Real World Endo: Design Features of Rotary Files and How They Affect Clinical Performance

by Ken Koch, DMD and Dennis Brave, DDS

The last 10 years have been witness to phenomenal growth in endodontic technology. The introduction of these new technologies has resulted in Endodontics becoming easier, faster, and, most importantly, better. Principle among these is nickel titanium rotary instrumentation that results in consistent, predictable, and reproducible shaping. This predictability of shaping has not only influenced instrumentation but obturation results as well.

Nickel titanium rotary instrumentation was introduced in the early 1990s and quickly acquired many advocates among endodontists. For those doing hand instrumentation, the shift to a rotary technique was significant for a number of reasons. Initially, we realized that a rotary technique was less fatiguing to the practitioner and, more importantly, produced a predictability of shaping not seen with hand instrumentation. Another benefit of this new technology has been a dramatic decrease in post-operative sensitivity for those patients having a root canal done with rotary instrumentation. This result is a combination of file design and utilizing a crown down procedure. As more dentists began utilizing rotary instrumentation, its benefits became firmly established. Truly, nickel titanium rotary instrumentation has been one of the most significant changes in dentistry in the past 25 years.

However, as our experience with rotary instrumentation grew, we realized that rotary instrumentation is not a panacea for every case. By developing hybrid techniques that combine different rotary systems, or combine rotaries with hand instrumentation, we successfully addressed most endodontic challenges. We have also come to realize that the file that works well for the endodontist, may not be the ideal file for the general practitioner who performs two to three root canals a week. This difference is a result of file design and how it affects the clinical performance of the file. Unfortunately, many dentists are not aware of how design features affect performance. Adding to this confusion is the fact that file design continues to be very fluid. The result is a series of new third generation rotary files in the marketplace, whose design features and performance are not well understood. The third generation rotary files are the ProTapers by Dentsply Tulsa Dental, the RaCe file by Brasseler, and the K^3 by SybronEndo (formerly Analytic Endodontics). These files are quite different in design and, in combination with existing files, offer a good comparison in concepts.

All endodontic companies are trying to produce files that will work more efficiently and safely. We sincerely believe the rotary files manufactured today, by all companies, are vastly superior to those produced five years ago. Some of the areas though, where file design continues to differ is in tip and taper design, presence of radial lands, rake angles, helical angles, and pitch. It is the intent of this article to compare the various files, based upon clinical performance, as dictated by their design features.

We strongly believe that most dentists are best served by using a rotary file with a non-cutting tip. Cutting tips on rotary files make them too aggressive. Yes, a cutting tip has the ability to enter narrow, somewhat calcified canals, but we have two serious concerns with a cutting tip. The first is if you accidentally go long

FIGURE 1 Profile vs. K file.

FIGURE 2 Quantec tapers.

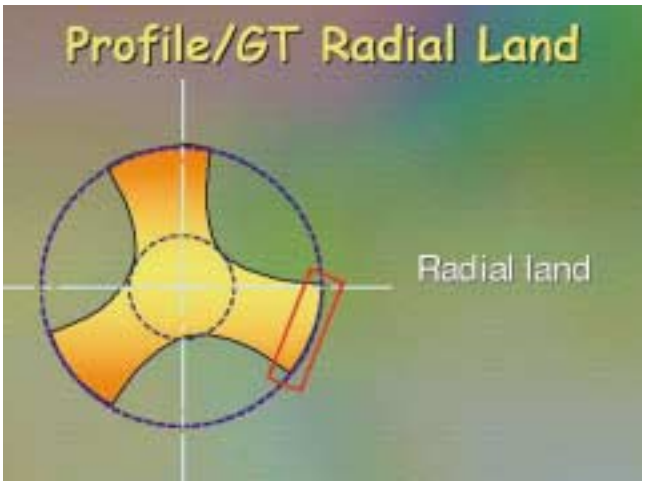

FIGURE 3 Profile / GT Land.

