The Twisted File: the greatest generation of rotary nickel titanium instruments

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Rotary nickel titanium (RNT) files are commonly manufactured by grinding a nickel titanium (NT) alloy, which contains either 54 percent or 57 percent nickel. Until now, all RNT files, except one, have been ground from NT wire (stainless steel blanks can simply be twisted to produce K-files or reamers). Consequently, NiTi instruments may have characteristic imperfections, such as milling marks, metal flashes, or rollover. Grinding NT imposes limitations on the possible geometries of RNT file design. This has implications for clinical file performance. Attempts have been made to manufacture RNT files with different methods and different shape memory alloys. For a host of reasons, none of these efforts has been commercially successful. The process of grinding NT creates microcracks on the surface of the metal that can act as the origin of file fracture if the metal is exposed to excessive torsion and/or cyclic fatigue. Among other methods, various surface treatments have been used with ground RNT files, (predominantly electro polishing) in an attempt to overcome the fracture risk associated with microcracks. While electropolishing has been shown to reduce fracture potential, the process can dull the cutting edges of RNT files and reduce cutting efficiency.

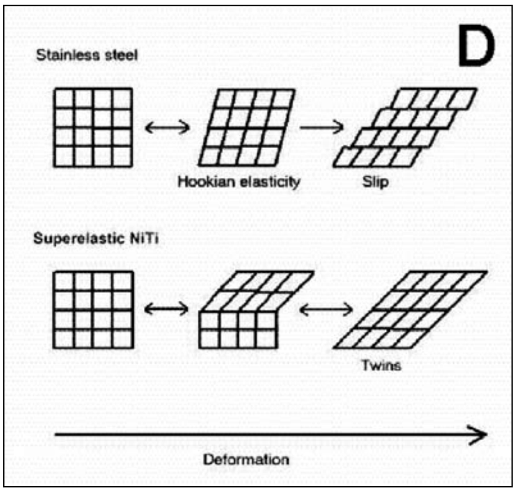


Fig. 1_Austenite, martensite and the P phase of nickel titanium alloy phase transformations. This schematic presentation shows lattice structure changes caused by outer stress in stainless steel or superelastic NiTi alloy. In stainless steel, outer stress first causes reversible Hookean type changes in the elastic area. In the plastic area, deformation takes place via a mechanism called slip. This deformation is irreversible. In superelastic NiTi alloy, outer stress causes a twinning type of accommodation that is recovered when outer stress is removed.

RNT instruments, despite their significant advantage over Gates Glidden drills and hand files, have limitations. File breakage, transportation, sequence complexity and canal blockage (among other secondary issues) have all proven challenging depending on the clinician's experience and the anatomy to be addressed. With the above considerations, it has obviously had value to continue to search for:

- A new and stronger alloy.
- A new manufacturing process.
- A new file design.
- A combination of the above features.

Intensive research into alternatives for grinding NT has led to breakthroughs in material science and design modifications. Advances have led to the ability to create an intermediate crystalline phase structure of NT between austenite and martensite, a pre-martensite phase, otherwise known as R phase. In R phase, the NT alloy can be twisted. NT alloy cannot be twisted in the austenite phase. This proprietary process is the genesis of the Twisted File (TF) (SybronEndo, Orange, Calif., USA). Twisting NT prevents cutting across the grain structure of the metal and provides many of TF's attributes.

Independent research on the TF has found, because of its utilization of R phase technology, that in comparison to traditional manufacturing methods, TF can withstand significantly more torque, more cycles to failure and more energy in bending than traditional RNT files during function. TF is significantly harder because of twisting and its final surface conditioning relative to ground RNT file alternatives.

