an era still dominated by lateral condensation, over-extension was a potential result.

The creation of endodontic excellence, especially in the era of nickel-titanium techniques, demands strict adherence to preparation length, a thorough understanding of cutting dynamics and awareness of the shape/design being created. The variable tapers in the instrument systems coming to market impart greater resistance to displacement in the apical third (the Apical Control Zone) and facilitate apical patency with minimal risk for the extrusion of thermolabile obturation materials.

THE APICAL CONTROL ZONE

The "Apical Control Zone" is a mechanical alteration of the apical terminus of the root canal space that affects the rheology of thermolabile gutta-percha, offering resistance and matrix style retention form against the condensation pressures of obturation.[18-21] This terminus region can be anatomically challenged, altered by pathologic resorption, or iatrogenic misadventure. It is essential that small file sizes be used to "survey" the glide path to the apical foramen (Fig. 1).

Vagaries that include merging canals, curvature, dilacerations, division et al must be "blueprinted" prior to the introduction of NiTi rotary systems. Properly done, an Apical Control Zone predictably ensures a round, symmetrical and well-cleaned apical foramen for obturation.

As originally described by Roane,[18] there should be predesigned preparations for each of three canal types. The control zone taper rate should vary from 1.0 to 2.0 mm per mm of canal length. Roane determined that this taper would provide a resistance of at least 4 times that of the canal shape itself thus enabling the use of apical patency with minimal risk for the extrusion of the obturating materials. In his technique, 0.5 mm step-backs created an operator fabricated terminating taper prior to the continuum with the periodontal ligament, thereby eliminating the procedural nuances of the search for the CDJ (Fig. 2).

THE NITI FILE SYSTEMS

The goal of this article was to structure a standardized comparison between the Apical Control Zones created by the more popular rotary NiTi instrumentation systems in the endodontic armamentarium; K3™, Lightspeed®, RaCe™, ProTaper® and ProSystem GT®.

The operator created apical constriction (AC) was considered

FIGURE 10—The RaCe NiTi rotary file system.

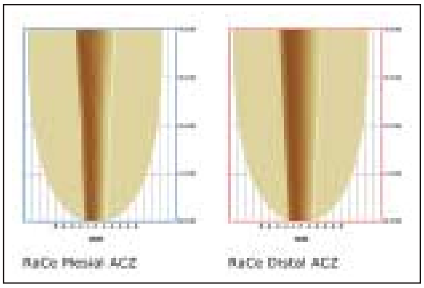
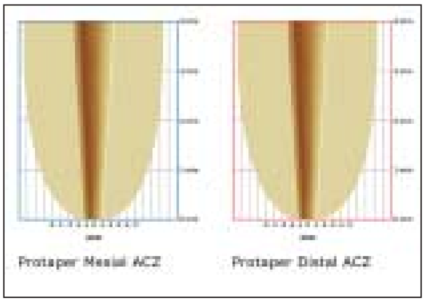


FIGURE 11—The mesial root graphic, outlined in blue, was derived from the following measurements: 0 mm - 0.20 mm, 1 mm — 0.26 mm, 2 mm — 0.32mm, 3 mm — 0.38mm, 4 mm — 0.44 mm. The distal root graphic was derived from 0 mm — 0.25 mm, 1 mm — 0.31 mm, 2 mm — 0.37mm, 3 mm — 0.43mm, 4 mm — 0.49 mm.

FIGURE 12A—The elegance of the flow characteristics of the RaCe system is demonstrated in tooth #3.6 (18).

FIGURE 12B—The RaCe System is adaptable for shaping all canal morphologies from small tortuous canals to larger apical diameters.



IGURE 13—The mesial root graphic, outlined in blue, was derived from the following measurements: O mm — 0.20, 1 mm — 0.27, 2 mm — 0.34, 3 mm — 0.41, 4 mm — 0.46. In the distal root, the F2 (.25/0.08) carried to WL was used as the standard.

