Recent Advances in Instrumentation Techniques

In recent years, 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 challenged until recently. With the discovery of new technologies and materials, manufacturers and clinicians alike began to question the solidity of these guidelines this was followed by advances in leaps and bounds of both instruments and instrumentation techniques that challenged what was conventional.

What is Conventional?

Before, venturing into the realm of 'recent advances in instrumentation techniques' 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 specifications
4. Used in a step-back technique

Examples: H-Files, K-files, K-reamers etc…

Components of a Preparation Technique (System 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. A Direction of instrumentation

    a. ***Step-back:*** This technique involves beginning the preparation from the apical portion of the root canal ending at the 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.

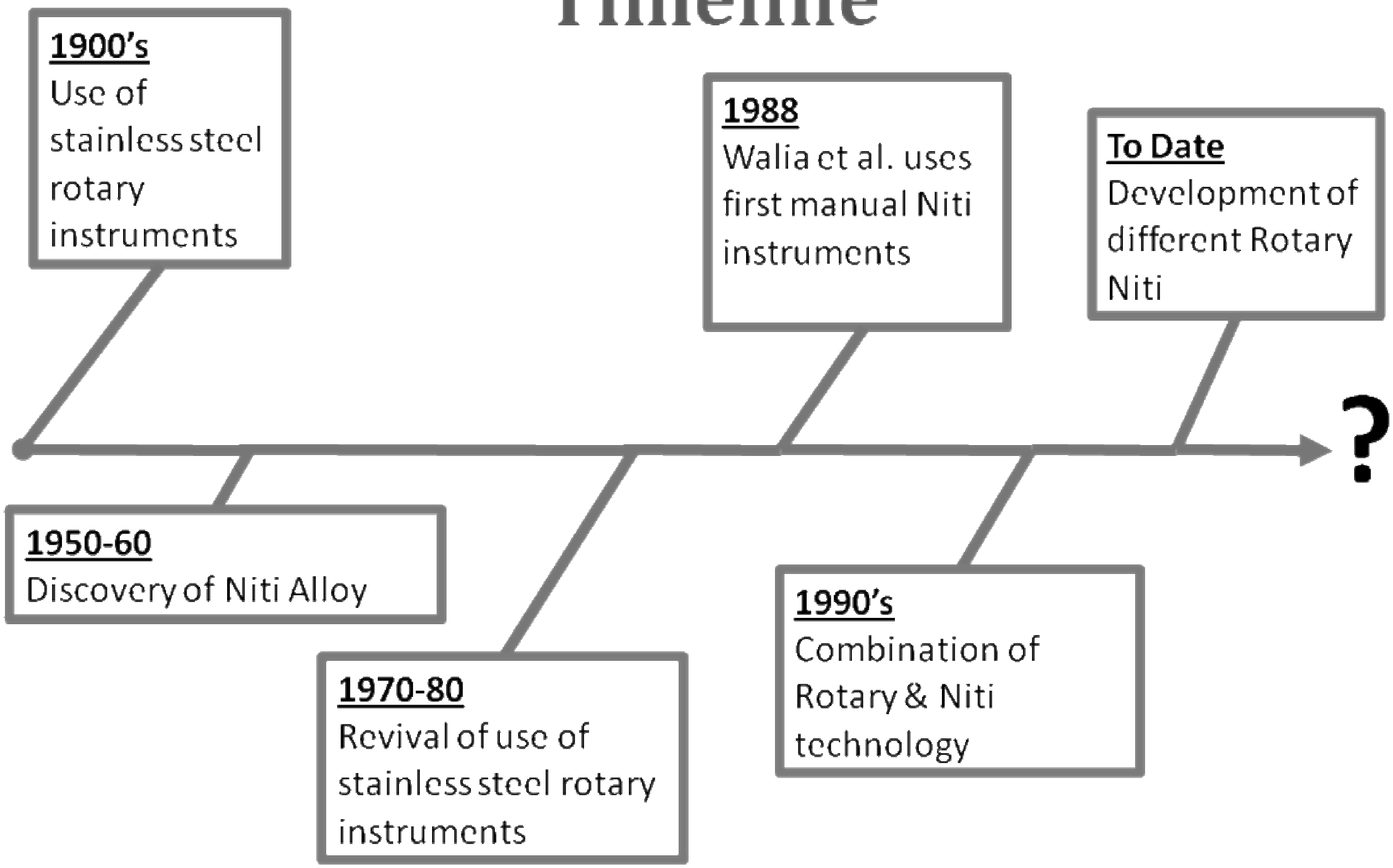
2. A Sequence of instruments i.e. #15 followed by #20, #25 etc…
3. An instrument motion i.e. Reaming, filing, balanced force etc…

