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SWORD OF ENDODONTIST: A REVIEW

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ABSTRACT
The last decade has 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. NiTi alloys overall are softer than stainless steel, are not heat treatable, have a low modulus of elasticity (about one fourth to one fifth that of stainless steel) but a greater strength, are tougher and more resilient, and show shape memory and superelasticity. The latter two properties are the main reasons why NiTi alloys have succeeded in endodontics. The purpose of this article is to review the design features of different rotary instruments used for pulp space preparation. Important mechanical features include the variability of taper, rake angle, cross-sectional geometry, tip configuration, design of blades, helical angle and pitch. These design features influence flexibility, cutting efficiency and safety. In this review, design features of commonly used NiTi rotary systems are summarized.

Key words: Helical Angle, Nickel Titanium alloys, Rotary Endodontics, Rake Angle, Taper

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INTRODUCTION

Preparation of the root canal system is recognized as being one of the most important stages in root canal treatment which includes both enlargement and shaping of the complex endodontic space together with its disinfection.[1,2]

The two primary goals for root canal instrumentation are:

1. To provide a biological environment that is conducive to healing.
2. To provide a canal shape that is conformable to sealing.

At the present stage of endodontic development, common to all instrumentation techniques is the use of endodontic files. Although not universally used, rotary instrumentation is gaining universal interest. With the introduction of nickel titanium, mechanical root canal preparation has quickly become a widely accepted modality in endodontics. The enhanced preparation results and reduced preparation time of rotary nickel titanium files have prompted the rapid adoption of rotary instrumentation. Yet, inspite of added advantages and excellent canal cleaning and shaping ability, a lack of information has caused the formulation of techniques that limited the comprehensive benefits of rotary instrumentation.[3]

Understanding the ramifications of file and technique design relative to canal anatomy enables the dentist to consistently achieve the most expeditious and excellent treatment with the least risks.

The K-type steel file has remained the instrument of choice for preparing root canals for over three quarters of a century.[4] Instrumentation with stainless steel files has been shown to produce undesirable results in canals regardless of the technique or file type used.[5] Problems with breakage and the inflexibility of stainless steel instruments have resulted in a search for new materials from which to fabricate endodontic instruments. Civjan was one of the first investigators to propose nickel titanium

(Ni-Ti) alloy for use in endodontics in 1975. Walia in 1988 evaluated the physical properties of some of the first Ni-Ti files that were machined from orthodontic wire.[6]

Recent advances in technology have permitted the manufacture of endodontic files from Nitinol, a nickel-titanium alloy with a very low modulus of elasticity.[7] Over the last few years, endodontics has undergone a complete revolution with the use of these Nickel-Titanium alloys for the manufacture of manual instruments initially and then rotary endodontic instruments.[4,8]

The extraordinary characteristics of super-elasticity, shape memory and strength of Ni-Ti alloy have made it possible to manufacture rotary instruments with double, triple and quadruplet taper compared to the traditional standard. This has made it possible to achieve perfect shaping with the use of very few instruments and in a short period of time.[8]

The cutting ability of root canal instruments is a complex interrelationship of different parameters such as cross-sectional design, chip removal capacity, helical and rake angle, metallurgical properties, and surface treatment of the instruments.[9]

It has become important for today's practitioner to understand some important design features of these rotary files. In using any file design, understanding the rudimentary physics involved in its use is imperative for the practitioner to take full advantage of its benefits. Recognition of instrument features that improve usefulness or pose possible risks must also be achieved. Figure 1 shows various components of a Rotary file.

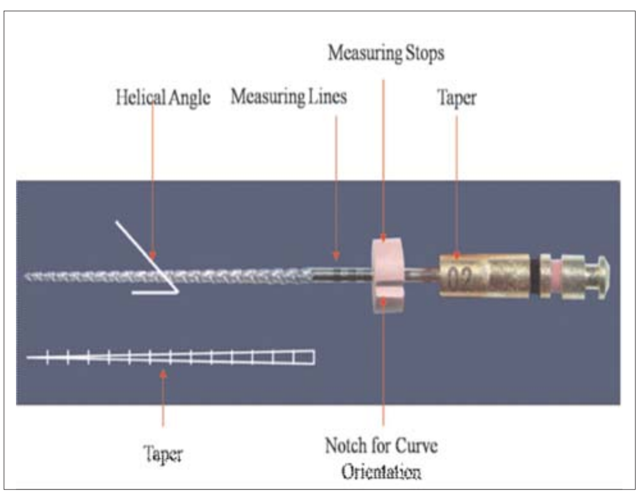

Figure 1: Various components of a Rotary file

Taper

Taper is a feature of file design which is particularly important concerning "system concepts." The ***taper*** is usually expressed as the amount the file diameter increases each millimeter along its working surface from the tip toward the file handle.[10,11]

