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Rotary Instrumentation: An Endodontic Perspective

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The introduction of nickel-titanium (NiTi) rotary files to endodontics almost two decades ago has changed the way root canal preparations are performed, enabling more complicated root canal systems to be shaped with fewer procedural errors. This publication is intended to give clinicians a knowledge base for NiTi rotary use and further aims at enabling them to select a system that is most suitable for their needs.

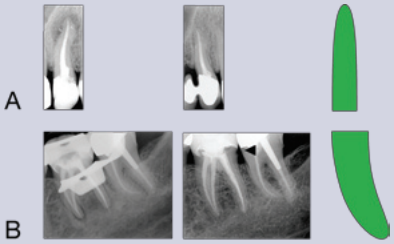

Fig. 1. Examples of root canal treatments done with NiTi rotary files, with schematic reference to canal shapes (green outlines).

A—Maxillary second premolar with a radiographic lesion and a relatively straight root canal. Follow-up radiograph after 8 years shows apical osseous repair.

B—Mandibular first molar with radiographic lesions on both apices and gently curved roots. Follow-up radiograph after 6 years shows osseous repair and caries at #18 (arrowhead).

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Background and Case Assessment

Nickel-titanium alloy was developed in the 1960s, initially for military purposes, but it soon became apparent that NiTi was also useful for other applications, such as orthodontic wires and dental burs. K-type root canal files were made of NiTi and tested extensively by Serene *et al.* (1), and the first NiTi rotary files appeared on the market around 1993. These early rotary files were designed with cross-sections that did not have cutting edges but rather broad radial lands. This is different from the traditional K-file that is triangular in cross-section with sharp cutting edges (see groups in Table 1). Those files (with the exception of LightSpeed) retained the 16 mm-long cutting blades but had a greater taper than the typical .02 for K-files.

Subsequently, numerous reports were published, detailing successful endodontic treatments with the aid of NiTi rotary files. Even so, the use of rotary files requires attention to detail in how they are manipulated. To that end, a detailed analysis of a presented case (for example, using the *AAE Case Difficulty Assessment Form)* should be executed. Then, following guidelines outlined below, cases of varying degrees of difficulty can be successfully and predictably treated (Figure 1).

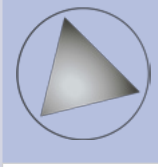
Clearly, not all root canals lend themselves to rotary preparation, due to varying degrees of clinician skill and case complexity. Furthermore, rotary files may fracture rather unexpectedly or create procedural errors. Therefore, knowledge of several clinical "Golden Rules" and basic understanding of metallurgical properties of NiTi rotary files are critical for successful use.

The "Golden Rules" for NiTi Rotary Preparation

1. Assess case difficulty
2. Provide adequate access
3. Prepare with hand files up to size #20 prior to rotary use
4. Use light touch and low rpm
5. Proceed with crown-down sequence
6. Replace rotary instruments frequently

Available Systems

Some of the more than 30 current NiTi instrument systems on the market are classified according to their design, shaping characteristics, breakage potential and clinical performance (Table 1). Manufacturers have placed great emphasis on various NiTi rotary design details but only two major factors have been identified that impact shaping potential—cross-sectional design and tip configuration (2,3). All currently available rotaries have noncutting tips, but some have radial land areas while others have a nonlanded design (see groups in Table 1). Generally, radial lands make preparation slower but safer while a nonlanded rotary cuts more rapidly, but can also lead to preparation errors. When used according to their specific guidelines both types of rotary files perform well.

Group	Rotary File	Enlargement Potential	Preparation Errors	Fracture Resistance	Clinical Performance
I Radial-landed 	ProFile[1], ProSystem GT[1], Quantec[2], Guidance[3], K3[2]	+, Depending on sizes, often time consuming	++ Low incidence, usually <150 µm canal transportation	+/- Fatigue + Torsional load, depending on system	++ Good, depending on treatment conditions. No difference between rotaries shown so far, except for inexperienced clinicians
II Nonlanded 	ProTaper[1], Pow-R[4], RaCe[5], Sequence[6]	+/-, Good with use of hybrid techniques	+/-, Overall more demanding of clinician's ability	+ Fatigue +/- Torsional load, depending on taper, handling	
III Others	LightSpeed & LSX[7], EndoEZE AET[8], Liberator[9]	Varies, + with LightSpeed	++ LightSpeed, - Other systems	Varies	Varies

