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Evolution of Rotary NI-TI File Systems: A Literature Review

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ABSTRACT *There have been numerous concepts, strategies, and techniques for preparing root canals from the beginning of modern day endodontics. Throughout the decades, a number of files has emerged for negotiating and shaping canals. Now a day, the clinical endodontics has progressed from utilizing a long series of stainless steel hand files and several rotary Gates Glidden drills to integrating Ni-Ti files for shaping canals. When performed properly they can be easy n helpful for shaping canals, 3-dimensional (3-D) disinfection, and filling of root canal systems. This article reviews regarding various generations of Ni-Ti rotary file systems.*

INTRODUCTION

There have been numerous concepts, strategies, and techniques for preparing root canals from the beginning of modern day endodontics. Throughout the decades, a number of files has emerged for negotiating and shaping canals. Endodontic treatment has been typically approached with optimism for probable success in spite of the design of the file, the number of instruments required, and the surprising multitude of techniques advocated. The first endodontic file was crafted by notching round wires at first from watch springs and then from piano wires in the mid 1800s by Edward Maynard. These files were capable of removing pulp and debris from teeth. While the K-files were developed by the Kerr company in 1915, which are the most commonly used stainless steel hand files in endodontics to these days.

Regardless of the methods utilized, the mechanical objectives for canal preparation were brilliantly outlined almost 40 years ago by Dr. Herbert Schilder.[1] Stainless steel hand file techniques, including the step-back, the anti-curvature, the step-down and the balanced force techniques have all been promoted in order to fulfill the instrumentation objectives proposed by Schilder. Now a day, the clinical endodontics has progressed from utilizing a long series of stainless steel hand files and several rotary Gates Glidden drills to integrating Ni-Ti files for shaping canals. When performed properly, the mechanical objectives promote the biological objectives for shaping canals, 3-dimensional (3-D) disinfection, and filling of root canal systems.[2]

The purpose of this article is to identify and compare how each new generation of endodontic Ni-Ti shaping files served to advance canal preparation methods.

SHAPING MOVEMENT OF NI-TI

In 1960 a novel nickel-titanium alloy was developed by William Bueller[3] in Silver Springs, Maryland at the United States Naval Ordinance Laboratory (that is why it is often refered to NITINOL where NOL stands for Naval Ordnance Laboratory). In 1988, Walia et al[4] proposed Nitinol for shaping canals, as it is 2 to 3 times more flexible, in the same file sizes, compared to stainless steel. Files manufactured from Ni-Ti can mechanically prepare curved canals utilizing a continuous rotary motion which has been proven as a trend changing outcome. By the mid- 1990s, the first commercially available Ni-Ti rotary files had come to market.[5] Mechanical classification of each generation of file systems is as per the following. Files will be characterized as having either a passive versus an active cutting action rather than identifying the available cross sections.

GENERATIONS OF ROTARY SYSTEMS[2,6]

1st generation rotary instruments:-

Name of File	Year Of Introduction	Tip	Taper	Unique Feature
Profile	1993	Non cutting	Fixed taper of 2%,4% and 6%	Negative rake angle Passive cutting blades
Quantec	1996	Non cutting	Constant taper	Semi active cutting blades
System GT	1998	Bullet nose tip	Constant rate of taper	Variable pitch reduce the screwing in effect

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Hero 642	1999	Inactive tip	Constant taper	Triple helix geometry
Flex Master	2000	Non cutting	Constant taper	K type cutting blades provide high cutting efficiency, improved torsional resistance

The first rotary NiTi instrument was designed by Dr. John McSpadden with a 0,02 taper and was placed on the market in 1992.At that time File breakage issues were substantial. Dr. Johnson in 1994 introduced the PROFILE line with 0.04 and 0.06 tapered instrument series and the ORIFICE SHAPERS. They were made from the machining of three U-shaped grooves around a tapered NiTi wire, with and unground space remaining between the grooves, providing the so called radial land area. Other rotary file lines, such as LightSpeed (Senia and Wildey), Quantec (McSpadden) and were developed soon afterwards.

By the mid to late 1990s, Greater Taper files - GT Rotary System by Dr. Buchanan (DENTSPLY Tulsa Dental Specialties) became available, providing a fixed taper on a single file of 6%, 8%, 10%, and 12%.[7] In general, first generation Ni-Ti files have fixed tapers of 4% and 6% over the length of their active blades.[8] The single most important design feature of first generation Ni-Ti rotary file was passive radial lands. This encouraged a file to stay centered in canal curvatures during work but these systems required a considerable number of files to achieve preparation objectives.