Providing this advance for RNT design and function, is, in part, related to modifying the behavior of the crystalline structure of the particular "shape memory" alloy utilized under stress. NT alloy, at rest, is in the austenite crystalline phase structure. As it is stressed, it temporarily rearranges its crystalline structure into martensite. When the stress is relieved, the martensite crystalline structure rearranges into austenite. This ability to regain its original shape makes NT a "shape memory alloy." In essence, it is "super elastic" in that it can change shapes and return to its original crystalline configuration. This capability is based on a phenomenon known as a stress-induced martensite formation. The macroscopic deformation (the bending of the file in function) is accommodated by the formation of martensite. During the first phase of deformation under stress, from the austenite, up to the yield point (the point of deformation of the file), the crystalline structure of the alloy will modify the angles and the shapes of the sides of the basic crystalline structure back to the parent phase when the stress is removed. This is characteristic of the Hookean elasticity form (the type of elasticity in which the deformation or strain of the material is proportional to the applied stress, in accordance with Hooke's Law). From yield level to separation level, the metal has a plateau of deformation under stress; a plateau that has a constant level of torque while the angle of rotation is increasing. Alternatively, if the stress is released before the yield point, the martensite transforms back into austenite and the specimen returns back to its original shape.

NT, due to its shape memory, is 500 percent more flexible than stainless steel. Superelastic NiTi can be strained several times more than ordinary metal alloys without being plastically deformed, which reflects its rubber-like behavior. All of the above is, however, only observed over a specific temperature range. The amount of stress (clinical use) that an RNT file can absorb before it becomes deformed is its elastic deformation. Once the metal becomes deformed, it is ductile or plastic – i.e., it is deformed but has not yet fractured. At the plastic limit, the metal cannot tolerate more deformation and fractures. (See Fig. 1.)

To describe this phenomenon in more detail and its relationship to TF, as austenite, a centric titanium molecule is surrounded by eight atoms of nickel in a cubic form makes the basic crystalline structure of the NT alloy. In this "perfect" cubic form, all the angles are 90 degrees and all the sides are equal. This is also referred to as the parent phase (or the stable phase) of the alloy. During root canal treatment, this "parent" cubic form is subjected to a shear stress resulting in a modified structure between the non-stressed austenite phase and stress induced martensite. Between those two phases (austenite and martensite) there is an intermediate phase, R phase, starting from the austenite to the yield point. Up to the yield point, the metal will revert to the parent phase when the stress ceases. After the yield point, the alloy will go into a non-reversible phase (plastic deformation) and the alloy will be more vulnerable to separation once the metal reaches the plastic limit.

Fig. 2_The Twisted File sequence (SybronEndo, Orange, Calif., USA).

Unloading and heating can recover about 8 percent strain (8 percent deformation of the metal). Strain above the limiting value (the yield) will remain as a permanent plastic deformation. The operating temperature for shape memory devices must not move significantly away from the transformation range, or else the shape memory characteristics may be altered.

Utilizing R phase for TF provides many benefits. Among them are the following:

- Changing the crystalline structure provides a longer recovery range under function than the original NiTi alloy, which gives TF a 100 percent increase in tolerating stress.
- The range between the yield and metal fracture is not constant, compared to the plateau of deformation of common NiTi alloys. With TF, in function, the torque level increases with the angle of rotation until it reaches an upper limit, called the ultimate deformation level. At the ultimate deformation, a small plateau of deformation exists at a constant torque level before separation. This unique feature allows TF to tolerate stress at a higher level than other RNT files with greater flexibility, a clinically advantageous attribute. In essence, R phase is allowing the new alloy to increase the Hookean elasticity properties, a very

Fig. 3_Clinical case treated with a single Twisted File.

desirable feature.

The clinical advantages and ramifications to these metallurgical properties are dramatic. These include:

- Less breakage of instruments.
- Faster and more efficient canal preparation.
- Less risk of transportation of canals.
- Greater file flexibility.
- Fewer instruments required.
- The files can be used in a number of sequences, crown down among others.
- Single file technique in many canal anatomies.
- If a single file root canal preparation cannot be accomplished, a 2-3 file preparation is often all that is needed.
- The possibility to rotate TF faster than traditional ground RNT instruments. Enhanced rotational speeds will reduce the amount of torsional stress on the instruments by minimizing file engagement.
- Universal use of these files. TF can be used in all canals. There are no curvatures or canal anatomy that would inherently require use of another RNT system.