++ Good **+ Adequate** **- Problematic** **+/- Undecided**

Manufacturers:

[1]Dentsply Tulsa Dental Specialties, Tulsa, OK/Dentsply Maillefer, Ballaigues, Switzerland

[2] Analytic Endodontics, Orange, CA/Sybron Kerr, Orange, CA

[3] Guidance Endo, Albuquerque, NM

[4] Moyco Union Broach, York, PA

[5] FKG, La Chaux-De-Fonds, Switzerland

[6] Brasseler USA, Savannah, GA

[7] Discus Dental, Culver City, CA (LightSpeed now replaced by LightSpeed LSX)

[8] Ultradent, South Jordan, UT

[9] Miltex, York, PA

Table 1. Suggested grouping of rotary files according to their mode of cutting and details about manufacturers. Group I consists of radial-landed rotaries with reaming action; Group II rotaries have triangular cross-section and cutting action; while Group III is made up of files with different geometry. Evaluations are based on recent reviews of the pertinent literature (2,3).

NiTi Rotary Usage and Fracture Prevention

What makes NiTi alloy so special? It is an alloy that exists in two crystal structures, austenite and martensite; transitions from one crystal lattice to the other make NiTi superelastic and give it a shape memory. Its high flexibility is critical for rotary endodontic files for two reasons. With highly elastic instruments, forces between the file and the canal wall during instrumentation are reduced. This results in the file remaining centered in the root canal space, and in a lower propensity towards canal straightening or other preparation errors. Secondly, rotational movement in curved canals will bend rotary files once per revolution. This ultimately leads to work hardening and brittle fracture, also known as cyclic fatigue.

Clinically, deformation and fractures of endodontic files do occur, but Spili *et al.* (4) showed that rotary files fractured in a specialist practice only slightly more frequently compared to stainless-steel hand files. However, any tooth with a file fragment lodged in a root canal presents a problem, and therefore, fracture prevention is very important.

If a rotary has fractured, it is imperative to inform the patient; after a qualified benefit-risk analysis, an attempt may be made to remove the fragment, or it may be appropriate to leave it in place and follow-up with the patient. In such

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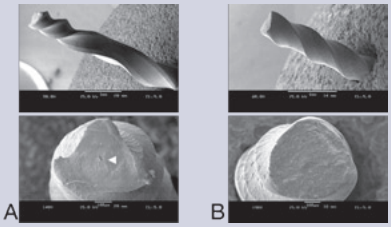

Fig. 2. Scanning electron micrographs illustrate NiTi rotary fracture mechanisms. Fractures were produced in experiments; note the grinding marks on both of the instruments.

A. Torsional fracture occurs when a rotary is forced into a small canal area, engaging the tip, which then becomes overloaded. Consequences are plastic deformation and a particular breakage pattern (arrowhead).

B. Fatigue fracture occurs when a rotary is overused and accumulates too much stress in curved canals over time. There are usually no warning signs and no particular patterns visible on the fracture surface.

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situations it is always advisable to consult with an endodontist.

Two distinct fracture mechanisms have been described in the literature —torsional load and cyclic fatigue (Figure 2). Torsional load is transferred into the file through friction against the canal wall while cyclic fatigue occurs with rotation in curved canals. Both factors work in concert to weaken the rotary file.

As a general rule, fine and flexible files are vulnerable to torsional load but are resistant to cyclic fatigue. Conversely, more rigid and larger files can withstand more torque but are susceptible to cyclic fatigue. The greater the amount and the more peripheral the distribution of metal in the cross section, the stiffer the file. Therefore, a file with a greater taper and larger diameter is more susceptible to fatigue failure; moreover, canal configuration becomes important here. A coronal root canal curvature is more dangerous than an apical one in terms of fracture, and a very acute canal curvature generates more fatigue than one with a larger radius (see below).

NiTi rotary handling needs to be carefully learned in well-conducted CE courses with further self education using extracted teeth. A clinician's skill and file-handling parameters are directly related to success with NiTi rotaries (5). Two reasons for this are the importance of proper case selection and the manual dexterity required for NiTi rotary use. Specific guidelines for file sequences are given for some rotaries but several principles apply to all instruments. For example, lower rotational speeds (~250 rpm) reduce file fractures. Typically, manufacturers give guidelines for their products, however, these recommendations may be incomplete or clinically insufficient. When in doubt, clinicians should consider other sources of available evidence or consult with an endodontist.