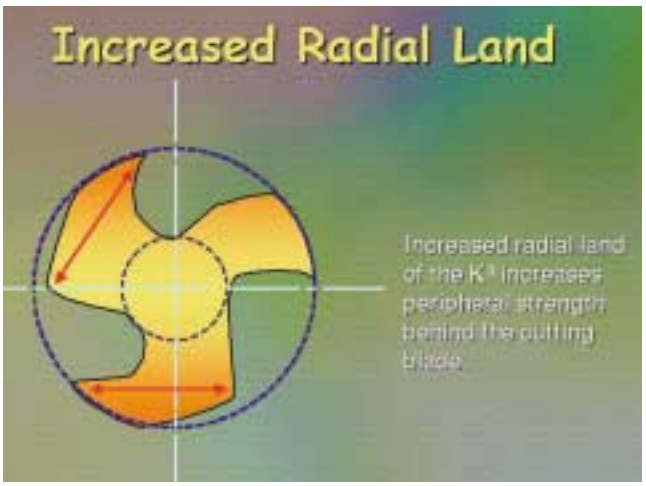

FIGURE 4 K3 land width.

(past the end of the tooth). Going long with a non-cutting tip will create a concentric circle at the end of the root. These are easily filled with a non-standardized cone. However, if you go long with a cutting tip, upon retraction of the file, you generally will create an elliptical tear. This is very difficult to repair and obturate.

Furthermore, if you place a cutting tip on a non-landed file, you have the distinct possibility of transportation. This is especially true if you hold the file at length for any period of time. Theoretically, a cutting tip will not transport if it goes to length and is immediately retracted. But, how many dentists hold a rotary file at length for less than a second? Established files such as the Profile and the GT, along with the new K[3], employ a non-cutting tip. (Fig. 1) Two of the new third-generation rotaries (ProTaper and the RaCe) have cutting tips. A point worth mentioning is that even the manufacturer's DFU (directions for use) for the ProTaper recommends that you do not stay at working length for more than one second. "Take any ProTaper instrument to length only one time and for no more than one second, otherwise you risk transportation." This gives you a slim margin for error.

But, is there an indication for cutting tips in endodontics? Absolutely. However, their use is limited and they should only be used in the hands of an experienced clinician. Also, do not fall prey to endodontic marketing. Some files claim to have "modified cutting tips" or "partially active" tips. Fine, but this is like being "a little bit pregnant." Either it is a cutting tip or it is not.

Taper is another feature of file design and it is particularly important concerning "system concepts." We basically have two options when instrumenting a root canal. First, we can instrument a root canal by using files of the same taper but with varying apical tip diameters. An example of this would be hand files that all have a consistent taper (.02) but with various tip diameters. A rotary file of constant taper would be the .04 taper Profile that has a constant taper (.04) but has varying apical tip diameters. Secondly, there is

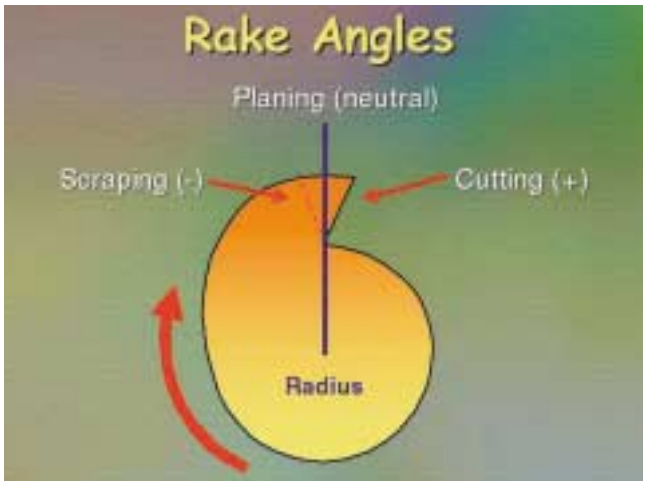

FIGURE 5 Rake angles.

FIGURE 6 Overly positive rake angles.