The TF system and design

TF comes in five tapers – 0.12, 0.10, 0.08, 0.06 and 0.04. TF is available in a fixed #25 tip size at this time. The file is available in 23 mm and 27 mm and has laser markings at various relevant positions along its shaft. TF is available in "large pack" configurations (0.10, 0.08 and 0.06) and "small pack" configurations (0.08, 0.06 and 0.04) as well as individual file packs.

TF has:

- A triangular cross section.
- A non-cutting pilot tip.
- A variable helical angle.
- Variable flute widths and depths.
- Variable flute lengths among the tapers except for the 0.04 and 0.06 taper. The Flute lengths are:
  - 0.04 taper – 15.20mm
  - 0.06 taper – 15.20mm
  - 0.08 taper – 12.00mm
  - 0.10 taper – 9.60mm
  - 0.12 taper – 5.45mm
- Laser markings along the shaft.
- A one-piece manufacturing design, the file is made from one piece of metal, the file shaft continuous with the handle.
- A surface conditioning after manufacture that cleans the metal but which does not dull the cutting flutes and which maintains the hardness of the file.
- Color-coding for both the taper and tip size. Since TF is fixed at a tip size of 25, the lower band of all TF files is red. The top band color gives the taper:
  - 0.12 purple
  - 0.10 pink
  - 0.08 aqua
  - 0.06 orange
  - 0.04 light green
- Color-coding for the packs:
  - Black - Individual file packs.
  - Blue - Large assorted packs.
  - Gray - Small assorted packs.

Clinical use of the Twisted File

Access should be straight line, and the cervical dentinal triangle should be removed.

Irrigation should be copious and frequent. After the insertion of each TF, the canal is irrigated and recapitulated and the TF file is wiped clean of debris.

The canal should be patent and open to the size of a #15 hand file (i.e., a glide path should be created). The M4 reciprocating handpiece (SybronEndo, Orange, Calif., USA) would be an optimal way to minimize hand fatigue and make creation of a glide path predictable and efficient.

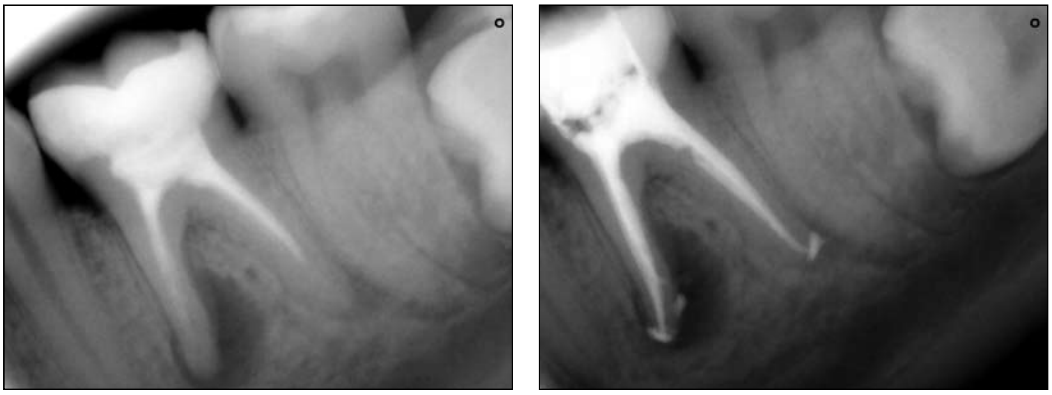
TF is inserted gently, passively, and from larger tapers to smaller, as needed. TF is never forced apically. When resistance is felt, the file is removed. The file should be rotating upon insertion into the canal. Insertion generally takes approximately two to three seconds. Clinically, when resistance is felt tactilely, the file is removed. Upon removal, dentin debris can be usually be observed on approximately 4 to 5 mm of the cutting flutes. It is difficult to describe in words alone how easily TF will both track a canal and cut dentin relative to the ground alternatives previously available. The difference is tangible.