Manufacturers recommend that rotaries should be advanced until slight resistance is met but the recommendations differ regarding the exact hand movements. Most rotaries are used with a gentle pecking motion; ProSystem GT rotaries are recommended to be continuously advanced while ProTaper Shaping files should be used in a lateral "brushing" motion. It is difficult to determine exactly the apically exerted force in the clinical setting but manufacturers stress that a very light apical touch is needed. Currently, electric motors with torque presets are recommended by most manufacturers and are one way to decrease fracture incidence, particularly if torque settings are low and accurate.

In order to reduce friction, it is often suggested to use gel-based lubricants such as RCPrep (Premier, Plymouth Meeting, PA) or Glyde (Dentsply Tulsa Dental Specialties, Tulsa, OK). In dentin, such lubricants have not been shown to be beneficial and can actually increase torque for radial-landed ProFile rotaries (6), while flooding canals with NaOCl not only reduces torque but also promotes disinfection of the root canal system. It is therefore important to use copious irrigation with NaOCl during the use of rotaries.

NiTi rotaries are often used in more than one patient, requiring cleaning and sterilization of the file. Thermal sterilization does not affect fatigue life or torsional resistance. However, the reuse of rotary files has to be closely monitored in order to avoid build-up of fatigue over time and NaOCl-related corrosion (7,8). In fact, several government agencies around the world, for

example in the United Kingdom, and many clinicians recommend single-patient use of a set of rotary files (8).

Preparation Quality With Rotary Files

Current experimental and clinical evidence shows that NiTi rotaries promote improved preparation quality (Figure 3). Specifically, the incidence of gross preparation errors is greatly reduced. The current technique of choice to demonstrate canal shapes before and after preparation is microfocus-computed tomography, also know as microCT. Figures 3A and 3B show canal shapes, reconstructed from microCT data that are virtually free of preparation errors after NiTi rotary preparation. Canals with wide oval- or ribbon-shaped cross-sections present difficulties for rotary files, and other techniques, such as circumferential filing and ultrasonics, are sometimes used in those canals. Oscillating files that have been recommended for these canal types do not perform as well as NiTi rotaries, particularly in curved canals (Figure 3C).

Changes in root canal paths with NiTi rotary preparation are usually very small (Table 1, Figure 3). This indicates that canal walls are not excessively thinned and apical canal parts are only minimally straightened even when preparing curved root canals (Figure 1). Rotary files with a radial-landed design prepare canals in a planing action and need to be advanced with light pressure in order to engage the perimeter of the canal and then cut the dentin there. Usually, these rotaries enlarge the existing canal path safely without creating procedural errors.

Nonlanded rotaries prepare canals with more of a cutting action; their blades can be used with a lateral movement towards a specific point on the canal perimeter. This allows the clinician to actively enlarge and relocate canal paths, for example, away from the furcation in the coronal and middle root canal thirds. Nonlanded rotary files are considered more efficient but require more operator skill to avoid procedural mishaps compared to radial-landed files.

An important design element of all current instruments is a passive, noncutting tip; it guides the body of the rotary file so that dentin is cut more circumferentially. Even when taken beyond the apical foramen by accident, radial-landed rotaries will not engage and create an apical zip formation due to their passive reaming action. However, actively cutting files should never be used long to avoid the occurrence of apical zipping and perforation.

Clinical Strategies

As stated before, excellent diagnostics including the exposure and analysis of adequate radiographs are important for successful rotary canal preparation. Clinicians need to carefully evaluate root anatomy as well as the existence, extent and position of canal curvatures. Additional radiographs and findings during the treatment phase usually help to determine canal dimensions, curvatures and merging points, which can all predispose rotary files to fracture.

Each NiTi rotary system has a specific, optimal way of use that should be learned in a quality CE course. Following are a few general strategic principles to help the practitioner safely and successfully use NiTi rotaries:

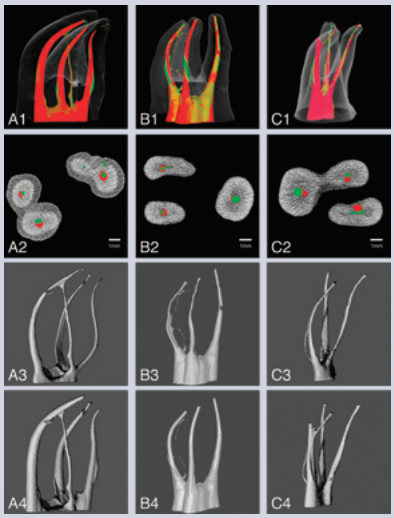

Fig. 3. Root canal anatomy and the effects of canal shaping illustrated by microCT. Panel A shows preparation with variably tapered files; panel B with .04 and .06 files; and panel C with oscillating tapered files.