For example, a size 25 file with a 0.02 taper would have a 0.27 mm diameter 1 mm from the tip, a 0.29 mm diameter 2 mm from the tip, and a 0.31 mm diameter 3 mm from the tip. Some manufacturers express the taper in terms of percentage in which case the 0.02 taper becomes a 2% taper. Historically, as an ISO standard, a file was fluted and tapered at 2% for 16 mm, but now files incorporate a wide variation of lengths and tapers of working surface (Figure 2).[3]

Figure 2: Taper indicators on a Rotary file

We have two basic 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 (0.02) but with various tip diameters. A rotary file of constant taper would be the 0.04 taper Profile that has a constant taper (0.04) but has varying apical tip diameters.

Secondly, there is the school of thought that prefers varying or graduating tapers.[12,13] These files have the same apical tip size but their taper varies from 0.04 to 0.12. The popular GT series of files employs a varying taper while the Quantec files use a graduated increase in taper.[14, 15] 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.[3]

Flute

The ***flute*** of the file is the groove in the working surface used to collect soft tissue and dentine chips removed from the wall of the canal (Figure 3). The effectiveness of the flute depends on its depth, width, configuration and surface finish.[3]

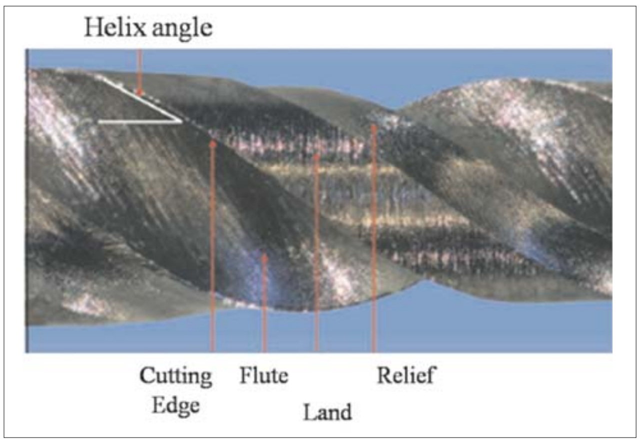

Figure 3: Quantec File

Cutting Edge

The surface having the greatest diameter that follows the groove (defined as where the flute and land intersect), as it rotates, forms the ***leading (cutting) edge***, (Figure 3) or the blade of the file that forms and deflects chips from the wall of the canal and severs or snags soft tissue. Its effectiveness depends on its angle of incidence and sharpness.[3]

Land

If there is a surface that projects axially from the central axis as far as the cutting edge, between flutes, this surface is called the ***land or radial land*** (Figure 3) (sometimes called the marginal width). The land reduces the screwing-in tendency of the file, reduces transportation of the canal, decreases the propagation of micro-cracks on its circumference, gives support to the cutting edge, and limits the depth of cut. Its position relative to the opposing cutting edge and its width determine its effectiveness.[3,16]

Previously, rotary files either had full radial lands (Profile, GT) (Figure 4a) or their lands were recessed (Quantec) (Figure 4b). 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.[3,16]

The K3 land (Figure 4c) design is unique and addresses the challenge of combining core and peripheral strengths. The K3, 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. Additionally, the combination of the three lands keeps the file centered in the canal.[3,16]

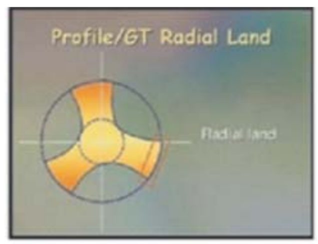

Figure 4a: Full radial land (Profile, GT)

Figure 4b: Recessed lands (Quantec)

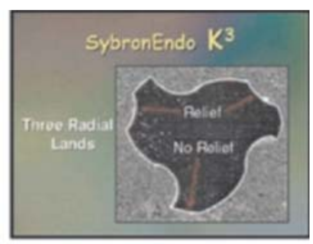

Figure 4c: K3 with Three Radial Land

The chance of transporting 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. However, two of the third generation files (ProTaper and RaCe) do not have the benefit of radial lands.[17]

Advantages of Land

- Reduce the torque requirements of the file,
- Keeps file centred in canal.

