Question 1. Understanding "why" may be more than I want to know, isn't knowing how enough?

Various techniques have been proposed to prevent nickel titanium file failure during canal preparation. Too often descriptions of these techniques have emphasized instructions over understanding, product promotion over objectivity, simplicity over complexity and artful presentations over science. Too often the practitioner is surprised to experience failure while conscientiously following instructions. On the other hand, when failure is experienced in one particular situation, techniques are designed to always avoid the action that caused failure even though it might often be beneficial in other applications. For example, we are often instructed to never rotate a file more than 350 rpm, yet in many circumstances 1200 rpm can be more than four times as effective with less threat of complications. *Consequently, without having the information needed to understand how to utilize the advantages while limiting the threat of failure, the practitioner frequently places limits on rotary instrumentation prematurely before expertise and its most significant benefits are ever realized.* ***Understanding the ramifications of file design relative to canal anatomy enables the dentist to consistently achieve exceptional treatment results with the most expeditious non-threatening technique.***

By and large, basic rudimentary physics of root canal instrumentation has been an elusive subject during the last century, denying endodontists the understanding necessary to fully attain their potential expertise in performing the task that often requires the major portion of their time, root canal preparation. Rotary instrumentation is certainly not a new concept; it was introduced in the late 19th century, as were the rubber dam, rubber dam clamps and even solid core carriers for gutta percha were introduced at the beginning of the 20th century.

The first mechanical rotary files were formed from straight piano wire that had flats ground on its sides and twisted to result in the configuration of files still used today. Files were first mass-produced by Kerr Manufacturing Co. in the very early 1900's, hence the name K-type file or K-type reamer. Although the term file is commonly used generically to describe all ground or twisted endodontic instruments, more specifically the term file is used to describe an instrument used primarily during insertion and withdrawal motions for enlarging the root canal whereas a reamer is used primarily during rotation. K-type files and reamers were both originally manufactured by the same process. Three or four equilateral flat surfaces were ground at increasing depths on the sides of wire to form a tapered pyramidal shape that was stabilized on one end and rotated on its distal end to form the spiraled instrument. The number of sides and spirals determined if the instrument was best suited for filing or reaming. Generally, a three-sided configuration with fewer spirals was used for reaming; a three- or four-sided configuration with more spirals was used for filing.

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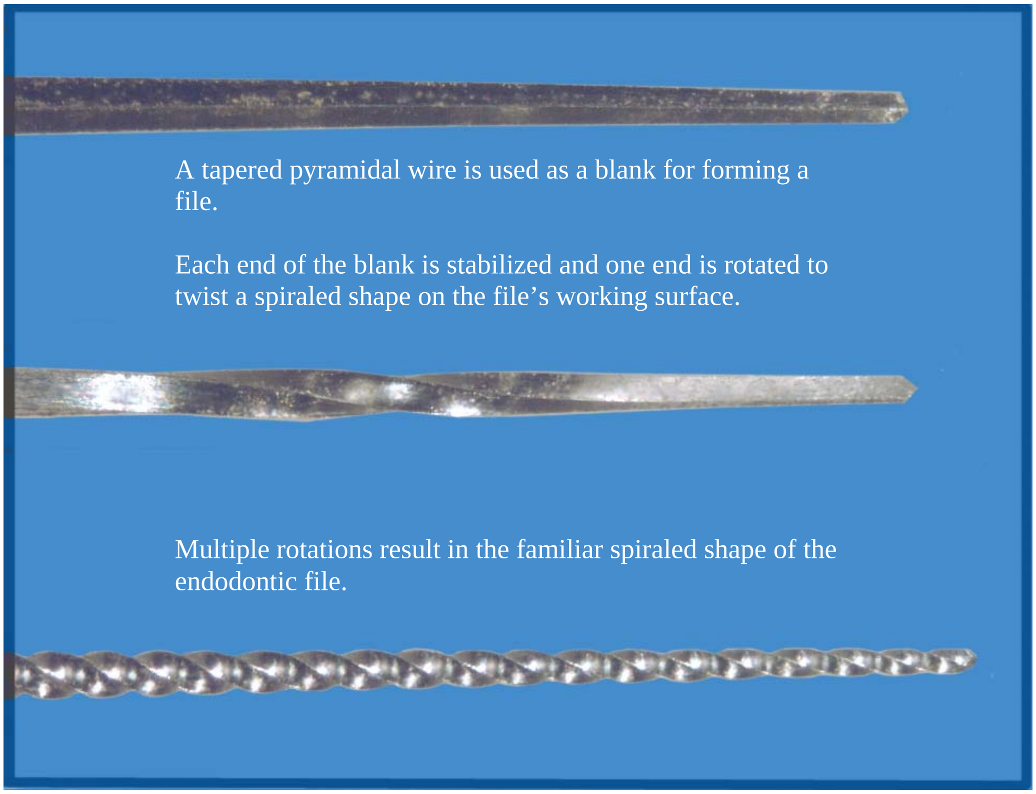
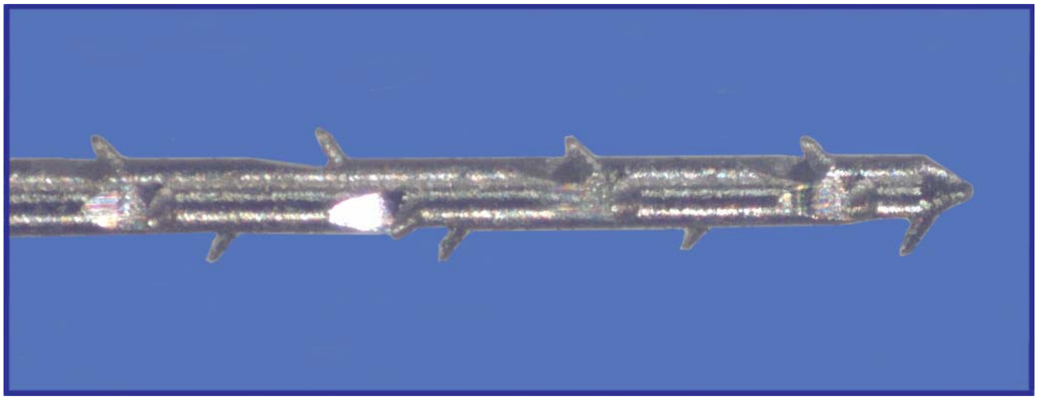


