Conventional Endodontics v/s Rotary Endodontics : A Review

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Abstract:

Comparison of physical and mechanical properties of one conventiona filel and a new NiTi file, which had received an additional thermomechanical treatment. Both conventional (NiTi) and the new type of wire, called M-Wire (MW), were subjected to tensile and three-point bending tests, Vickers microhardness measurements, and to rotating-bending fatigue tests at a strain-controlled level of 6%. Flexibility is more better in rotary ni-ti file.Files with M-Wire is technology apparently increased the tensile strength and Vickers microhardness of the material, but its apparent Young modulus was smaller than that of conventionally treated NiTi. M-Wire presented mechanical properties that can render endodontic instruments more flexible and fatigue resistant than those made with conventionally processed NiTi wires.

Keywords: M wire, niti instrument, stainless steel instrument.

Introduction

Rotary instruments have allowed the instrumentation process to become easier and more productive .The introduction of rotary instruments has allowed the practitioner to "mill" the canals thereby creating shapes that are easier to obturate . As a result of which improved technology ,file breakage has decreased and cutting efficiency has increased along with improvements in file flexibility .Advances in technology and demands from endodontists for instruments that create faster and more standardized preparation has influenced the direction taken by manufacturers when designing new instruments .For nearly half a century endodontic instruments have been manufactured according to guidelines set by the ADA (American Dental Association).These guidelines were rarely challenging. With the discovery of new technologies and materials , manufacturers and clinicians alike began to question solidity of these guidelines this was followed by advances in leaps and bounds of both instruments and instrumentation techniques that challenged what was conventional.

Prior to the prescient review article by Civjan et al.[1] on the potential uses of nickel-titanium alloys for dentistry ,pioneering feasibility studies for orthodontics were performed by George Andreasen et al[2,3] This work led to the commercial development of the first NiTi alloy for orthodontics (Nitinol) by the Unitek Corporation (now 3M Unitek , Monrovia , CA).The mechanical properties of this alloy , along with its notable clinical applications ,were presented in a classic article by Andreasen and Morrow.[4] Particularly important were the very low elastic modulus and very wide range of the NiTi alloys compared with the stainless steel , which was the major orthodontic wire alloy for clinical us at that time

Subsequently , Harmeet Walia thought that this nickel-titanium alloy might have enormous potential for endodontic files , because its very low elastic modulus would permit the negotiation of curved root canals with much greater facility than stainless steel instruments available at the time.Using special large-diameter orthodontic wires contributed by the Unitek Corporation , Quality Dental Products (Johnson City ,TN) fabricated the first prototype NiTi hand files by machining rather than the conventional manner of twisting the tapered stainless steel wire blanks.The properties of these first NiTi files in bending and torsion were compared with those for stainless steel wire blanks.The properties of these first NiTi files in bending and torsion were compared with those for stainless steel hand files of the same size manufactured by a similar machining process..

Based on these promising research results , innovative dental manufacturers began to market NiTi endodontic instruments in the 1990s.A major impetus was the merger of the Quality Dental Products with Tulsa Dental Products (now Dentsply Tulsa Dental ,Tulsa , OK), and this latter company introduced ProFile NiTi rotary files in 1993. Subsequently , many other manufacturers introduced NiTi rotary instruments for endodontic, and studies of the properties and perforamance of these instruments became an intensive area for endodontists research. In January 2007 , PubMed listed over 350 articles dealing with various aspects of the NiTi endodontic instruments since their inception.

What is Conventional

Before ,venturing into the realm of 'recent advances in instrumentation technique's a revision of what is considered conventional would be wise.