FIGURE 14—The current iteration of the NiTi ProTaper rotary instrument series is comprised of just three shaping and three finishing instruments. ProTaper hand files are in development as are accessory rotary files for larger canals.

to be point zero and the instrument fitted to the MAD (minimum apical diameter) of the mesial root of the mandibular molar chosen as the template was a #20 file, the instrument in the distal root, a #25 file. The Apical Control Zone was created by those instruments that negotiated the canal space in 0.5 mm increments back to the arbitrary interface of apical and middle thirds of a typical molar root (Fig. 3). It is understood that a sophisticated irrigation protocol is mandatory for all systems under discussion.[22] All files whether hand files or NiTi files must be used in the presence of a lubricant.

FIGURE 15A—This endodontically treated maxillary molar demonstrates that the Protaper system can safely shape the complexities of the apical one third of the most traditionally difficult canals (courtesy of Dr. Yosef Nahmias).

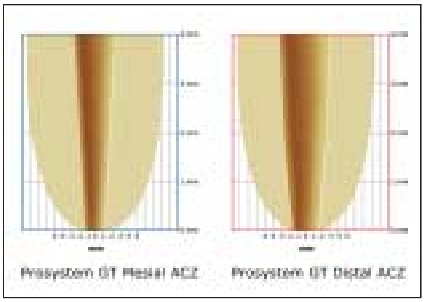


FIGURE 15B—The creation of the ACZ ensures a resistance form that enables optimized density to the obturation of the apical one-third of the root canal space (courtesy of Dr. Yosef Nahmias).

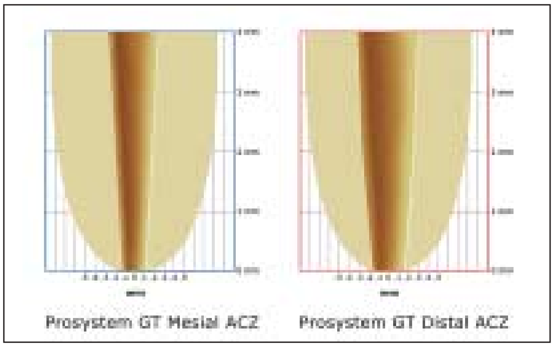


FIGURE 16—The graph on the right illustrates the ACZ created by using a GT file 20/.08 taper. This file is used to provide with the ideal shape in smaller canals. On the left, this graph shows the use of a GT file 30/.08 that can be used to create an ideal ACZ in larger canals, such as a distal canal of a lower molar. Note that the GT system produces predetermined shapes in contrast to operator-machined shapes using the step back approach. As in the Protaper system, the files create the shapes, not the operator.

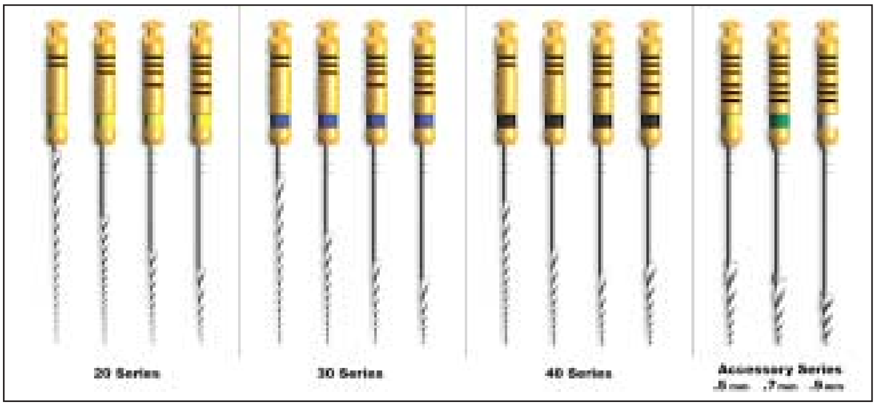


FIGURE 17—The ProSystem GT NiTi file system features an extensive array of rotary as well as hand files.