SybronEndo recommends rotating TF at 500 rpm. TF should be inserted or withdrawn while in motion at all times. TF should never be held stationary in the canal.

TF should be used once, be that a single canal or a single molar tooth.

Whether TF is rotated with or without torque control is a matter of clinician preference. TF can be rotated and powered by any standard electric motor. The Elements Motor (SybronEndo, Orange, Calif., USA) is an excellent choice for powering TF due to its torque control and auto reverse features and range of rotational speeds.

Gates Glidden drills and Peezo reamers are not needed to open up the orifices of canals to facilitate the insertion of TF. The system does not need orifice



Figs. 4a, 4b_Clinical case retreated with two Twisted Files.

openers to function. The largest TF taper taken into the coronal third is generally the largest taper that is taken into the apical third. Choosing the initial TF to insert into the coronal third is determined by the initial size of the canal. Large open and patent canals generally will be initially enlarged with 0.12 and 0.10 TF. Medium sized canals will initially be enlarged with 0.10 and 0.08 TF. Small, narrow and curved canals will be initially enlarged with 0.08 and 0.06 TF. TF is flexible and cuts well enough to generally allow the same taper to be placed to the apex that was used initially at the orifice.

Whether TF is used as a single file (SF) instrument or technique or in a Crown Down (CD) sequence, the tactile use of the file is the same. Many canals will allow a SF technique (approximately 30 to 50 percent). The remainder will be divided between canals that require a two-file or three-file technique. Use of TF as a one-file, two-file or three-file technique is largely a matter of clinician preference. With experience, the number of files needed will likely be reduced. Using TF as a SF or two-file technique is largely a matter of appreciating when to remove the file from the canal during insertion. If TF is allowed to enter the canal as described here and not continue to push the file when it should be removed, with subsequent insertions the clinician will appreciate that they can reach the TWL often in three to four insertions of the single instrument, especially if the correct TF taper is used initially at the orifice.

The initial choice of taper chosen is very important. TF, due to its flexibility and cutting efficiency, will facilitate larger tapers than ever before to be taken into the apical third. For example, in a SF technique, most molar canals can easily be taken along their entire length to a 0.10 taper. This capability has never existed before. One appropriate taper, of the sizes listed above, chosen initially and then used along the length of the canal, can assure the production of a continuous taper to the entire preparation.

TF Protocol and Precautions

TF is inherently very safe. This said, there are three concerns with TF that can easily be avoided if the file is used correctly:

- Apical perforation: It is vital that the clinician be aware of his or her relative position in the canal at all times. In other words, if the estimated working length of the tooth is 22 mm and the clinician begins to enlarge the apical third, it has obvious value to appreciate the final and true working length of the canal before taking TF further into the apical third. It may be possible in some anatomies to bypass the minor constriction of the apical foramen and perforate the apex with TF because of its efficiency.
- Stripping perforation: Due to TF's cutting efficiency, if an excessive taper is taken into a highly fluted root it is possible to create a strip perforation exactly as it would be with any ground RNT. Because of TF's cutting efficiency, using the largest TF taper, 0.12, is limited to open, easily negotiable and minimally curved roots. For central incisors, the distal roots of many lower molars, the palatal canals of upper molars, etc., this is an excellent file option. The 0.12-tapered TF would not be used in, for example, for the mid root of a lower molar mesial buccal or mesial canal.

FAQ

How many times can TF be used?

SybronEndo recommends a single use of TF. TF can be powered by any electric motor. Whether torque control is used, is a matter of personal preference.

Does TF technique need to be modified in extremely curved canals?