Dating from the early to mid 19th century, the earliest endodontic instruments used for extirpating the pulp and enlarging the canal were broaches or rasps. Still used today, these instruments are manufactured by hacking a round tapered wire with a knife type blade to form sharp barbs that project out from its side to form cutting or snagging surfaces. Although mostly used to engage and remove soft tissue from the canal, these instruments are commonly used in sonic or reciprocating hand pieces for canal enlargement and have the potential, as demonstrated by prototypes, for becoming effective nickel titanium rotary instruments. The evolutionary development for endodontic instruments is far from over.



Question 2. What are the terms I need to know when comparing the physical properties of files?

The success of using instruments while preventing failure depends on how the material, design and technique relate to the forces exerted on the instruments. To fully understand how the file reacts to applied forces, terms have been defined to quantify the actions and reactions to these forces. Common terms related to forces exerted on files have the following definitions:

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***Stress* - ** The *deforming force* measured across a given area.

Stress concentration point- An abrupt change in the geometric shape of a file, such as a notch, will result in a higher stress at that point than along the surface of the file where the shape is more continuous.

***Strain* - ** The *amount of deformation* a file undergoes**.**

***Elastic limit* - ** A set quantity which represents *the maximal strain*, which, when applied to a file, allows the file to return to its original dimensions. The residual internal forces after strain is removed return to zero**.**

***Elastic deformation* - ** The *reversible deformation* that does not exceed the *elastic limit*.

Shape memory – the *elastic limit* is substantially higher than is typical of conventional metals.

***Plastic deformation* - ** Permanent bond displacement caused by exceeding the *elastic limit.* The file does not return to its original dimensions after strain is removed.

***Plastic limit* -**The point at which the *plastic deformed* file breaks.

Question 3. Why Nickel-Titanium?

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Manual stainless steel files provide excellent manipulation control and sharp, long-lasting cutting surfaces. However, due to the inherent limited flexibility of stainless steel, preparation of curved canals is often a problem for manual files and mechanical use poses the likely threat of file breakage or canal transportation.

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The significant advantage of a file made of a nickel titanium alloy is its unique ability to negotiate curvatures during continuous rotation without undergoing the

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permanent plastic deformation or failure that stainless steel files would incur. The first series of comparative tests demonstrating the potential advantages of endodontic files made of nickel titanium over stainless steel were conducted and by Drs. Walia, Gerstein and Bryant. The results of the tests were published in an article entitled “An Initial Investigation of the Bending and the Torsional Properties of Nitinol Root Canal Files”, (*Journal of Endodontics*, Volume 14, No.7, July 1988, at pages 346-351). In 1991, the first commercial nickel titanium manual and rotary files were introduced by NT Co. In 1994, NT Co. also introduced the first series of nickel titanium rotary files having multiple non-conventional tapers, the McXIM Series, which had 6 graduating tapers ranging from the conventional .02 taper to a .05 taper file in order to reduce stress by limiting the file’s engagement incurred during rotary instrumentation. Based upon the initial success and recognized advantages, the use of nickel titanium rotary files has proliferated and become widely accepted by the profession

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Nickel titanium is termed an exotic metal because it does not conform to the normal rules of metallurgy. As a super-elastic metal, the application of stress does not result in the usual proportional strain other metals undergo. When stress is initially applied to nickel titanium the result is proportional strain, however, the strain remains essentially the same as the application of additional stress reaches a specific level forming what is termed ***loading plateau***. Eventually, of course, the application of more stress results in more strain that increases until the file breaks. This unusual property is the result of undergoing a molecular crystalline phase transformation. External stresses transform the austenitic crystalline form of nickel titanium into the martensitic crystalline structure that can accommodate greater stress without increasing the strain. Due to its unique crystalline structure, a nickel titanium file has shape memory or the ability to return to its original shape after being deformed. Simply restated, nickel titanium alloys were the first and, for the time being, are currently the only readily available economically feasible materials that have the flexibility and toughness necessary for routine use as effective rotary endodontic files in curved canals.