What is Wrong with Conventional Files and Techniques (Disadvantages):

1. Preparation is time consuming
2. Occupational hazards i.e. Carpal Tunnel Syndrome
3. The root canal preparations are not standardized
4. Managing curved canals is difficult
5. Higher possibility of preparation errors i.e. Ledging & Perforation
6. Step-back techniques result in a large amount of debris being extruded into the apical area during preparation

Dr. Ashraf Refai BDS, MSc, DD, HMD 2008

Endodontic Advancement Timeline



The Endodontic Advancement Timeline:

Early 1900's: Technology at the turn of the last century was still in its infancy, rotary instruments were large, stiff and crudely manufactured and had very limited use in endodontics (Anterior teeth). When used it was common for these instruments to damage the root canal.

1950-1960: During the period Nickel Titanium alloy was discovered by researchers in the NASA space program. Its first use in Dentistry was in the orthodontic specialty while its use in endodontics didn't appear till the 1980's.

1970-1980: Improvement in machining technology and material science brought about a revival of the use of rotary instruments in endodontics. These instruments were better manufactured and designed than those of the turn of the century, but there use was limited to the straight portions of the middle & coronal thirds of the canals. These instruments, like the Gates Glidden & Peso Drills, if not used properly could also result in damage to the root canal anatomy.

1988: Walia and associates used files machined from the flexible nickel titanium alloy and used them in preparation of root canals successfully.

1990's: A general direction of the endodontic community to combine the use of rotary instrumentation and nickel titanium technology. This resulted in the appearance of the first rotary nickel titanium instruments.

To Date: After the appearance of the first rotary nickel titanium instruments, the dental market became flooded with differently designed instruments each claiming to be better than their competitors. This was followed by exhausting research to prove or disprove these claims.

Recent Advancement Options:

The question arises? What are the possible *recent advances*?

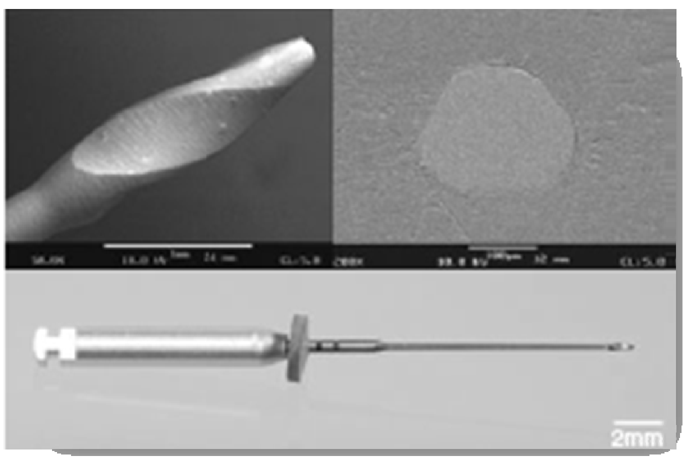
1. Innovations in Instrument shape, design & standardization
2. Change in material of manufacture i.e. Nickel Titanium Alloy
3. Use of engine driven instruments & instrument motion

4. Utilizing crown-down techniques

Rotary Nickel Titanium Instruments:

1. Lightspeed instrument
2. Profile instrument
3. GT Rotary instrument
4. K3 Instrument
5. Hero instrument
6. RACE instrument
7. Pro Taper instrument

1. Lightspeed Instrument:



This instrument was introduced in the early 1990's. It has a very unique design unlike any other instrument in the market. It has the following characteristics:

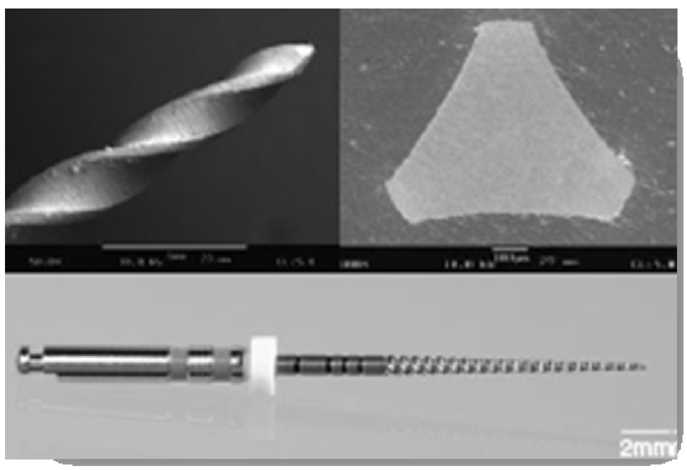
1. Similar in design to the Gates Glidden drill, only the tip of the instrument cuts
2. Minimal incidence of fracture and when fracture occurs it occurs high on the shank of the instrument so it is easy to remove
3. The predecessor of this instrument was called Canal Master U system they were made out of stainless steel
4. The most recent lightspeed instrument is called Lightspeed LSX

5. Used in a low torque hand piece at 1500-2000 rpm
6. **Disadvantage:** Too many instruments in the sequence

Lightspeed Instrument Details

No. of Instruments/ set	Tip sizes	Size Increments	r.p.m. (recommended)	Lengths
25	20-140	2, 5 From #60: 5 From #70: 10	1500-2000, very low axial force, low torque	21, 25, 31 mm

2. Profile Instrument:



This was one of the first rotary nickel titanium instruments it was introduced in 1994. It has the following characteristics:

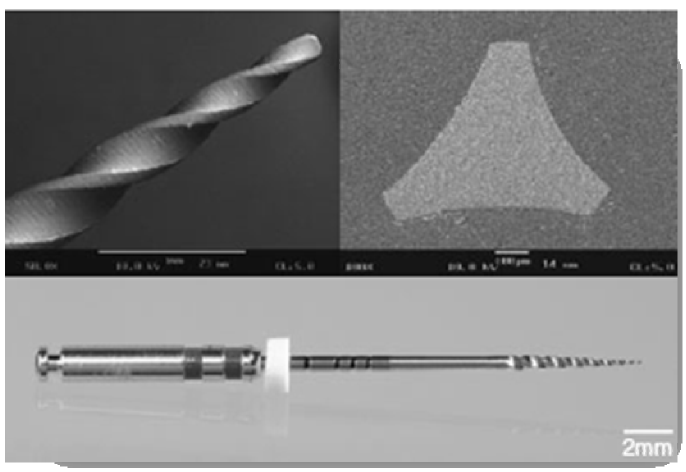
1. It has a U-Shape designed cross-section with *radial lands* that center the instrument in the canal
2. It has 16 mm cutting portion
3. The instrument has a blunt non-cutting tip to minimize ledging and perforation
4. Comes in 0.04 and 0.06 tapers & recently introduced 0.02 taper
5. Used in a high torque hand piece at speeds between 150-300 rpm

6. **Disadvantages:** Larger sizes are very stiff, high fracture incidence & easily pulled into the canal

Profile Instrument Details

No. of instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
Orifice Shapers: 6	20-80	10; from 60: 20	150 to 350, low apical force, torque to fracture and working torque dependent on instrument size	19 mm
ProFile .06: 6	15-40	5		21 mm, 25 mm, some 31 mm
ProFile .04: 9	15-90	5; from #45: 15; from #60: 30		
ProFile .02: 6	15-45	5		
Profile Series 29	13-100	Varies, 29%		21 mm, 25 mm

3. GT Rotary Instrument:



This instrument was also one of the first rotary nickel titanium instruments to be introduced to the endodontic community. This instrument first appeared in 1994 with the introduction of the profile instrument. It has the following characteristics:

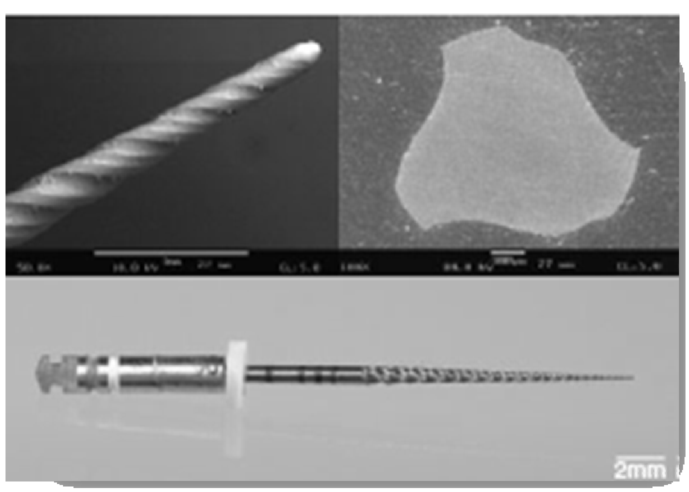
1. Initial the instrument was designed with a tip size corresponding to a size #20 iso standardized instrument.