Disadvantages of Land

- Makes file less sharper & less efficient

- Decreased flexibility of file due to increased metal thickness.

Relief

In order to alleviate frictional resistance or abrasion resulting from a land, some of the surface area of the land that rotates against the canal wall may be reduced to form the ***relief*** (Figure 3).[3]

Helical Angle

The angle that the cutting edge makes with the long axis of the file is called the ***helix angle*** (Figure 3) and serves to auger debris collected in the flute from the canal. By definition, the helical angle is the angle that the cutting edge makes with the long axis of the file. 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.[3]

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.[18] For example, in the K3, the helical angle increases from the tip to the handle. The result of this design is more successful channelling that allows for superior debris removal.

The RaCe file is unique and utilizes an "alternating helical design" that reduces rotational torque by using spiralled and non spiralled portions along the working length. This design feature also reduces the tendency of the file to get "sucked into" the canal.

Core

The ***core*** is the cylindrical center part of the file having its circumference outlined and bordered by the depth of the flutes. The flexibility and resistance to torsion is partially determined by the core diameter. The core taper and total external taper can be different and the relative diameter of the core, compared to the file's total diameter, may vary along its working portion in order to change the flexibility and resistance to torsion. The importance of the ratio of core diameter to total diameter is often overlooked in predicting a file's susceptibility to failure and can be different for each file size of the same series.[3,4]

Rake Angle

Rake angles are also important and affect 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.[3,8]

Positive rake angles (Figure 5a) 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. A negative rake angle (Figure 5b) is least aggressive but the cutting efficiency of a file can also be affected 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.[3]

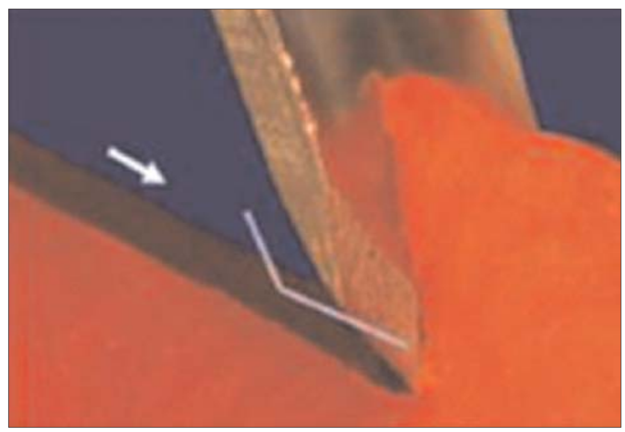

Figure 5a: Positive Rake Angle (Obtuse Angle)

Figure 5b: Negative Rake Angle (Acute Angle)

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. This can lead to separation.

The K3 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. [1,3,8]

Pitch

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.[19]

However, one file, the K3, has addressed this issue. This file has purposely been designed with constant tapers but with variable pitch and helical angles. 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 0.06 preparation.

Examples of variable pitch, helical angle & constant taper [in each file]: GT, RaCe, K 3, Mtwo, HERO 642, Endowave.

Their variable pitched flutes provide a reamer like efficiency at the shank and K-file strength at the tip. Examples of variable pitch, helical angle & progresive taper [in each file]: Protaper.

Tip

Most dentists are best served by using a rotary file with a non-cutting tip (Figure 6a). Cutting tips on rotary files make them too aggressive. A cutting tip (Figure 6b) has the ability to enter narrow, somewhat calcified canals, but has two serious concerns. The first is if a cutting tip goes beyond, upon retraction of the file, it will create an elliptical tear.[3]

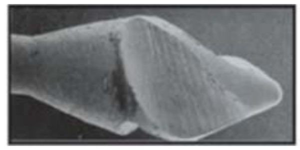

Figure 6a: Non- cutting Tip

Figure 6b: Cutting Tip

This is very difficult to repair and obturate when one accidentally go past the end of the tooth. However, going beyond 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.