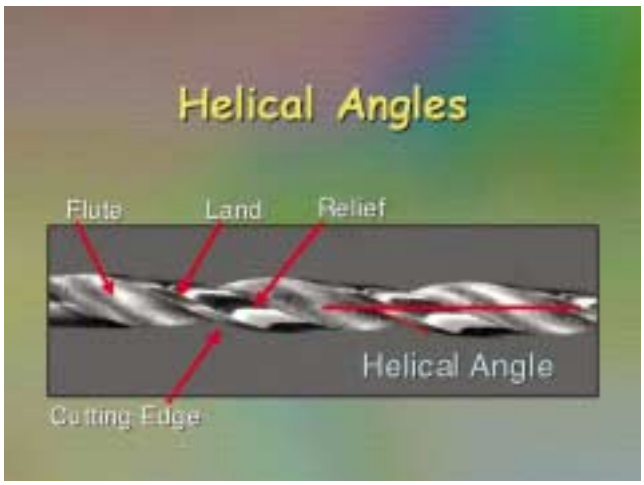

FIGURE 7 Helical angles.

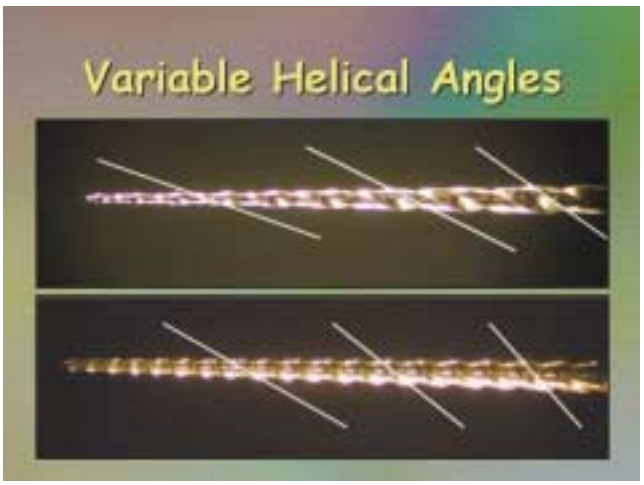

FIGURE 8 Variable helical angles.

the school of thought that prefers varying or graduating tapers. These files have the same apical tip size but their taper varies from .04 to .12. The popular GT series of files employs a varying taper while the Quantec files use a graduated increase in taper. (Fig. 2) The idea behind variable or graduating tapers is that each successive file is only engaging a minimal aspect of the canal wall. Therefore, frictional resistance is reduced and requires less torque to properly run the file. We also have a file (the ProTaper) that features a progressive taper along its shank. One of the benefits of such a design, according to the manufacturer, is reduced torsional loading.

Another critical design feature is the concept of radial lands. A radial land is a surface that projects axially from the central axis, between flutes, as far as the cutting edge. It is the combination of a non-cutting tip and radial land that keeps a file centered in the canal. This has been the great success of the Profile. Another way of evaluating radial lands is blade support. Most rotary files derive their strength from the mass of material in the core. Peripheral strength can also be added to a file by extending the width of the radial land. This feature has been incorporated into the K^3, a new third generation file.

Previously, rotary files either had full radial lands (Profile, GT) or their lands were recessed (Quantec) (Fig. 3). However, there still exists some controversy over what is the best type of land. Advocates of a full land feel such a design effectively keeps the file centered, while proponents of a recessed land feel such engineering allows for less frictional resistance. The K^3 land design is unique and addresses the challenge of combining core and peripheral strengths. The K^3, like the Profile, is a three fluted file with three lands. However, two of the lands are broad and recessed, while the third one is a narrow full land. The brilliance of this design is that the relieved portion of the recessed lands minimizes resistance while the extended width maximizes strength (Fig. 4). Additionally, the combination of the three lands keeps the file centered in the canal. The chance of transporting

FIGURE 9 Brasseler instrument.