Second generation rotary files:-

Name of File	Year Of Introduction	Tip	Taper	Unique Feature
Race	1999	Non cutting safe tips	Varying taper	Reamer with alternate cutting edges
Protaper	2001	Modified guiding tip	Multiple degree taper	Multiple increasing / decreasing taper
K3	2001	Safe ended tip	Constant rate of taper	Positive rake angle For Crown down preparation
Hero shaper	2002	Inactive tip	Constant taper	Positive cutting angle Adapted pitch concept
Enosequence	2004	Non cutting precision tip	Constant taper	Alternate contact point electropolished file, Variable pitch
Biorace	2011	Non cutting safe tip	Constant taper	Electrochemical surface treatment Alternating cutting edge

The next generation of NiTi rotary files came to market in 2001.[9] These instruments were different from the previous generation in their cutting edges (and the absence of radial lands). It required a reduced number of instruments to fully prepare a canal by this generation. To this generation belongs EndoSequence (Brasseler USA) and BioRaCe (FKG Dentaire) which provide file lines with alternating contact point.[10] This helps to discourage taper lock and the resultant screw effect associated with both passive and active fixed tapered Ni-Ti cutting instruments. Although these file lines still have a fixed tapered design over their active portions. The critical breakthrough occurred when ProTaper (DENTSPLY Tulsa Dental Specialties) came to market. They have multiple increasing or decreasing percentage tapers on a single file. This revolutionary, progressively tapered design limits each file's cutting action to a specific region of the canal and affords a shorter sequence of files to safely produce deep Schilderian shapes.[11]

During this time to increase the resistance to file separation, some manufacturers electropolished their files to remove surface irregularities caused from the traditional grinding process. However, electropolishing dulls the sharp cutting edges which has been clinically observed and scientifically reported. Hence undesirable inward pressure was required to advance a file up to length. Excessive inward pressure, especially when utilizing fixed tapered files, invites taper lock, the screw effect, and excessive torque on a rotary file during work.[12] More cross-sectional designs have become available to offset deficiencies in general, or inefficiencies resulting from electropolishing. However, increased yet more dangerous, rotational speeds are advocated.

Third generation rotary files:-

Name of File	Year Of Introduction	Tip	Taper	Unique Feature
Twisted	2001	Safety tips	Constant taper	R-phase of NiTi alloy positive rake angle
Wave one	2012	Modified tip	Variable taper	Reciprocating motion
Hyflex	2012	Safety tips	Constant taper	Controlled memory NiTi files

Due to the development of new manufacturing technologies, it was possible to optimize the microstructure of NiTi alloys. Improvements in Ni-Ti metallurgy gave rise to the third generation of mechanical shaping files. In 2007, manufacturers began to focus on utilizing heating and cooling methods to reduce cyclic fatigue and improve safety when rotary Ni-Ti instruments work in more curved canals.[13] Special heat treatment provides files with more resistance to stress and fatigue and hence, broken files. The instruments that underwent this type of processing include HYFLEX CM (HyFlex; Coltene Whaledent, Cuyahoga Falls, OH), K3XF (SybronEndo, Orange, CA), PROFILE GT SERIES X (GTX; Dentsply Tulsa Dental Specialties, Tulsa, OK), PROFILE VORTEX (Vortex) and VORTEX BLUE (Dentsply Tulsa),TWISTED FILES (TFs; SybronEndo , and WaveOne (DENTSPLY Tulsa Dental Specialties).

Fourth generation rotary files:-

Name of File	Year Of Introduction	Tip	Taper	Unique Feature
Self Adjusting File (SAF)	2010	Pointed cylinder	Adapts to canal	Compressible open tube design Up & down, back & froth motion

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Another advancement in canal preparation procedures utilizes reciprocation, which may be defined as any repetitive up-and-down or back-and-forth motion. This technology was first introduced by Blanc, a French dentist in 1950s. In comparison to full rotation, a reciprocating file that utilizes an equal bidirectional movement requires more inward pressure to progress and will not cut as efficiently as a same-size rotary file. Also it is more limited in augering debris out of the canal. From these earlier experiences and better performance reached in reciprocation technology led to a fourth generation of instruments for shaping canals. The 4th generation comprises instruments used with a motion different from rotary or those crafted for as single file techniques which mean they can be used as the only tool to perform the whole shaping phase.