THE K3 ACZ TECHNIQUE (SYBRON DENTAL SPECIALTIES, ORANGE CA)

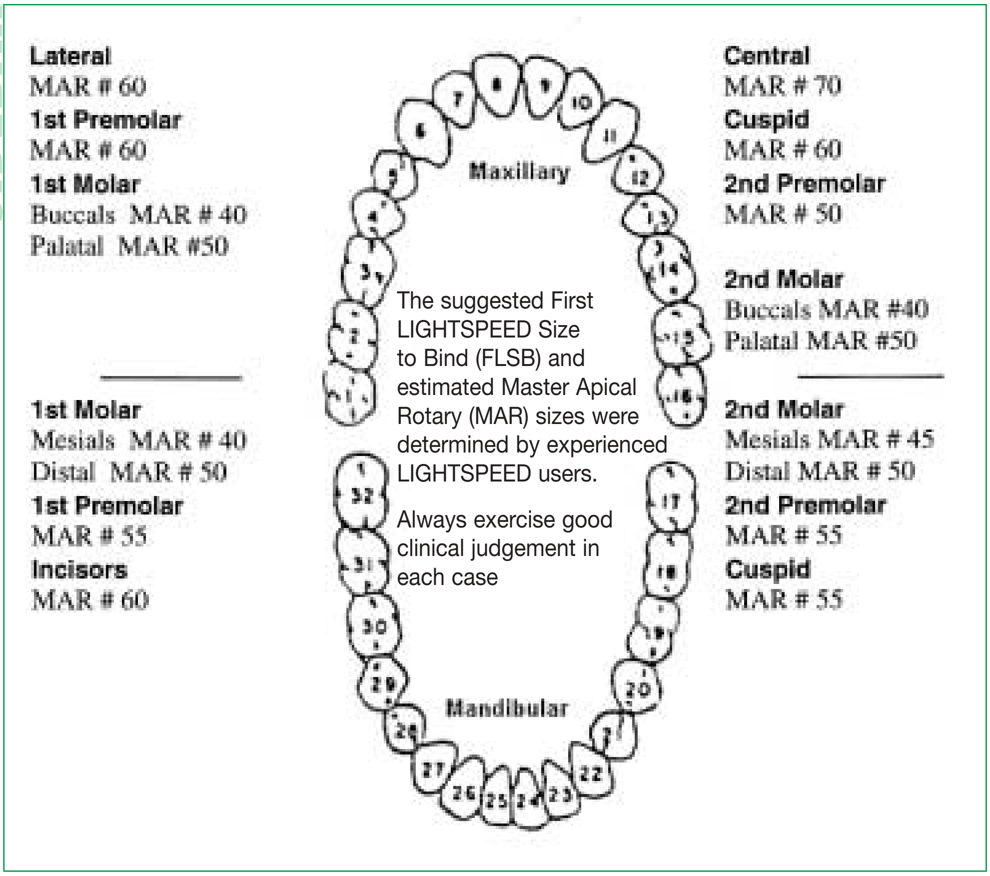
All NiTi procedures begin with a Class I style access preparation to facilitate straight-line access to the root canal space. The instrumentation procedure is routinely initiated by coronal scouting with SS hand files to determine the axial angulation of the canal glide path.

After the glide path determination, a typical K3 case starts with the #25/.10 and #25/.08 orifice openers or the #25/.06 file for smaller canals. These files are used to debride the bulk of coronal pulp tissue or necrotic debris and also to remove the cervical restrictive dentin from deflecting access into the root canal space. A working length is then established with an electronic apex locator (EAL). A variable taper/tip size sequence is then employed in a crown-down sequence to the working length.