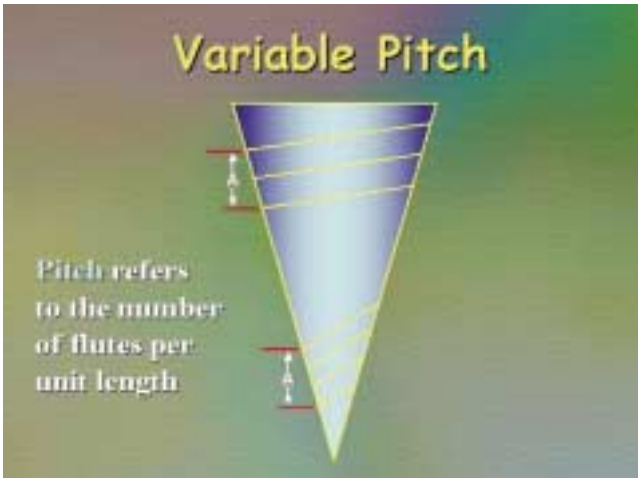

FIGURE 10 Variable pitch.

FIGURE 11 ProTapers.

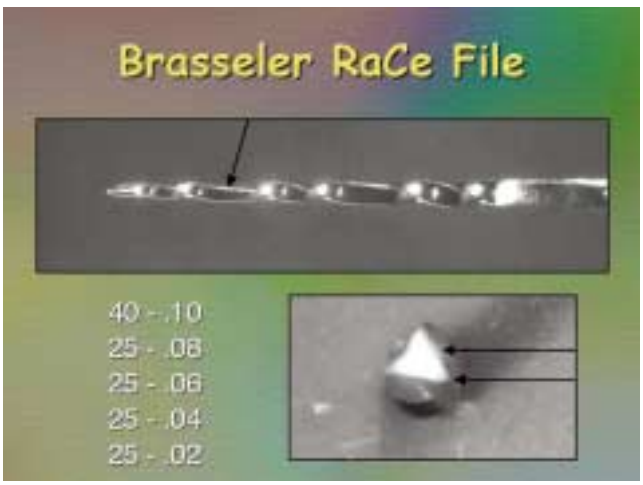

FIGURE 12 Brasseler RaCe files.

a root canal with a rotary file that has a non-cutting tip and radial lands is minimal. There is an important concept of rotary instrumentation that should be remembered. The concept is not of "drilling" a hole in a root. Rather, it is one of taking a small hole, planing the inside, and making it larger. We find the concept of radial lands reassuring in rotary endodontics. However, two of the third generation files (ProTaper and RaCe) do not have the benefit of radial lands.

Rake angles are also important and effect the cutting efficiency of the instrument. There remains confusion over what constitutes a rake angle and what is the cutting angle. The rake angle is the angle formed by the cutting edge and a cross section taken perpendicular to the long axis of the instrument. The cutting angle, on the other hand, is the angle formed by the cutting edge and a radius when the file is sectioned perpendicular to the cutting edge. Positive rake angles will cut more efficiently than neutral rake angles, which scrap the inside of the canal. Most conventional endodontic files utilize a negative or "substantially neutral" rake angle (Fig. 5). A negative rake angle is least aggressive but the cutting efficiency of a file can also be effected by the blank design. For example, the ProTaper has a negative rake angle but due to its modified K blade and progressive taper, the instrument cuts very effectively. However, many practitioners believe the ideal rake angle is, in fact, slightly positive but not overly positive. An overly positive rake angle will result in digging and gouging of the dentin (Fig. 6). This can lead to separation.

The K^3 is the only third generation file to feature a slightly positive rake angle. This results in optimum cutting efficiency. Part of the success of this new file can be attributed to the new manufacturing capability that allows the manufacturer to produce files with a consistent, slightly positive rake angle. This precision and consistency was difficult to achieve with the previous technology.