Row 1 displays color-coded compound figures, red indicating postoperative shapes and green indicating preoperative canal systems. Mixed colors indicate summation, *i.e.,* no changes during shaping.

Row 2 shows representative postoperative cross sections in red superimposed with preoperative canal shapes in green (magnification indicated by white bars).

Rows 3 and 4 are three-dimensional renderings of preoperative and postoperative canal systems, respectively.

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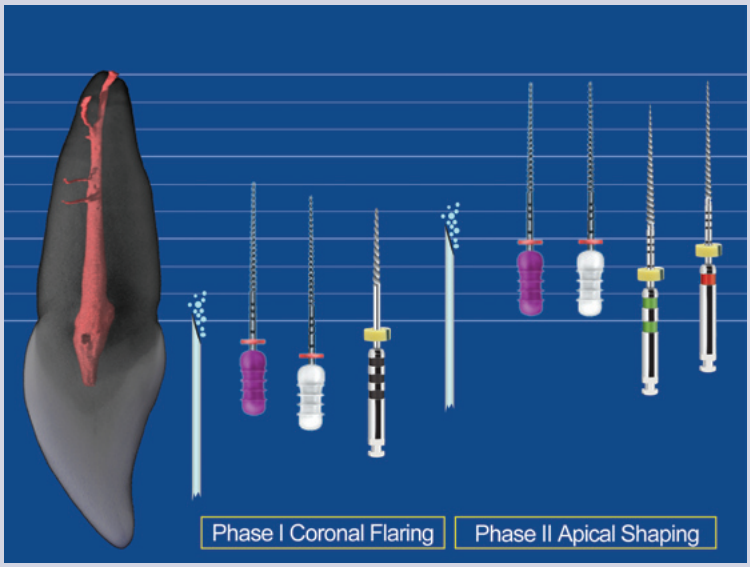

Fig. 4. Two phases are distinct during the preparation of curved canals with NiTi rotaries: (sometimes called a hybrid technique). A reservoir of NaOCl is deposited into the optimally prepared access cavity. The coronal path of the canal is then explored with K-files that are *not* precurved. After a glide path is confirmed, an actively cutting NiTi rotary may be used in a crown-down approach limited to the extent of the straight canal portion. After this canal segment is opened and irrigated with NaOCl, subsequent small K-files can progress apically, ultimately defining patency and again confirming the accessible canal space. Further NiTi rotaries are then used in a second crown-down phase to prepare the working length and finally enlarge to the desired final apical size and taper. This is a basic concept and modifications may be necessary depending on the tooth being treated.

1. Access Preparation—poor access will promote procedural errors. While generally important in root canal preparation, adequate access is crucial for the use of NiTi rotaries. Always attempt to create straight-line access into the coronal or middle root canal third prior to rotary use.

2. Don't Force Files—NiTi rotaries require a passive technique. If resistance is encountered, don't force the file! Stop immediately, and before continuing, increase the coronal taper and recapitulate using small stainless-steel hand files.

3. Difficult Canal Anatomy—canals representing difficult anatomy should be detected, analyzed and carefully instrumented with hand files prior to introduction of rotaries.

4. Don't Overuse Files—"Once only" is the safest number, but the actual stress accumulating in the file depends upon the case. Therefore files may be used for more than one canal, but may have to be replaced during shaping of one particularly difficult canal. Inspect instruments frequently and discard any bent rotaries.

5. Avoiding Breakage Takes Practice—rotary breakage occurs more often during the initial stages of the learning curve. The clinician changing from stainless steel to nickel titanium should take continuing education courses with experienced clinicians and educators, followed by extensive in vitro practice on plastic blocks and extracted teeth.

6. Don't Try to Bypass Ledges—confirmation or creation of a pathway with straight K-files is required prior to the use of any NiTi rotary.

7. Avoid Cutting With the Entire Length of File—the more file engaged in the root canal, the higher potential for instrument fracture. This total or frictional fit of the file in the canal will cause taper lock and fracture. Remember that an unnoticed and broken rotary can cause serious procedural errors.