Once the K3 files (Figs. 4a, & 4b) have reached the electrometrically determined working length, the clinician needs to determine the appropriate degree of apical enlargement for each canal. Final apical gauging can now be accomplished with a series of stainless steel hand files. If, for example, the final apical gauging procedure allows for a size #35 hand file to be placed to the WL, it may be prudent to take the #35/.06 K3 rotary file to length. This will create a continuous taper from orifice to constriction. If the root is thin and/or if the canal is moderately to severely curved, a K3 #35/.04 rotary file taken to length may be more appropriate.

The Apical Control Zone is created by stepping-back in 0.5mm increments with either the .04 or .06 tapered K3 files (Figs. 5, 6a, 6b). This technique can be viewed on the Internet at www.k3endo.com.

SIDEBAR



The RaCe ACZ Techique (Brasseler USA, Savannah, GA)

THE LIGHTSPEED ACZ TECHNIQUE (LIGHTSPEED TECHNOLOGY INC. SAN ANTONIO, TX)

Straight-line endodontic access preparation is initiated and the coronal third of the root canal space prepared with an instrumentation protocol of the operator's choosing. The apical foramen is located with an EAL and working length established; (WL) 0.25 mm to 1.00 mm short of the foramen (practitioner's choice). Note that for the ACZ graph in Figure 7, a WL was chosen that is 0.25 mm from point zero for the size 40 LS and a WL that is 0.50 mm from point zero for the size 50 LS.

Canal patency is assured to the WL with at least a size 15 K-file. Rotary instrumentation is initiated with the smallest LS size that binds on the canal walls before it gets to WL when advanced apically by hand. Mechanical preparation to WL begins with the smallest LS file that binds and continues with sequentially larger sizes (Figs. 8a, 8b). The final apical preparation size is determined using the "12 pecks" rule. This rule ensures the canal is instrumented to a large enough size to ensure optimal canal debridement.[23] This technique can be viewed on the Internet at www.LightSpeedUSA.com

The ACZ for LightSpeed (Fig. 7) is based on an apical stop preparation (dentinal matrix) preparation. In Figure 7, the operator created (AC) or point zero was chosen to be a #20 file for the mesial canals and a size 25 for the distal to standardize the procedural formats. The preferred apical preparation size for the mesial canals is a size 40, therefore, on the graph, point zero would be a size 20 and 0.25 mm from point zero the preparation would be a size 40. It remains parallel (size 40) to the end of the graph (4 mm).

The suggested apical preparation size for the distal canal is usually a size 50. Therefore, on the graph, point zero would be a size 25 and 0.50 mm from point zero the preparation would be a size 50. It would remain parallel (size 50) to the end of the end of the graph (4 mm). In an actual case, enlargement is based on the original anatomy (diameter) of the canal in the ACZ. With experience, tactile feedback from LightSpeed's unique design will give the practitioner a very accurate means of determining when the canal has been instrumented to the proper diameter. Estimates of canal preparation diameters in the ACZ are provided based on clinical and research statistics (Figs. 9a, 9b). (See sidebar.)

THE RACE ACZ TECHNIQUE (BRASSELER USA, SAVANNAH, GA)

Straight-line access preparation is established and debridement of the coronal aspect of the root canal space initiated with a #25/.06 instrument. This file is effective in opening the orifice, eliminating the cervical dentinal ledge and removing the bulk of coronal pulp tissue (Fig. 10). The #25/.06 file can generally be taken half to two-thirds of the way down the canal. The clinician is thus able to feel the presence of coronal or midroot curvatures. Furthermore, it removes sufficient tissue to prevent the creation of a tissue plug that characteristically occurs with SS hand

FIGURE 18A—The obturation of this maxillary molar demonstrates the uniformity of the smooth tapered multiplanar shapes possible with the ProSystem GT *(courtesy of Dr. Ken Serota)*.

FIGURE 18B—The goal of the ACZ is additionally to ensure optimal cleansing of the root canal space by creation of a shape that enhances the exchange of irrigants thereby ensuring delivery of an adequate volume of irrigant to the full extent of the confines of the system *(courtesy of Dr. Ken Serota)*.

files when coronal pulp is pushed apically and compacted. Working length is established with an EAL using a NiTi rotary file or stainless steel hand file.