2. The instrument has a blunt non-cutting tip to minimize ledging and perforation
3. The instrument variability is in the taper, they come in 0.04, 0.06, 0.08, .1 and even .12 tapers.
4. The instrument has a u-shaped cross-sectional design with radial lands
5. Used in a high torque low speed hand piece at 150-300 rpm
6. Instruments with larger tip sizes were developed to accommodate for larger canals
7. **Disadvantages:** Larger sizes are very stiff, high fracture incidence & easily pulled into the canal

GT Rotary Instrument Details

No. of instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
Size 20 GT rotary files: 4	20	None, tapers of .04 to .10	150 to 350, minimal axial force, low torque to fracture but higher working torque	18, 21, 25 mm
Size 30 GT rotary files: 4	30	None, tapers of .04 to .10		
Size 40 GT rotary files: 4	40	None, tapers of .04 to .10		
GT accessory files: 4	35, 50, 70, 90	Varies, taper .12		

4. K3 Instrument:



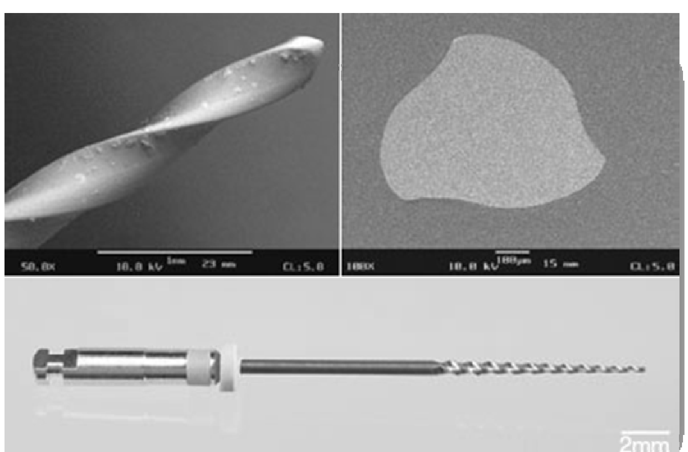
This instrument has a complicated design and comes from a line of instruments designed by Dr. McSpadden the Quantec 2000, Quantec SC, Quantec LX and finally the K3 instrument. It has the following characteristics:

1. The tip has a bullet head non-cutting tip
2. The instrument core thickness is variable making it stronger at the apical part
3. Comes in 0.02., 0.04 and 0.06 tapers and various tip sizes
4. Has wide radial lands to keep instrument centered in the canal
5. Has a slightly positive rake angle (Better cutting efficiency)
6. Used in a high torque low speed hand piece at 300-350 rpm
7. **Disadvantages:** Similar to the Profile & GT instruments

K3 Instrument Details

No. of Instruments/ set	Tip sizes	Size Increments	r.p.m. (recommended)	Lengths
27	15-45 with .02 taper; 15-60 with .04 and .06 taper	5	300 to 350, minimal axial force	21, 25, 30 mm

5. ***Hero Instrument (High Elasticity in Rotation):***



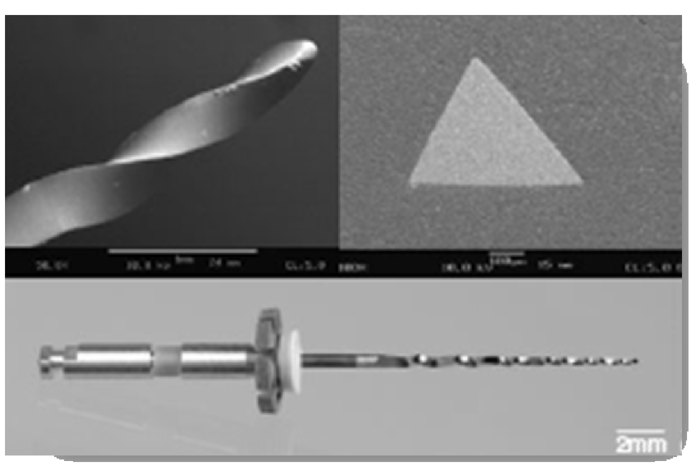
The hero 642 instrument is one of the first 2[nd] *generation instruments* that incorporated a positive rake angle into its design, this supposedly improves cutting efficiency. It has the following characteristics:

1. It has a somewhat triangular cross-section with a close resemblance to and H-file
2. The instrument has a non-cutting tip
3. The instrument comes in sizes from size #25 to size #40
4. The instrument comes in different tapers 0.02, 0.04 and 0.06
5. The instrument has a high level of flexibility hence its name
6. Used in a high torque low speed hand piece at 300-600 rpm
7. Newer version called the, *heroshaper instrument,* are better manufactured and have slight design improvements that prevent instrument binding and reduce instrument fractures

<u>HERO Instrument Details</u>

No. of instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
12	20, 25, 30 with .02, .04, and .06 taper; 35 to 45 with .02 taper	5	300-600, with minimal axial force	21, 25 mm

6. RACE Instrument (Reamer with Alternating Cutting Edges)



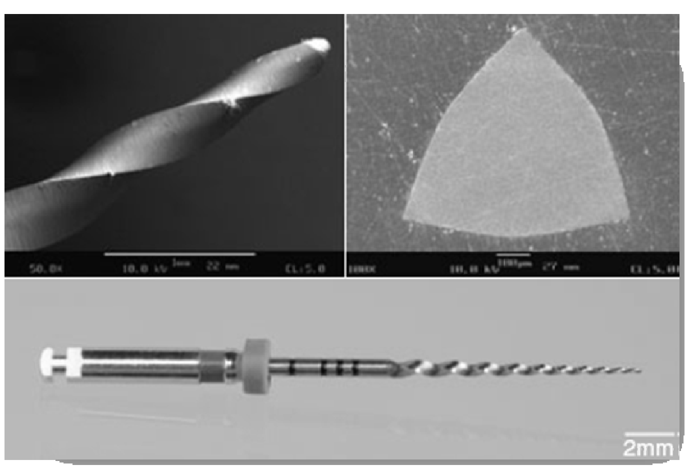
This is a novel instrument produced with a few differences from the previously mentioned instruments. It has the following characteristics:

1. The instrument has a triangular (0.04 & 0.06) or square cross-section (0.02 taper)
2. Initially designed in 0.02 taper but comes in 0.04 and 0.06 tapers as well
3. The instrument is more flexible than its competitors
4. The instrument tip is non-cutting
5. It looks similar to conventional files, it has twisted areas alternating with straight areas
6. Used in low torque hand piece at speeds around 600-700 rpm

<u>RACE Instrument Details</u>

No. of Instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
15	15-60 (.02)	5 and 10	Up to 600,	19,
	25-35 (.04) 30, 40 (.06) 35 (.08) 40 (.10)	Varying tapers	Minimal axial force	25 mm

7. ProTaper Instrument



The ProTaper instrument is one of the most readily available and widely used rotary nickel titanium instruments used today. It is based on a unique design incorporating a variable taper along the length of the instrument. It has the following characteristics:

1. The instrument has a triangular cross-section and appears to be a modified K-File
2. It has no radial lands
3. The Shaping files have a partially active tip while the finishing files have a non-cutting tip
4. Each size instrument has a progressively variable taper along the length of the cutting portion
5. The instrument come in 6 sizes (3 Shaping files & 3 Finishing files):

   a. SX File:
   Tip Size = 0.19 mm
   Taper = D_0 to D_9: Taper increase from 0.19mm to 1.1 mm
   D_9 to D14: A reduction in taper to increase flexibility

   b. S1 File:
   Tip Size = 0.185 mm
   Taper = D_0 to D_{14}: Taper increase from 0.185 to 1.2 mm variably along the length of the file (increasingly larger taper)

   c. S2 File:
   Tip Size = 0.20 mm
   Taper = D_0 to D_{14}: Taper increase from 0.02 to 1.1 mm variably along the length of the file (Increasingly larger taper)

d. F1 File:

Tip Size = 0.2 mm

Taper = D_0 to D_3: Taper increase equal to 0.07 mm/mm

D_3 to D_{14}: A reduction in taper to increase flexibility

e. F2 File:

Tip Size = 0.25 mm

Taper = D_0 to D_3: Taper increase equal to 0.08 mm/mm

D_3 to D_{14}: A reduction in taper to increase flexibility

f. F3 File:

Tip Size = 0.3 mm

Taper = D_0 to D_3: Taper increase equal to 0.09 mm/mm

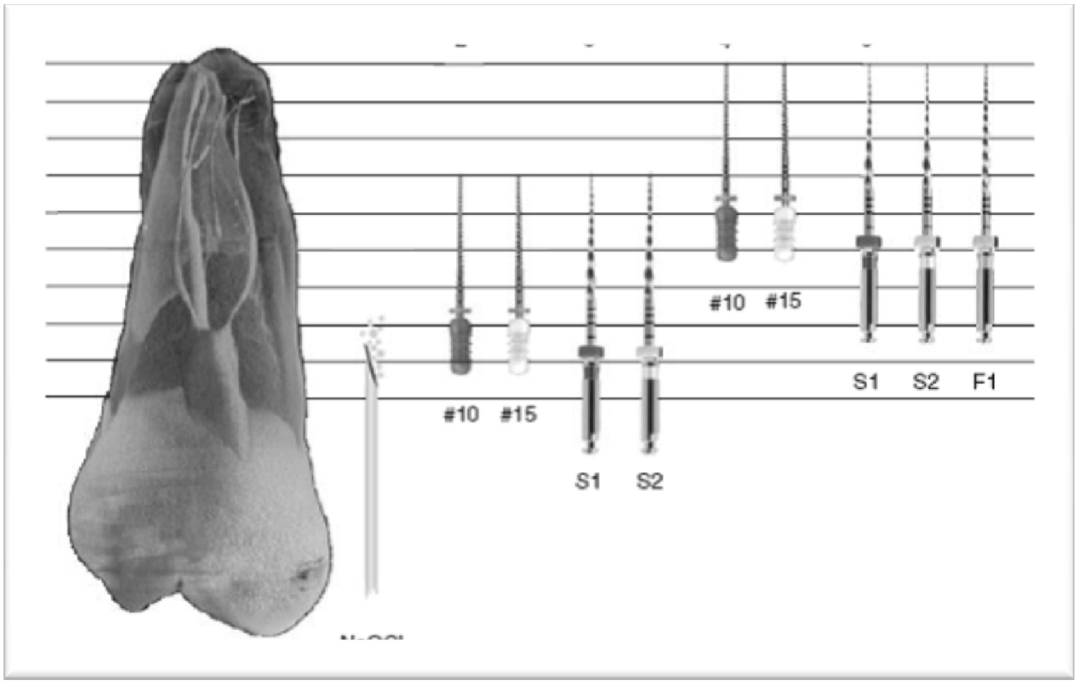
D_3 to D_{14}: A reduction in taper to increase flexibility

6. Used in High torque hand piece at speeds around 150-300 rpm

ProTaper Instrument Details

No. of instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
6 (3 shaping files; SX, S1, S2; 3 finishing files; F1, F2, F3)	19-30	Vary along the working part of an individual instrument	150 to 350 minimal axial force, low to medium torque to fracture, varying working torque	19, 21, 25 mm

<u>ProTaper Instrument Sequence:</u>



1. Fill the access cavity brim full with NaoCl.
2. Negotiate the canal & create a glide path with size #10 followed by #15 files
3. Begin enlarging the coronal portion of the canal using the SX in a passive light motion do not force the instrument.
4. Irrigate the enlarged potion of the canal and maintain patency with hand files #10 & #15.
5. Begin enlarging the canal with the S1 file followed by the S2 file two thirds of the way into the canal, irrigate frequently and in between the files.
6. Estimate your working length using an apex locator (If available) and a confirmatory tooth length x-ray.
7. Irrigate the enlarged potion of the canal and maintain patency with hand files #10 & #15.
8. Enlarge the canal to the full working length using S1 & S2 Followed by the finishing files to the required apical size #20 (F1), #25 (F2) or #30 (F3).
9. Finally, rinse with NaoCl and confirm patency

<u>Note:</u> Once an instrument reaches the full working length, don't linger, remove the instrument and use the next one in the sequence. Continuous preparation at the length will only increase possibility of errors or instrument fracture.

<u>Guidelines For Using Rotary Nickel Titanium Instruments</u>

1. **S**traight **L**ine **A**ccess (SLA): This is mandatory, so the instruments long axis is a parallel as possible to the long axis of the root canal. If the instrument doesn't have enough SLA Gates Glidden drills maybe used to further straighten the coronal portion of the canal before preparation using Nickel Titanium Instruments.