Conventional instruments are :

1) Hand driven
2) Made out of stainless steel
3) Standardized according to ADA specifica-tions.
4) Used in step-back technique

Examples : H- Files , K - Files , Reame

Systems of Preparation

Currently,with the available technology that utilizes a combination of mechanical shaping & chemical cleaning any instrumentation technique must be comprised of the following:

1. Direction of instrumentation
   - **a. Step-Back** : This technique involves beginning the preparation from the apical portion of the root canal upto coronal most part. For many years this was considered the conventional direction when doing root canal treatment.
   - **b. Crown-Down** : In its purest form , this technique involves starting at the most coronal part of the canal and finishing the preparation at the apical part. Along the years variations of this technique have appeared but in essence they are the same.
   - **c. Hybrid(Combination)** : The hybrid technique involves a combination of both step-back and crown down techniques. The line here is hazy , between what is considered a crown-down technique and what is considered a hybrid technique. Some crown-down techniques may also be considered hybrids.
2. A Sequence of instruments i.e. # 15 followed by # 20 , # 25
3. An instrument motion i.e. Reaming , filing , balanced force

Disadvantages with Conventional Files & Techniques

- Preparation is time consuming
- Occupational hazards
- The root canal preparations are not standardized
- Step-back technique results in large amount of debris being extruded into apical area during preparations

Nickel – Titanium Alloy:

In early 1960s , nickel – titanium alloy was developed by W. F . Buehler , a metallurgist investigating non-magnetic , salt resistant , water proof alloys for the space program at the " Naval Ordinance Laboratory " , Silver Springs , Maryland , USA[8]

This was named " Nitinol " , an acronym for the elements from which the material was composed . Ni for nickel , Ti for titanium and NOL for the Naval Ordinance Laboratory. Nitinol is the name given to a family of intermetallic alloys of Ni and Ti which have been found to have unique properties of shape memory and super elasticity.

The first investigation of nickel –titanium in endodontics was reported in 1988 by Walia , Brantely and Gerstein using # 15 files fabricated from the nickel – titanium orthodontic alloy.

The desirable properties of nickel – titanium instruments are :

a. Super elasticity
b. Shape recovery c.High resistance to cyclic fatique

Properties of Niti Instruments

1 **Elasticity :** NiTi being superelastic in nature , it is impossible to twist NiTi blank counterclockwise to produce spiral because NiTi alloy undergoes nearly no permanent deformation. Moreover they will fracture when being extensively twisted to produce a spiral.

2. **Wear Resistance & Hardness :-** Grinding of nickel based alloys is quite difficult because considerable wear of the milling head occurs within a short time. This leads to structural defects especially on the cutting edge of NiTi.10 The

microhardness of NiTi is 303 to 362 VHN whereas that of stainless steel is 522 to 542 VHN.Due to these surface irregularities and low surface hardness cutting efficiency of NiTi files is less as compared to stainless steel.

3. **Fracture :-** In general , instruments used in rotary motion break in two distinct modes , torsional and flexural. Torsional fracture occurs when an instrument tip is locked in a canal while the shank continues to rotate , thereby exerting enough torque to fracture the tip.

This also may occur when instrument rotation is sufficiently slowed in relation to the cross-sectional diameter[11]

In contrast , flexural fracture occurs when the cyclic load leads to metal fatigue .This problem precludes the manufacture of continuously rotating stainless steel endodontic instruments , because steel develops fatal fatigue after only a few cycles.

NiTi instruments can withstand several hundred flexural cycles before they fracture . Rotary nickel-titanium instruments with larger tapers and sizes consistently fractured after fewer rotations , and although the radius of the curves was halved , fatigue – life was reduced by 400%.The torque generated during canal preparation depends on a variety of factors , and an important one is the contact area. The size of the surface area contacted by an endodontic instrument is influenced by the instrumentation sequence or by the use of instruments with different tapers.[12]

Advantages & Disadvantages of Nickel-Titanium over Stainless Steel

Advantages:

- NiTi files have 2-3 times more elastic flexibility than stainless steel.
- NiTi files can retain the shape of the canal and do not straighten like stainless steel instrument.[13]
- NiTi files are biocompatible as indicated by trace element studies and have excellent anticorrosive properties.
- Post treatment pain is greatly reduced by NiTi due to fewer incidences of ledges and perforation during their use.
- During autoclaving or dry heating NiTi instruments for sterilization , rotation to breakage studies indicate a transformation of residual martensite to austenite to restore the hardness of the instrument.