When minimal coronal curvature is detected with the scouting #25/.06, the #40/.10 is used to remove additional coronal dentin. A #25/.02 is taken to length or until more apical pressure is required to make apical progress than was required for the first mm of engagement. With the #25/.02 instrument to length, a #25/.08 is advanced as far as possible. The #25/.04 is generally taken to length followed by the #25/.06 to length. If the #25/.06 will not go to length, the #25/.08 or #40/.10 is used to remove more coronal dentin. With a #25/.06 to length, the majority of cases have an apical capture zone ideally suited to thermo-softened obturation (Fig. 11). In distal or palatal roots, it may be possible to take the #25/.08 to length. A #35/.02 can be taken to length should apical gauging indicate a larger apical diameter is required (Figs. 12a & b).

THE PROTAPER ACZ TECHNIQUE (TULSA DENTAL PRODUCTS, TULSA, OK)

Root canal preparation procedures are optimized when there is straight-line access to the orifice(s). The ProTaper shaping technique begins by first negotiating the coronal two-thirds of a canal with #10 and #15 hand files which are utilized within any portion of a canal until they are loose and a smooth, reproducible glide path is confirmed.[24] The depth of insertion of the #15F is measured and this length transferred to Shaping File No. 1 (purple ring) and Shaping File No. 2 (white ring), which are termed S1 and S2, respectively. The secured portion of the canal can be optimally pre-enlarged by first utilizing S1 then S2 (Fig. 13).

The auxiliary Shaping file, or SX, may be used to relocate the coronal aspect of canals away from external concavities, and to produce more shape, as desired, within any canal. Without pressure, and in one or more passes, each ProTaper Shaping file is allowed to passively cut into the canal until its apical travel slows, then may be used like a brush to laterally cut dentin on the outstroke until this region of the canal is optimally prepared.

When the coronal two-thirds of the canal is fully prepared, then the apical extent of the canal is fully negotiated, working length confirmed, patency established and the foramen enlarged to at least a size 15 hand file.[25] If a smooth, reproducible glide path to the terminus is verified, then the ProTaper sequence is to carry the S1 then the S2 to the full working length. Following the use of the Shaping files, working length should be reconfirmed as a more direct path to the terminus has been established. Three ProTaper Finishing files termed F1, F2 and F3 have yellow, red and blue identification rings corresponding to D0 diameters/tapers of 0.20/.07, 0.25/.08 and 0.30/.09, respectively.

Depending on the length, diameter and curvature of the canal, the F1 will generally achieve length in one pass. The finishing criterion is to remove the F1, inspect its apical flutes and, if they are loaded with dentin, the shape is cut. To confirm the size of the foramen, gauge with a #20 hand file. If the #20 hand file is snug at length then the ACZ is fully shaped and, if irrigation protocols have been followed, ready to pack (Fig. 14). If the #20 hand file is loose at length, proceed to the F2 and, when necessary, the F3, gauging after each Finisher with the 25 and 30 hand files, respectively. The ProTaper sequence is always the same regardless of the tooth or anatomical configuration of the canal being treated. In many cases it's as easy as one, two, three or, in endodontic language, purple, white, yellow (Figs. 15a & b). Further information on ProTapers can be viewed at www.endoruddle.com.

THE PROSYSTEM GT ACZ TECHNIQUE (DENTAL EDUCATION LABORATORIES, SANTA BARBARA, CA)

As with other systems, rotary shaping files must have straight-line access into the root canal space and should not be used until patency has been established with a #10 k-file at least 1mm past the terminus of the canal. Straight-line access is easily accomplished using the LA Axxess Bur (Sybron Dental Specialties, Orange CA)

Crown-down shaping always starts with the 20-.10 GT File, regardless of root size and continues in a crown-down fashion until the first GT File gets to length (20-.10, 20-.08, 20-.06 or 20-.04).