TF technique does not need to be modified if the file is used in the manner described. TF is more than flexible enough to handle even the most difficult clinical challenges. What some clinicians may do is to instrument the canal to a smaller taper first and then create a larger taper, in essence to use the file step back in the final preparation of the apical third. For example, clinically, a 0.04 taper may be used first to the TWL and then possibly a 0.06 and 0.08 taper could be taken to the TWL.

Can TF be used in retreatment?

TF can effectively remove GP, pastes and warm carrier based obturators. As with other RNT files, it may be more efficient to increase the RPM for these applications.

What type of master cones and sealer are used to match with TF preparations?

TF preparations can be obturated with TF gutta percha — i.e., gutta percha that is matched to the taper and tip size of the TF files. If the clinician is bonding their obturation, using a product like RealSeal, they can use #25 tip sizes of the various RealSeal tapered cones (SybronEndo, Orange, Calif., USA). Any of the commercially available sealers can be used to cement gutta percha perches into TF preparations. Obturation technique is not modified in any way to accommodate TF preparations. Obturation can take place with lateral condensation, warm techniques and carrier-based techniques as desired.

How much pressure should I use to insert TF?

TF should be inserted until mild resistance is felt. By the time the clinician experiences tactile resistance, TF is ready for withdrawal. Usually, a single canal can be instrumented in three to four apical insertions — sometimes less, sometimes more. With experience, the optimal pressure for the given TF use in a canal will easily become intuitive.

If I see TF unwound, do I have to discard the file?

Yes. TF is a single-use instrument — one canal or one tooth (up to five canals).

If TF only comes in one tip size, how can I create a larger master apical diameter?

The clinician can create a larger master apical diameter any way they desire. Some clinicians may wish to create larger apical diameters, many will not. TF can be blended with any other RNT file system if the clinician desires it. It is not neccessary to use Gates Glidden Drills, Peezo reamers or use specific orifice openers to initially open canals with TF.

How is TF different from other RNT files?

The primary difference is that TF is not a ground RNT file. The alloy is never cut across the grain structure producing microcracks. The file is twisted to create the flutes and has a final surface conditioning that maintains the hardness of the metal as well as the sharpness of the cutting flutes. The ramifications of these manufacturing parameters cannot be overstated clinically.

Can TF be used as a pathfinder in calcified canals?

TF is exceptionally resistant to breakage, cuts extremely well and is far more flexible than the alternatives. With these strengths, it is possible to start with a canal that has only patency achieved (with a #10 or #15 file) and from this minimal initial diameter, create a final prepared canal as mentioned above in three to four passes in many anatomies. The above not withstanding, the file is not designed to be a "pathfinder" and is not designed to bore through calcifications.

What are the clinical implications of TF?

TF will shorten treatment times, shorten the instrumentation phase of treatment and make creation of optimal shapes more predictable and technically simple for all clinicians. One byproduct of this process will be a recognition that irrigation regimens may need to be altered to allow enough irrigant to penetrate the canals and be exposed to the canal contents long enough to optimally clean the space. One way to optimize the irrigation process would be to heat irrigants and ultrasonically activate them. In any event, since the amount of time that shaping canals will be reduced through the efficiency of TF, irrigation regimens will likely need modification to assure the greatest degree of debridement.

A clinically relevant discussion of the new Twisted File has been presented, taking into account its innovative and original manufacturing process as well as its implications for endodontic practice.

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Professor Philippe Sleiman received his DDS from the Lebanese University School of Dentistry in 1989. He conducted a DES in the endodontic program at St Joseph University and a PhD at the Lebanese University Dental School. He authored several international articles. He has his own line of instruments with the Hu-Friedy company and contributed in several project developments, and he has lectured internationally. Prof. Sleiman is an instructor at the Lebanese University and an international trainer for the University of North Carolina. He is a fellow in the ICD and the AAE. Prof. Sleiman maintains a private practice in Beirut, Lebanon, and in Dubai.

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