Disadvantages:

- Expensive when compared to stainless steel files.
- Does not give any indication before fracture
- Cutting efficiency of NiTi is only 60 % than that of a matching stainless steel file.
- It cannot adapt to sudden variations in speed resulting in fracture of the instrument.

Comparing Nickel - Titanium & Stainless Steel:

a) Using direct digital imaging on nickel-titanium and stainless steel instrumentation we found that NiTi files cause significantly less transportation.

b) Portion removed from the canal by NiTi and stainless steel files was not significantly different.

c) Time required for instrumentation was not significantly different for NiTi and Stainless steel instrument

PROPERTY	NITINOL	STAINLESS
Density G/Cm^2	6.45	7.9
Melting Temperature ^{0}C	1310	1500 – 1550
Vickers Hardness	303-362	600 – 610
Rockwell	30 above TTR , 17 below TTR	
Tensile Strength	827-117 above TTR	2000
Yield Strength	621 – 793 above TTR	1600
Modulus of Elasticity	83- 110 above TTR	285 x 10^3N/mm^2
Elongation %	1-15 above TTR - 60/below TTR	2
Biocompatibilty	Excellent	Fair
Torque	Excellent	Poor
Magnetic	No	Yes
Coefficient of Thermal Expansion Cm/cm/0C	6.6 – 11 X 10-6	17.3 x 10 -6
Resistivity micro-ohm * cm	80 - 100	72

Table : Shows Difference in Nitinol & Stainless Steel Files Properties

Recent Advances in Nickel - Titanium Metallurgy:

R Phase : The R phase is an intermediate phase with a rhomboidal structure that can form during forward transformation from martensite to austenite on heating and reverse transformation from austenite to martensite on cooling.

M Wire Technology : According to the latest study on metallurgical characteristics of M-wire this system is composed of three crystalline phases - deformed and micro twinned martensite , premartensitic R - phase , and austenitic phase .Some of the rotary systems based on this technology are :- Protaper Next , Twisted Files.

Controlled Memory Wires : This system consists of subjecting the files to a specialized heat treatment with an austenitic finish temperature of approximately 55 degree C , e.g. , Hyflex rotary instruments.

Niti Phases for Nickel-titanium Alloys:

The mechanical behavior of the superelastic ,nonsuperelastic , and shape memory NiTi alloys arises from the nature and proportions of their microstructural phases , which has been discussed by Brantley14 for orthodontic NiTi wires. There are three NiTi phases in these alloys.[15] Austenitic NiTi (austenite) has a complex body-centered cubic structure, and exists at higher temperatures and lower stresses

MARTENSITIC

Martensitic NiTi (martensite) has a complex structure described as monoclinic , and exists at lower temperatures and high stresses. Transformation between austenite and martensite occurs by a twinning process at the atomic level, and the reversibility of this twinning is the origin of shape memory.[15,16]

During tensile loading , the upper superelastic plateau corresponds to the stress-induced transformation from the initial austenitic structure to martensite , and the lower superelastic plateau corresponds to reverse transformation from martensite to austenite.

R- Phase

The R-phase is an intermediate phase with a rhombohedral structure that can form during forward transformation from martensite to austenite on heating and reverse transformation from austenite to martensite on cooling.[15] Formation of R-phase is favoured by the presence of dislocation and precipitates in the NiTi alloy.[17] A substantial density of dislocations is expected in NiTi orthodontic wires and endodontic instruments, because the alloy experiences considerable permanent defor-mation during the manufacturing processes. Because of the relatively narrow range of the equiatomic NiTi phase field in the nickel-titanium phase diagram at low temperatures ,Ti2Ni and Ni3Ti precipitates are expected in Ti-rich and Ni-rich alloys, respectively.[18] Oxide particles also form during processing of the NiTi alloy by manufacturers.15Such nickel-titanium oxide precipitates have been observed by Alapati et al.[15] on the cutting tip of a rotary instrument and were presumably elongated during the manufacturing process for the starting wire blank.