As a general rule small roots (mandibular incisors, 2 & 3 canal premolars, mesial roots of lower molars and buccal roots of upper molars) are shaped to a .06 or .08 taper; or in canals with abrupt apical bends or multi-planer curves a .04 taper. Medium roots are: distal roots of lower molars and palatal roots of upper molars, and usually have a .10 taper. Large roots are: lower cuspids, upper anteriors and one-canal pre-molars.[25,26]

These roots usually require a .10 taper, but can also require .12 tapered accessory instruments (Fig. 16). Increase the taper in the canal to the shaping objective file. This technique can be viewed on the Internet at www.endobuchanan.com

K-files are used to gauge the terminal diameter. The function of apical gauging is to measure the apical diameter of the canal after the shaping objective file has been cut to length.

This is necessary to confirm that apical continuity of taper exists and that the tapered preparation extends all the way to the terminus of the canal. The shaping objective file taken to length has a .20 mm tip diameter; gauging is done with a #15 file passed through the canal terminus.

A #20 k-file is taken to the terminus without pushing or cutting dentin. If it lightly binds at length and the #25 and #30 file bind shorter in the canal, there is apical continuity and the shape of the canal has been determined. If the #20 k-file can still pass through the end of the root canal without meeting resistance, the k-file that binds at length is determined and the shape is adjusted by taking the same size tapered instrument into the canal with a larger tip size—either a .30mm or a .40mm GT File.

The function of apical gauging is to measure the apical diameter of the canal after the shaping objective file has been cut to length.

GT files provide a level of forgiveness in regard to length determination errors. As in the case of the ProTaper system, the ProSystem GT files are designed to create a predetermined ACZ (Figs. 17, 18a & b).

CONCLUSION

The authors of this article are all members of the endodontic cybercommunity ROOTS (roots@ls.rxdentistry.com). Its daily goal is to raise the bar on endodontic education and the means by which that education can be delivered with unprecedented speed, accuracy of content and the facility for dialogue. The membership was polled for the creation of this article and several trends were evidenced from the responses;

– Tapered apical preparations were the norm; the range in taper varied from 0.06 to 0.20 mm or greater.

– Thermolabile obturation predominated.

– Patency was a primary objective in the majority of the treatment protocols.

– Electrometric devices were used in virtually 100% of treatment. Many of the respondees DO NOT use WL x-rays and some use paper points for length confirmation.

– The creation of an apical control zone was technique dependent—it was not a priority for all practitioners, however, they were used by most in wide canals/open apices.

With vision, patience, an open mind and the ability to assimilate, by combining evidence based science, clinical empiricism, technical acumen, with the transactional capacity for three dimensional perception, the successful outcome of any endodontic procedure has never been more attainable. And this is just the beginning of the era of the "NiTi Jamboree"............. **OH**

The authors would like to thank Drs. L. Stephen Buchanan, John McSpadden and Clifford J. Ruddle for their assistance in the preparation of this manuscript.

The ACZ images can be viewed in Shockwave animation at www.sybronendo.com, the ROOTS SUMMIT III image map - the tab marked ACZ.

Frederic Barnett, DMD is an Associate Professor of Endodontics at Albert Einstein Medical Center in Philadelphia and maintains a private practice in Endodontics in West Chester, PA. He has published and lectured internationally on Endodontic Infections, Dental Traumatology and Contemporary Endodontic Treatment.

Yosef Nahmias, DDS, MSc., is a

clinical instructor in the postdoctoral Endodontic program at the University of Toronto Faculty of Dentistry and maintains a private practice limited to endodontics in Oakville, ON.

Kenneth Serota, DDS, MMSc., is a graduate of the Harvard Forsyth School of Dental Medicine and recipient of the American Association of Endodontists Memorial Research Award. He maintains a practice, Endodontic Solutions, in Mississauga, ON.

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