2. The canals must be patent and negotiated to a minimum size #10 preferably a size #15 file. This is to create a 'glide path' for the rotary instrument to reach the apical portion of the canal easily.

3. Be familiar with the canal anatomy, curvatures, recurvatures and merging canals (Type I,II,III,IV).

4. Use the instruments in the recommended sequence and at the torque and speed as per the manufacturers' instructions to minimize the possibility of instrument fracture. **<u>NEVER SKIP FILES.</u>**

5. Use copious irrigation and Intracanal lubricant at all times during the instrumentation procedures to minimize stress on the instruments.

6. Use minimal pressure & don't force the instruments, the optimum amount of pressure is less than that necessary to break a sharp lead pencil. The rule is 'Take what the canal will give you'. If the instrument is not progressing into the canal take the smaller size instrument and make sure it reaches the required working length then use the instrument again.

7. Insert and remove the instruments from the canals while they are rotating never stop the rotation while the instrument is in the canal and never start rotation with the instrument placed in the canal. Both these situations could lead to instrument fracture.

8. While in the canal, the instrument should not be left to rotate in the same position it should always be accompanied with an in and out motion to minimize errors or instrument fracture.

9. Most Nickel Titanium instruments are designed to be single use so be careful not to overuse the instruments to minimize the incidence of fracture.

Torque Control Motors:

With the recent push for use of rotary endodontic instruments, it became apparent that these instruments were prone to fracture. So manufacturers began to develop sensitive motors that could monitor the speed and resultant torque while the instrument was in the canal. These torque control motors, have various torque and speed settings so that operator can adjust both depending on the type and size of the instrument being used. In other words, some instruments have lower fracture resistance than others; these instruments would have a lower torque setting than other during preparation. If during the preparation the torque incumbent on the instrument was higher than the torque setting the motor would either stop or reverse its direction of rotation to prevent instrument fracture.

<u>These are examples of Torque Control Motors</u>

<u>Apex Locators '*an Endodontic Adjunct*':</u>

One of the toughest and most time consuming steps during root canal instrumentation is the estimation of working length. Conventionally, this entailed taking multiple radiographic exposures of instruments inside the root canal followed by careful adjustment of the inserted instruments to reach the optimum working length at the cemento-dentinal junction. This technique has its drawbacks:

1. It is impossible to estimate the position of the CDJ from a radiograph
2. The radiographs taken are sometimes distorted
3. The radiograph is a two dimensional representation of a three dimensional situation

4. Sometimes while utilizing the *'shift technique'* overlap of different roots may occur that make it difficult to discern the apical portion of the prepared root
5. Early exits of the canals in the bucco-lingual dimension are not visible on a radiograph
6. Multiple exposures maybe required to properly estimate the tooth length.
7. The process of repetitive adjustment and re-exposure is time consuming

In response to all these disadvantages, endodontic manufacturers and researchers set out to develop an instrument that could overcome these problems. These devices are called *'apex locators'*.

The idea: The science behind these devices is simple; these devices apply an electric current and then measure the difference between the flow of the current in the canal and outside of the canal. The flow of the current outside the canal is between the periodontal ligaments and the oral mucosa the resistance of these tissues to the electric current is stable at 6.5 kilo-ohms.

> "All apex locators function by using the human body to complete an electrical circuit. One side of the apex locator's circuitry is connected to an endodontic instrument. The other side is connected to the patient's body, either by a contact to the patient's lip or by an electrode held in the patient's hand. The electrical circuit is complete when the endodontic instrument is advanced apically inside the root canal until it touches periodontal tissue. The display on the apex locator indicates that the apical area has been reached." ***Endodontics 2002 (John F. Ingle)***

Research in apex locators started in the early 1900's, initially the apex locators were inaccurate and used to be affected by moisture or blood in the canals. With continuous improvement the apex locators became less sensitive and more accurate. Nowadays, apex locators have up to 95% accuracy when estimating working length.