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Comparison of Properties of NiTi and Stainless Steel

Property	NiTi	Stainless Steel
Recovered Elongation	8%	0.8%
Biocompatibility	Excellent	Fair
Effective Modulus	approx. 48 GigaPascal	193 GigaPascal
Torqueability	Excellent	Poor
Density	6.45 g/cm3	8.03 g/cm3
Magnetic	No	Yes
Ultimate Tensile Strength	approx. 1,240 MegaPascal	approx. 760 MegaPascal
Coefficient Thermal	6.6 to 11.0 x 10^{-6}	17.3 x 10^{-6}

Expansion	cm/cm/deg.C	cm/cm/deg.C
Resistivity	80 to 100 micro-ohm*cm	72 micro-ohm*cm

Although stainless steel files could negotiate abrupt apical curvatures, canal transportation could easily occur due to the file's lack of flexibility. Note the transportation that occurred in the apical curvature of the distal root of the first mandibular molar that occurred during instrumentation with stainless steel files.

J.T. McSpadden

Question4. Are nickel titanium files always advantageous over files of stainless steel during rotary instrumentation?

If all canals were straight, stainless steel files would have results as good as or better than nickel titanium. Work hardened stainless steel files have more torsion strength and are able to maintain sharp edges longer. Of course, few canals are entirely straight and rarely can we determine beforehand very accurately when they are. The minor curvatures of most canal anatomies can cause excessive stresses on stainless steel files and result in unwanted canal transportation. Nevertheless, the introduction of nickel titanium files seemed to ignore the fact that nickel titanium offers no advantage for files having large diameters and tapers that lack any appreciable flexibility. Accordingly, these instruments have become an unnecessary expense only because these larger files were a part of a series of instruments. The advantage of stainless steel rotary files of larger diameters and tapers to compliment the use of nickel titanium files is now recognized by many that have become familiar with the attributes and limitations of nickel titanium. Stainless steel rotary files by FKG (Switzerland) and other manufacturers are being introduced for use in lieu of nickel titanium files in larger sizes and tapers that lack the flexibility to merit their necessity and are only available in sizes that correspond to nickel titanium files that lack functional flexibility.

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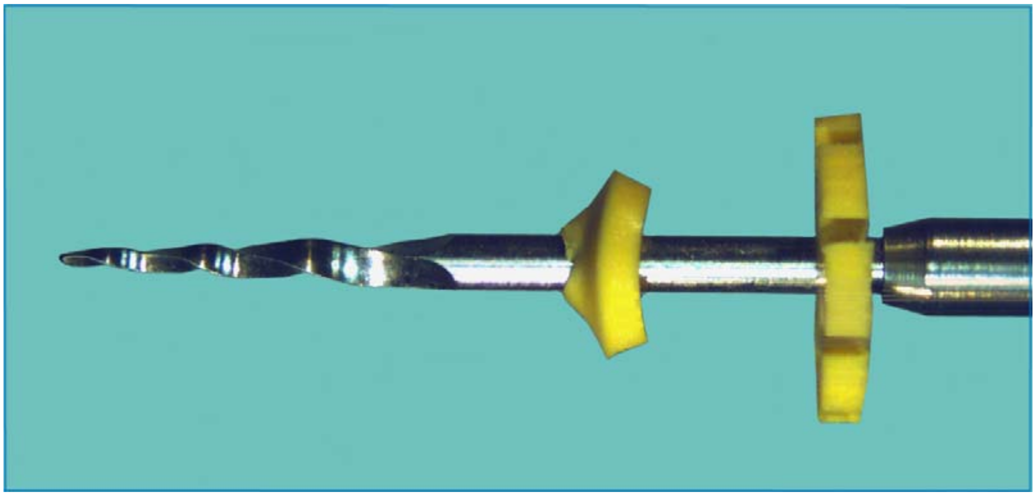

The FKG stainless steel rotary files are available in sizes that NiTi files would lack any appreciable flexibility or advantage.

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Question 5. Are there other alloys that offer advantages as rotary files?

Other alloys have been developed that are suitable for rotary files and might have properties that are advantageous over those of nickel titanium. The problem is one of economics. In order to be feasible, any other alloy usually must have applications in addition to rotary files that can help offset the cost of production. Otherwise the costs can be prohibitive.

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One alloy having considerable potential and economic feasibility is a nickel titanium niobium alloy having a substantially higher *loading plateau* making it tougher than either stainless steel or nickel titanium and has sharper more durable cutting edges and more resistance to breakage. Somewhat stiffer than the conventional NiTi alloys but more flexible than stainless steel, it is particularly advantageous for rotary activation of smaller files. The flexibility is sufficient to negotiate acute curvatures with minimum canal transportation yet stiff enough to withstand the pressure desirable to feed it into small canals.

Other titanium alloys contain molybdenum and zirconium to increase stability, workability or corrosion resistance. Only time will tell if the economic feasibility of these and other alloys will eventually provide a better endodontic rotary file.