Several phase transformation temperatures are Important: As the starting temperature for transformation to austenite ; Af the temperature at which transformation to austenite is finished; Ms ,the starting temperature for transformation to martensite; and Mf ,the temperature at which transformation to martensite is finished .The Rs and Rf temperatures for transformations involving the R-phase are defined in a similar manner.

If a NiTi orthodontic wire or endodontic instrument is cooled to a sufficiently low temperatures , it will consist entirely of martensite .Upon heating ,martensite will start transforming to R-phase at the Rs temperature , and this transformation will be finished at the Rf temperature. With further heating , R-phase starts transforming to austenite at the As temperature and transformation is finished at the Af temperature. Alternatively , if the NiTi orthodontic wire or endodontic instrument is heated above the Af temperature, it will be converted entirely to austenite. Then upon cooling to sufficiently lower temperature, the alloy starts transforming from austenite to R-phase at the Rs temperature, and this transformation will be finished at the Rf temperature. With further cooling , R-phase starts transforming to martensite at the Ms temperature , and transformation is finished at the Mf temperature.

Temperature Induced Phase Transformation

The crystal strcture of NiTi alloy at higher temperature ranges (1000 c) is stable , body centered cubic lattice which is referred to as the austenite phase or parent phase . NiTinol has the particular characteristic that when it is cooled through a critical transformation temperature range (TTR) ,the alloy shows dramatic changes in its modulus of elasticity (stiffness) , yield strength and elastic resistivity as a result of changes in electron bonding.

By reducing the temperature through this range , there is a change in the crystal structure which is known as the marten sitic transformation. This phenomenon causes a change in the physical properties of the alloys and gives rise to shape memory characteristic.

R-Phase is formed during forward transformation of martensite to austenite on heating and reverse transformation from austenite to martensite on cooling.

Forward transformation sequence – M R A (Heating)

Reverse transformation sequence – A R M (cooling)

Recent Rotary Instruments:

1) Wave One Gold (Dentsply)

Introduced in 2014.

Reinforces Patient Safety

- Primary Wave One GOLD file is 50% more resistant to cyclic fatigue than Wave One Primary file.
- Reduced screwing effect compared to standard rotary systems[54].

Covers a Wider Range of Canal Morpho logies-

- Enhanced file flexibility
- Extended size range : small , primary ,medium , large.

Shortens the Shaping Time

- Takes the cutting efficiency to a higher level.
- A single file per treatment translates into faster shaping time and thus more time for irrigation.

Ready to Use + Single Use

- Simplicity.
- Increased safety margin , by always using files with maximum fatigue resistance potential.
- Maximised cutting efficiency
- Wave One Gold brings a metallurgically advanced single-file technique with optimized tip diameters , tapers , and the cross-section to produce a file that really improves safety , efficiency and flexibility when preparing canal

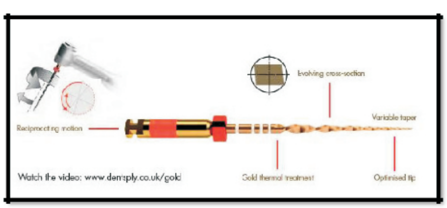
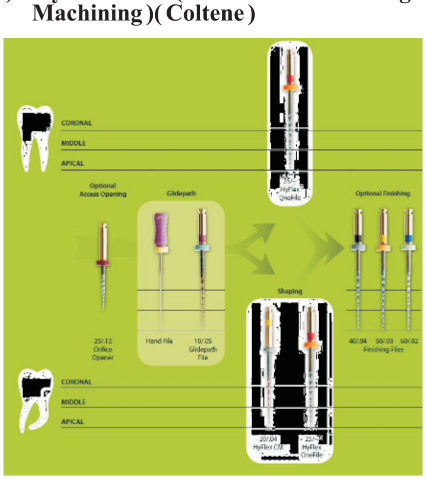


Figure1- wave one gold file

2) Hyflex-EDM(Electrical Discharge Machining)(Coltene)



Introduced in 2015

- The new Hyflex EDM files constitute the 5th generation root canal files. **(Figure2)**
- Hylex EDM files have completely new properties d/t their innovative Manufacturing process using electric discharge machining.