Secondly, if a cutting tip is placed on a non-landed file, it will have the distinct possibility of transportation. This is especially true if the file is held at same length for any period of time. Theoretically, a cutting tip will not transport if it goes to length and is immediately retracted. Established files such as the Profile and the GT, along with the new K3, employ a non- cutting tip. Two of the new third-generation rotaries (ProTaper and the RaCe) have cutting tips. Even the manufacturer for the ProTaper recommends that the file does not stay at working length for more than one second. This gives you a slim margin for error.[3,4]

However, the use of cutting tips is limited and they should only be used in the hands of an experienced clinician. Some files claim to have "modified cutting tips" or "partially active" tips. But these are just fake marketing views. So the tip is either a cutting tip or it is not.

Table 1, 2 & 3 shows basic features of some currently available rotary file systems.

CONCLUSION

The choice of a specific rotary system for daily use requires consideration of the combined evaluation of all described parameters. The question arises that what is the best design and which is the superior file. It really depends upon the working condition like position of tooth in the arch, number of roots and root canals, size of pulp space, degree and level of curvatures of root canal. One thing we can say with confidence is that before you choose a rotary file, you must try it. Understanding the fundamentals of file design and combining that with your pre-clinical trial 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

Table 1: Basic features of rotary file systems

Feature	Lightspeed	Profile	Quantec	Hero	Race
COMPANY	Sybron Endo	Tulsa Dental	SybronEndo	Micro-Mega	FKG Dentaire
RANGE OF TIP SIZES	#20 to #140	#15 to #90	ISO tip sizes	#20 to #45	#15 to #40
TAPERS AVAILABLE	Taperless shafts	2%, 4%, 6%	2% to 12%	2%, 4%, 6%	2% to 10%
CROSS-SECTION	U shaped	Triple U shaped	Double helical	Triple Helix geometry	Triangular
RADIAL LANDS	3 radial lands present	3 radial lands present	2 recessed radial lands present	Absent	Absent
TIP TYPE	Non-cutting pilot tip	Non-cutting bullet nose tip	QLX : Non-cutting tip; QSE : Cutting tip	Inactive	Cutting tip
RAKE ANGLE	Negative	-20°	Positive	Positive	Negative
LENGTHS AVAILABLE	21, 25, 31, 50 mm	21,25,31; OS – 19mm	21,25; Orifice opener - 17mm	21,25	19,21,25,28,31
TECHNIQUE USED	Crown down technique	Crown down technique	Modified Crown down technique	Crown down technique	Step back technique or Crown down technique
SPEED RANGE	1500-2000 rpm	150 - 300 rpm	300-350 rpm	500-600 rpm	300 - 600 rpm
AVAILABLE IN HAND FILES	No	Yes	No	Yes	Yes
HELICAL ANGLE	Constant	Constant	Variable	Constant	Variable

Table 2: Basic Features Of Rotary File Systems

Feature	Protaper	K3	Hyflex	Twisted files	Revo-s
COMPANY	Dentsply Mailefer	Sybron Endo	Coltene Whaledent	Sybron Endo	Micro – Mega
RANGE OF TIP SIZES	#17 to #50	#15 to #60	#8 to #80	#25 to #50	#25 to #40
TAPERS AVAILABLE	Progressively variable	2% to 10%	4% to 8%	4% to 12%	6% & 4%
ROSS-SECTION	Convex Triangular	Asymmetric cross-section	Symmetrical	Triangular	Asymmetrical
RADIAL LANDS	Absent	3 radial lands present	Absent	Absent	Absent
TIP TYPE	Modified guiding tip	Safe cutting tip	Non - Cutting tip	Non-cutting pilot tip	Inactive tip
RAKE ANGLE	Positive	Positive	Negative	Positive	
LENGTHS AVAILABLE	19,21,25	21,25,30	21,25	23, 27	21, 25, 29
TECHNIQUE USED	Coronal then apical sequential	Crown down technique	Crown down technique & apical enlargement	Crown down technique	Crown down technique
SPEED RANGE	150-350 rpm	300 -350 rpm	500 rpm	500 rpm	250 - 400 rpm
AVAILABLE IN HAND FILES	Yes	No	No	No	Yes
HELICAL ANGLE	Variable	Variable	Constant	Variable	Constant