Variable helical flute angles are another feature that have improved the performance of rotary files. By definition, the helical

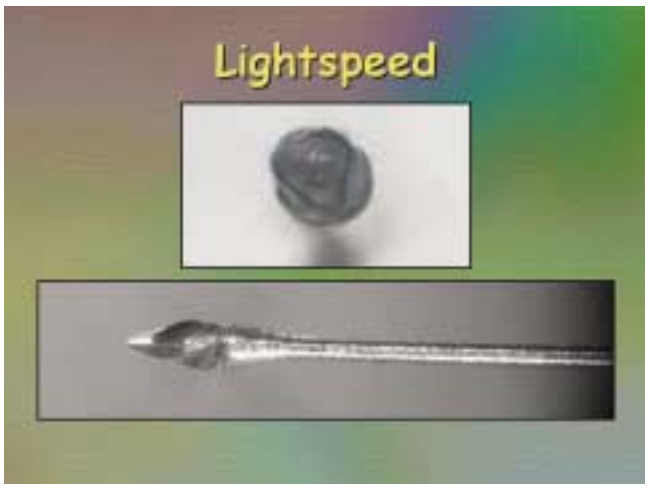

FIGURE 13 Light Speed.

FIGURE 14 SybronEndo K3.

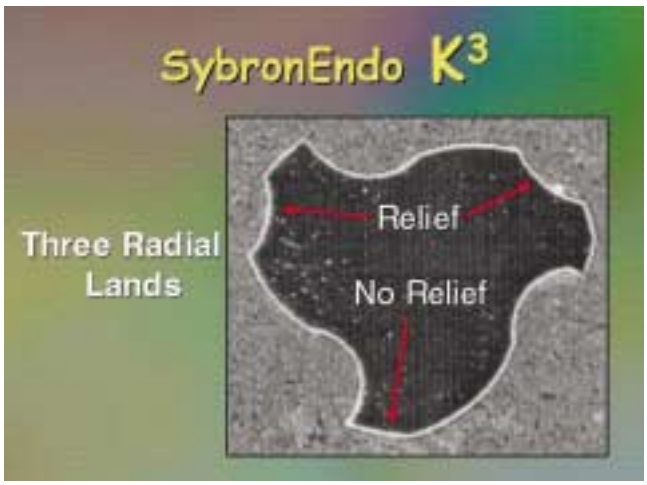

FIGURE 15 SybronEndo K3 (semi).

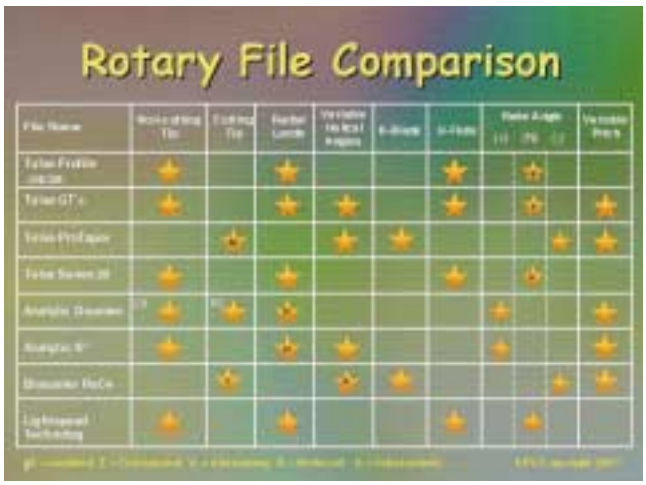

FIGURE 16 Rotary file comparison chart.

angle is the angle that the cutting edge makes with the long axis of the file (Fig. 7). The first rotary file to take advantage of this factor was the GT. As a rotary file works in a canal, the dentinal debris needs to be removed quickly and effectively. Files with a constant helical flute angle allow debris to accumulate, particularly in the coronal part of the file. Additionally, files that maintain the same helical angle along the entire working length, will be more susceptible to the effect of "screwing in" forces. By varying the flute angles, debris will be removed in a more efficient manner and the file will be less likely to screw into the canal (Fig. 8). For example, in the K^3, the helical angle increases from the tip to the handle. The result of this design is more successful channeling that allows for superior debris removal. The RaCe file, is unique and utilizes an "alternating helical design" that reduces rotational torque by using spiraled and non spiraled portions along the working length (Fig. 9). This design feature also reduces the tendency of the file to get "sucked into" the canal.