Work pieces are machined in the EDM manufacturing process by generating a potential between workpiece and the tool.

The spark causes generated in this process the surface of the material to melt and evaporate.

This creates the unique surface of the new NiTi files and makes the Hyflex EDM files stronger and more fracture resistant.

All Hflex EDM NiTi files can be used at 400 rpm and at a torque of to 2.5 Ncm (25 mNm) except the Glidepath files which can be used with 300 rpm and at a torque of upto 1.8 Ncm (1.8 mNm).

- Upto 700% higher fracture resistance.
- Specially hardened surface.
- ess filing required for treatment successs.

Reduced Number of Files[57]

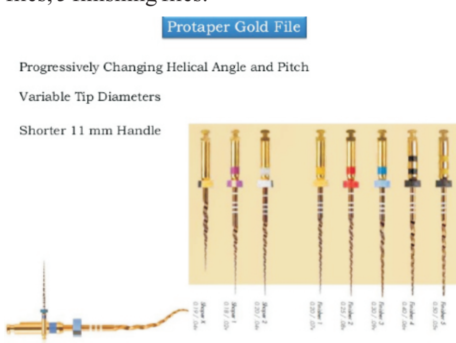
Depending on the clinical situations , use of Hyflex EDM files reduces the number of files to 2-3 pieces particularly in straight and larger canals.

3) Protaper Gold:

Introduced in October 2016 by Sirona Dentsply

Taper- variable tapered files

No of files It is a set of 8 files …..3 shaping files, 5 finishing files.



(Figure 3)- sequence of protaper gold file

Contraindication

As with all mechanically driven root canal instruments, Protaper Gold™ files should not be used in cases of severe and sudden apical curvatures due to heightened risk of separation Protaper Gold™

Speed is 300rpm and torque is 1.5- 3

Technology

It has advanced metalurgy and greater f lexibility, greater resistance to cyclic fatigue

I Race Unicon Endostar

Introductory set of system Endostar E5 consists of 5 nickel-titanium files, numbered 1, 2, 3, 4, 5 markedwith blue stripes on the handle and K file size 15, which should be used to check the patency of the root canal

Rotary Endostar E5 files easily "fit" even in most curved canals, minimizing the risk of perforation

They have modified shape of S NiTi file with two 90 degree cutting angles, which facilitates and accelerates the treatment of the canal apical part.

All files have shallower cuts (grinds), very elongated flutes and safe, rounded tip. Endostar E5 rotary files can work with all endodontics contra angles/ micro motors with speed of 150 to 300 rotations per minute. They are very well matched with S5 Endo Motor, which has settings numbered 1, 2, , 4, 5 for the appropriate E5 instruments.

Figure 4- sequence of rotary endo star files

The size , taper and the length of individual files:

Instrument Size	No. of Strips on the Handle	Taper (%)	ISO Size	Instrument Length
1	1	8	30	18mm
2	2	6	30	23,28mm
3	3	4	30	23,28mm
4	4	4	30	23,28mm
5	5	4	30	23,28mm

Clinical instruction of use for End ostar E5 rotary files:

1. Prepare tooth
2. Locate all root canals
3. Prepare a chamber
4. Determine the working length of the canal
5. Prepare a root canal to working length
6. Preparation of the apex

The preparation of the apex begins with file number 5, gradually changing the size of files. Start preparing with last used file and change the sequence numbers such as 5, 4, 3.