ReDent-Nova (Henry Schein) introduced the self-adjusting file (SAF). It was designed as a thin-walled, hollow cylinder made out of a delicate NiTi grid, featured with an abrasive surface. It has a compressible open tube design. Regardless of the cross-sectional configuration of the canal, it is purported to exert uniform pressure on the dentinal walls. The SAF is mechanically driven by a handpiece that produces both a short 0.4 mm vertical amplitude stroke and vibrating movement with constant irrigation.[14]

Another most popular single-file concept is termed as WaveOne and RECIPROC (VDW). WaveOne is a convergence of the best design features from the second and third generation of files, coupled with a reciprocating motor that drives any given file in unequal bidirectional angles. The counterclockwise (CCW) engaging angle is 5 times the clockwise (CW) disengaging angle which is designed to be less than the elastic limit of the file. After 3 CCW and CW cutting cycles, the file will have rotated to 360°, or one circle. This novel reciprocating movement allows a file to more readily progress, efficiently cut, and effectively auger debris out of the canal.[15]

Fifth generation rotary files:-

Name of File	Year Of Introduction	Tip	Taper	Unique Feature
Revo-S	2012	Inactive tip	Constant taper	It has 3 cutting edges, all located at 3 different radiuses, R1, R2 and R3
One Shape	2013	Safety tips	Constant taper	Variable cross section
ProTaper Next	2013	Modified tip	Variable taper	Unique Asymmetric Rotary M wire technology

The fifth generation of shaping files have a wave motion along the active part of the files. They have been designed such that the center of mass and/or the center of rotation are offset that conveys mechanical rotation into wave motion. This offset design serves to further minimize the engagement between the file and dentin.[16] It also enhances augering debris out of a canal and improves flexibility along the active portion of the file. Brands that produce variations of this technology are REVO-S (Medidenta), ONE SHAPE (Micro-Mega, Besançon, France), and PROTAPER NEXT (PTN; Dentsply Tulsa Dental Specialties/Dentsply Maillefer).

Revo-S, is a unique system, uses only 3 instruments. It has an asymmetrical cross section which increases the available volume for upward debris removal. It has 3 cutting edges, all located at 3 different radiuses, R1, R2 and R3 which allows more flexibility and offers a better ability to negotiate curves.[17] It produces a snake like movement inside the canal.

One Shape is the one and only Nickel Titanium instrument in continuous rotation motion allows for curved canal negotiation with an instrumental and easy dynamic.[18] It has a non- working (safety) tip which ensures an effective apical progression avoiding obstructions. The instrument presents with a variable cross-section along the blade. There are 3 different cross-section zones: The first zone presents a variable 3-cutting edge design. The second, prior to the transition, has a cross-section that progressively changes from 3 to 2 cutting edges. The last (coronal) is provided with 2 cutting edges.[2]

PTN files are the convergence of 3 significant design features, including progressive percentage tapers on a single file, M-wire technology, and the fifth generation of continuous improvement, the offset design. The ProTaper Next files offer improved efficiency with fewer files when compared with the ProTaper Universal files. It has features like Variable taper, Rectangular off-center cross-section design for greater strength, Unique Asymmetric Rotary (AR) Motion and the axis of rotation differs from the center of mass. As a result in PTN files only two points of the rectangular cross section touch the canal wall at a time. New proven M Wire Nickel Titanium alloy provides increased flexibility and resistance to cyclic fatigue as compared to traditional NiTi.[19]

CONCLUSION

New endodontic files for root canal instrumentation are put on the market non-stop, just like older systems are updated. Today, the safest, most efficient, and simplest file systems utilize the most proven design features from the past, coupled with the most recent technological advancements currently available. Rotary instrumentation is an exciting and valuable advancement in canal preparation. The concept of shaping the root canal walls and maintaining the original canal curvature and shape has now become the prime motive of designing the new generation of Nickel Titanium rotary files. In contrast to stainless steel files, Nickel Titanium instruments have sufficient cleaning ability and can preserve the root canal anatomy. Thus appropriate handling of engine driven Nickel Titanium systems in combination with sufficient irrigation facilitates endodontic treatment. To minimize the risk of instrument fracture the use of Nickel Titanium rotary instruments with torque controlled motors not exceeding the recommended speed for the specific system should be used. However, each rotary system has its own advantages; so a hybrid concept should be utilized to gain optimum advantage of the newer generation rotary systems.

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