The last feature we wish to evaluate is pitch. Pitch is possibly the least understood of all design features. Pitch is the number of spirals or threads per unit length. Screws historically have had a constant pitch. The result of a constant pitch and constant helical angles, is a "pulling down" or "sucking down into" the canal. This is particularly significant in rotary instrumentation when using files with a constant taper. However, one file, the K^3, has addressed this issue. This file has purposely been designed with constant tapers but with variable pitch and helical angles (Fig. 10). The result is a dramatic reduction in the sense of being "sucked down into" the canal. This is very significant, especially when performing a fully tapered .06 preparation.

We have now discussed the most significant design features of nickel titanium rotary files. Let's now look at the individual files and the various companies. The companies we wish to discuss are Dentsply Tulsa Dental, Brasseler, Lightspeed, and Sybron-Endo. Let's begin with the largest manufacturer of rotary files, Dentsply Tulsa Dental.

Dentsply Tulsa Dental markets a series of files in North America. These are the Profile, the GT, and the new ProTaper. The Profile system, which has been the gold standard, is a constant taper file that employs a non-cutting tip, along with three full radial lands. Additionally, it has a constant pitch throughout its cutting shank. The GT is also a U blade file (similar to the Profile) that utilizes a non-cutting tip with three radial lands. However, the GT has variable helical angles and a variable pitch. This file was a big step forward in debris removal. Additionally, their variable pitched flutes provide a reamer like efficiency at the shank and K-file strength at the tip. The GT system, in contrast, uses multiple tapers with a constant apical tip size to prepare canals. Simply choose a shaping objective (small, medium, or large) and this gives you the apical tip size. Following this decision, the canal is shaped "crown down" through a series of varying tapers. For example, #20 .10 taper, #20 .08 taper, #20 .06 taper, and finally, #20 .04 taper to working length.

The latest addition to the Dentsply line of rotary files is the ProTaper. This is a series of six files (three shaping and three finishing) that utilize a cutting tip, a modified K blade, and a progressive taper (Fig. 11). This design results in a very fast, effective cutting action. The progressive taper according to the manufacturer, "ensures flexibility and reduces torsional loading." Some dentists are, in fact, using the three shaping files to gain access and then finishing the preparation with a landed file such as the Profile.

Brasseler is a company that is well known for its superior cutting instruments such as diamonds and burs. But they have also been in the rotary business with a .02 tapered NiTi file. Now, they also produce a new third generation rotary file that is gaining traction in the Endodontic market. This is the RaCe file (RaCe is an acronym for reamers with alternating cutting edges). The RaCe file is a very creative design that employs a "spade-shaped safety tip" (cutting) with a non landed shank. It features one set of cutting edges that alternates with a second set, pitched at a different angle. Consequently, we have two different cutting edges on one file. However, the cutting shank is short (8 mm) and, as mentioned, employs an alternating spiral design (Fig. 12). Naturally, this results in variable helical angles along with a variable pitch. This file has been designed to minimize frictional resistance inside the canal, thereby reducing the torque demands. As a result of these design features, along with a shorter cutting shank, the RaCe files are run at 500 RPM.

A different type of file design comes from the Lightspeed company. Lightspeed has been well established in the rotary community for years. These files as designed, also utilize a U-blade design but on a pilot tip that is similar to a Gates Glidden bur (Fig. 13). When compared to other rotary systems, the Lightspeed differs considerably, regarding the shaft and cutting blade. The Lightspeed file has a shaft diameter that is always less than the blade. The blade also is different in that the largest portion of the blade is at the tip. The manufacturer feels that this combination of a smaller shaft and widest portion of the blade at the tip, contributes to superior tactile awareness. The Lightspeed System employs 22 multiple sizes ranging from 20 to 100. Due to its smaller pilot tip, the Lightspeed is optimally run at 1700 – 2000. This is in contrast to other systems that run generally between 300 – 350 RPM. Some practitioners use one or two Lightspeed tips, as an apical verifier, in conjunction with a greater taper file system such as the Profile.