8. Don't Start and Stop—sudden changes in the direction of a rotary caused by the operator must be avoided. A smooth gentle reaming motion is most efficient; rotaries should be inserted and withdrawn from a canal while rotating.

9. Length Control is Critical—working length should be well established and controlled, as should the actual length of the file.

The importance of adequate, straight-line access to the root canals cannot be overstated. Access into the root canal system needs to provide a direct pathway into the orifices without weakening the remaining tooth structure. Coronal flaring (9) facilitates direct access into the middle root canal third and promotes access of irrigants.

Rotary files have noncutting tips; they should be advanced only into an explored and open canal section. Therefore it is recommended a glide path be created with stainless steel K-files, sizes 10, 15 and possibly 20 to the depth that a subsequent rotary should go (Figure 4).

As soon as this glide path is secured, NiTi rotaries are used in a "crown-

down" rather than in a "step-back" fashion. In other words, rotaries are used from large to small sizes or tapers moving coronally to apically (Figure 4). Any one file is advanced until a certain resistance is met and then withdrawn. The next smaller rotary can then be advanced further; that way the canal is sequentially prepared.

The apical canal portion is first explored with small K-files and prepared up to a size #20 to working length, using a watch-winding or a Balanced Force motion. This procedure is important as it secures an open glide path (10), allowing a subsequent NiTi rotary to predictably reach working length.

The guidelines mentioned above may need to be modified to accommodate particular canal types. Canals that abruptly curve or merge (Figure 5) cannot easily be prepared with NiTi rotaries.

The extent and position of any curvature determines the strain and fatigue a rotary is subjected to; a more coronally located and/or more acute curvature precludes a file of larger taper and/or larger tip diameter to safely operate at working length. Also, merging points and ribbon-shaped canal areas can lead to deflection of a file tip into an unexplored canal area and subsequent file fracture. An astute clinician needs to consider those situations carefully before entering a canal with a rotary file.

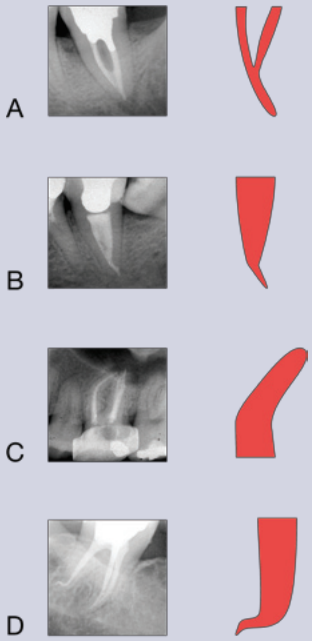

Fig. 5. Examples of root canal treatments done with the aid of NiTi rotary files in cases of difficult anatomy (red outlines). In all cases hand files were also used.

A. Mandibular second molar with two canals that merge.

B. Mandibular second molar with a C-shaped canal system.

C. Maxillary first molar with acute curvature mesiobuccally in the middle root third.

D. Mandibular molar with extreme apical curve in the distal root.

Conclusions

Root canal preparation with NiTi rotaries is a very effective and safe procedure. However, it demands understanding of root canal anatomy and the usage principles of the selected rotary system. Every canal needs to be evaluated on its own merit regarding length, width and curvature. It is only then that an educated decision about the strategy for the preparation of that particular canal can be made. NiTi rotary usage also requires training provided in quality CE courses. Following the guidelines outlined above allows clinicians to successfully prepare most root canals using nickel-titanium rotaries.

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- Full-Text Article: Young GR, Parashos P, Messer HH. The principles of techniques for cleaning root canals. *J Austral Dent* (Supplement) 2007;52:S52-63.
- Full-Text Article: Hülsmann M, Peters OA, Dummer PMH. Mechanical preparation of root canals: shaping goals, techniques and means. *Endod Topics* 2005;30-76.
- Full-Text Article: Peters OA. Current Challenges and Concepts in the Preparation of Root Canal Systems: A Review *J Endodon* 2004;30;559-567.
- Full-Text Article: Bergmans L, Van Cleynenbreugel J, Wevers M, Lambrechts P. Mechanical root canal preparation with NiTi rotary instruments; rationale, performance and safety. Status report for the American Journal of Dentistry. *Am J Dent* 2001;14:324-33.
- "Ask the Author" Discussion Board for all of your questions and comments
- *AAE Case Difficulty Assessment Form* for a detailed preoperative analysis of teeth prior to the use of nickel-titanium instruments

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