The last instrument which should be used is file number 3. All instruments should reach the apex, thereby ending the treatment. Finish the treatment with hand instrument confirming the patency of the canal working length. If you need a wider apex preparation, continue with hand instruments of larger sizes such as 45, 50 etc.

In certain clinical cases Big Apical instruments should be used to get the properly treated apex.

Important notes about end ostar E5 rotary files.

1. Use to work with an appropriate hand

piece as to obtain the speed of 150-300 rpm. The speed of the contra angle/hand piece/micro motor should be constant during the canal treatment. During work do not use an excessive force, move the contra angle/hand piece/micro motor up and down ('pumping movement"). Work in canal as short as possible, and always use a wetting agent.

2. Files 5, 4, 3 should be used with a maximum of 5 times, if they are not evidently deformed. Files number 2 and 1 can be used 10-15 times, provided that they are not deformed and are used judiciously
3. If the files have been subjected to high twisting forces, especially in highly curved canals, the dentist should consider using the files only once

File size	Torque(GCM)	Torque(NCM)	S5 Endomotor Settings
5	30-50	0.3-0.5	5
4	50-100	0.5-1.0	4
3	100-200	1.0-2.0	3
2	200-300	2.0-3.0	2
1	300-400	3.0-4.0	1

Torques for E5 Instruments :

Working speed of the contra angle/ micro motor/ hand piece: 150 - 300 rotations/ minute. These levels should be treated as indicative and apply them to the closest values available in a particular type of equipment used (always use lower, not higher values).

If the contra angle/handpiece/micromotor allow only the pre-determined values always choose lower value, not exceed the ranges specified above. The values are given in terms of different scientific units (gcm, Mcm etc) so as to easily adapt them the most commonly used equipment.

Effectiveness

+ Unique design of the instrument brings quick and safe preparation of a root canal with reciprocal movement. + Allows for easy obturation with 6% great taper gutta percha points.

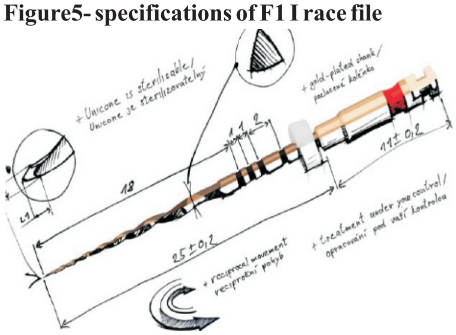
Flexibility

+ Made from high flexible Nickel-Titanium with extended lifetime thanks to a special technology treatment. + Variable triangular cross-section design guarantees ideal combination flexibility and resistance.

Originality

+ Comfortable force and easy to manage by the dentist. + Gold plated shank for better protection of dental handpieces.

Figure5- specifications of F1 I race file



Its unique construction and material processing predestines the Unicone instrument to highly professional results when treating root canals.

Reciprocal movement intensifies the instrument's unique properties.

The key instrument is Unicone 6/025. The 6/020 is intended for narrow root canals, and the 6/040 for wide root canals.

Unicone has an inactive tip designed based on our experience gathered while developing our previous successful systems (WIZARD CD Plus and WIZARD Navigator), the risk of root canal perforation is thus further eliminated.

Special heat-treated NiTi material increases Unicone's flexibility and durability

New refined NiTi material The newly developed procedure improves both the instrument's flexibility and brittl fracture resistance.

Comparison of a instrument made of a standard NiTi alloy with the one made of the refined alloy by MEDIN (artificial canal – 5 mm radius; 60 ° angle)

Comparison of the Unicone with other reciprocal instruments available on the market; in an artificial canal (5 mm radius; 60 ° angle)

Conclusion:

An explosion in knowledge and technology has created an exciting time in the speciality of endodontics.

New instruments and materials seem to appear faster than clinicians can learn about the preceding versions, This has created an educational challenge for practitioners , universities , and manufacturers , requiring a greater degree of cooperation among these groups than ever before.

Clinicians should only use those instruments and materials that have been shown safe and effective by independent studies

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