The final company we wish to discuss is SybronEndo. Most practitioners are not familiar with this name. SybronEndo is actually the combination of Kerr Endo and Analytic Endodontics. Analytic has produced the Quantec series of files for many years. These files are still manufactured and offer the clinician a choice of cutting or non-cutting tips. They also employ a positive rake angle, which contributes to their cutting efficiency. The Quantec file, in contrast to the Profile, is a two fluted file that has two recessed radial lands. However, SybronEndo is now producing a new file that seems to incorporate many of the outstanding features of previous files. The K^3 is a three fluted file, of constant taper, with three radial lands. It is available in tapers .02, .04 and .06 (Fig. 14). Concerning the radial land design, two of the radial lands are broad and recessed, while the third one is a narrow full land. This land design imparts tremendous strength to the file (Fig. 15). It also employs variable helical angles (like the GT) and has a variable pitch. This is very significant as the .06 taper K^3 does not suck you down into the canal. Additionally, the K^3 has an improved cutting efficiency as do the other third generation files (ProTaper and RaCe files). However, the K^3 achieves this through a well contolled postive rake angle, rather than a modified K blade design.

So what is the best design and which is the superior file? That is a difficult question. It really depends on what you are looking for. If you want a file that cuts quickly, then a file such as the ProTaper may fulfill your needs. However, with a fast file, you must understand the limitations and potential complications. The progressive nature of the taper does seem to put the file at greater risk for separation, if there is any deviation from the

recommended technique. Additionally, the lack of radial lands and the cutting tip must be fully appreciated. Be sure to follow the "directions for use." If efficiency with safety is more of an issue, perhaps the K^3 should be your choice. The K^3 combines a non-cutting tip, along with a positive rake angle with variable pitch, and radial lands. If you prefer to instrument your canals through a series of varying tapers, then a system such as the GT or Quantec may satisfy your needs.

One thing we can say with confidence is that before you choose a rotary file, you must try it. Extracted teeth are a big help in this case. Understand the fundamentals of file design and combine that with your pre-clinical trial. This will facilitate making the correct choice in rotary files. Keep in mind, that as you become more experienced your expectations of rotary files will change. Eventually, you will realize there is a place in the endodontic armamentarium for many of these file designs (Fig. 16). **OH**

Dr. Kenneth Koch is the founder and past Director of the New Program in Postdoctoral Endodontics at the Harvard School of Dental Medicine, and currently maintains a faculty position at Harvard. He is the author of numerous articles on Endodontics, and has lectured extensively in the US and abroad.

Dr. Dennis Brave is a diplomate of the American Board of Endodontics, and was the senior managing partner of a group specialty practice for 27 years. Dr. Brave was voted "Baltimore's Best" Endodontist by Baltimore Magazine. The holder of multiple patents, including the Visi Frame, Dr. Brave has performed over 28,000 endodontic cases.

Drs. Koch and Brave together are Real World Endo. They can be reached at 1-866-RWE-ENDO or visit www.RealWorldEndo.com. All graphic images are property of Real World Endo.

Oral Health welcomes this original article.

REFERENCES

1. Walia H. Brantley, WA, Gerstein H.An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1984;4:346-51.
2. 21st Century Endodontics. Gerald N. Glickman D.D.S., M.S. and Kenneth A. Koch, DMD. Journal of the American Dental Association, Volume 131, June 2000, 39S - 46S.
3. Introduction to Rotary Endodontic Instrumentation, Dr. Ken Koch, 2 CE Credit on-line tutorial, 2000-2001. WWW. TULSADENTALDENTSPLY.com
4. Pro System GT – The Evolution of Endodontic Technique,Dr. Ken Koch, Dental Town May 2001, Vol.2/Issue 4, pgs 38-40.
5. Gems of Wisdom, Kenneth Koch, DMD. and Dennis Brave, DDS. Dental Economics August 2001, PennWell Publishing.
6. More Gems of Wisdom, Kenneth Koch, DMD and Dennis Brave, DDS. Dental Economics October 2001, PennWell Publishing.
7. Fundamentals for Choosing a Rotary File: File Design and Performance, Ken Koch, DMD. Endodontic Therapy, Vol. 1, Number 1, Pg.12. Montage Media Corporation, Mahwah, NJ 07430.