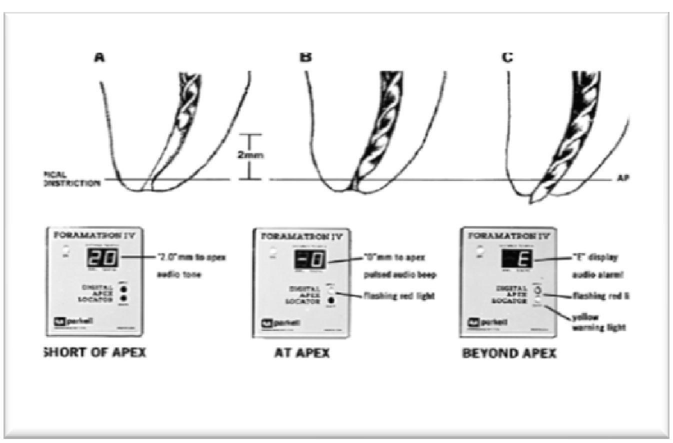
Considerations: Although apex locators are accurate they should *never* be used alone to estimate the working length. They should be used in conjunction with the radiographic technique mentioned previously. Why?

1. Apex locators may give false reading especially with presence of multiple accessory or lateral canals
2. Moisture can still adversely affect the reading
3. Any contact with metallic restorations can result in an inaccurate reading
4. Any early contact with the oral mucosa may also result in accurate readings
5. Sometimes narrow canals may not give any readings
6. Large lesions related to root apices can prevent proper readings
7. Iatrogenic errors made by the endodontist can also give early or false readings
8. When retreating cases, the gutta percha and sealer in the canal sometimes prevent any readings

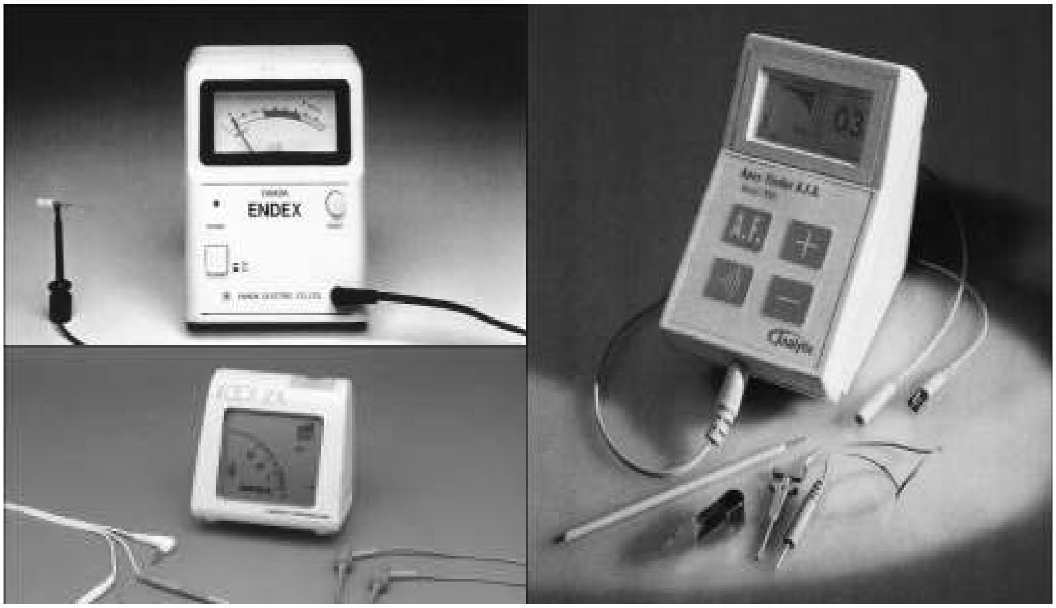
Therefore, using the apex locator alone will not be enough for an endodontist to be sure of the working length. A combination of both the apex locator and the radiographic technique will ensure the best possible results.

Examples of apex locators are: Formatron IV, Endex, Apex Finder, Root ZX, Exact-A-Pex and Neosona Ultima EZ

<u>Example Apex Locator Reading</u>



Different Types of Apex Locators



The Future:

1. Development of different instrument designs to overcome the disadvantages of the current rotary instruments. i.e. Twisted File (a twisted Niti file instead of machining) or The Liberator file (The file cutting blades are parallel to the long axis of the instrument improving cutting efficiency).

2. Combination of both the idea of torque control motors and apex locators so that a clinician can have a *'live'* reading of the length during preparation procedures. i.e Tri-Auto ZX.

3. Using laser technology in endodontics this is still in an experimental phase various types of lasers have been advocated for use to prepare the root canal and other have been used to disinfect the root canals. Preparation of root canals using laser technology is still being researched.