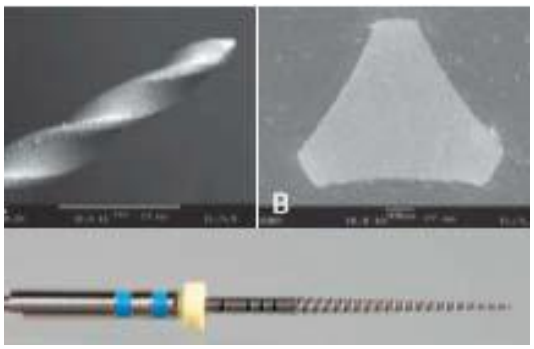
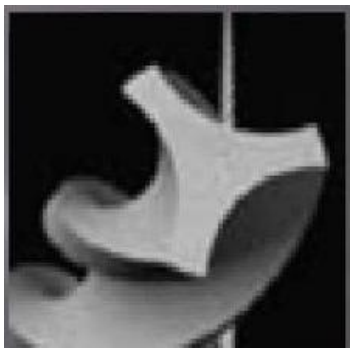
Rotary Instrumentation systems using Nickel Titanium

- **ProFile system**

The ProFile system was introduced in 1994. ProFile instruments have increased tapers compared with conventional hand instruments. The tips of the ProFile Series 29 rotary instruments had a constant proportion of diameter increments (29%). The cross-section of a ProFile instrument has a U-shape design with radial lands and a parallel central core. Lateral views show a 20-degree helix angle, a constant pitch, bullet-shaped noncutting tips, and a neutral or slightly negative rake angle. This configuration facilitates a reaming action. Debris is transported coronally and is effectively removed from the root canals. The preferred speed is 275-325 rpm.

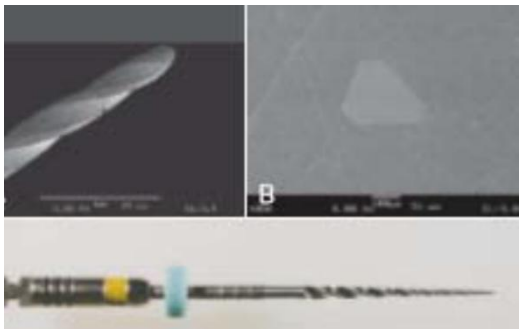






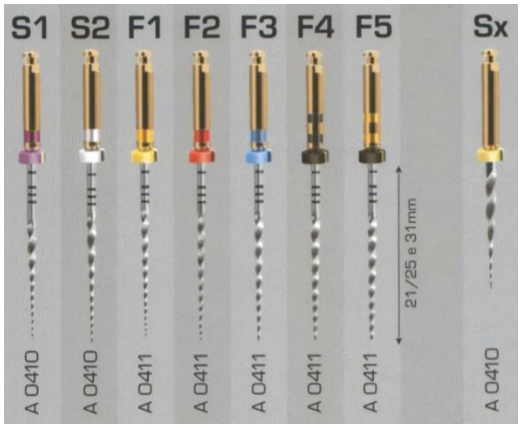
- **ProFile GT Files**

The Greater Taper (GT) file was introduced in 1994. This instrument also has a U-shape file design. The instruments come in four tapers (0.06, 0.08, 0.10, and 0.12), and the maximum diameter of the working part coronally is 1 mm. The instruments have a variable pitch and an increasing number of flutes in progression to the tip; the apical instrument diameter is 0.2 mm. Instrument tips are noncutting and rounded.

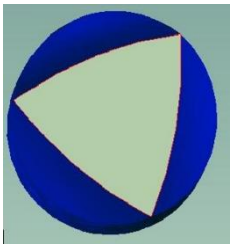




- **ProTaper Universal system**



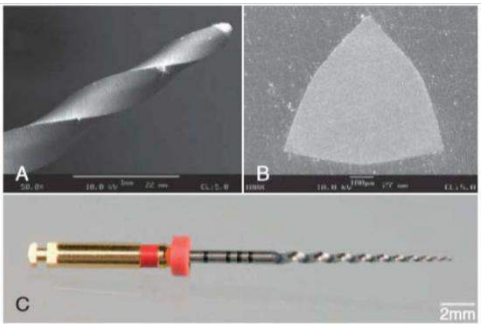
The ProTaper system is based on another concept and is composed of six instruments: three shaping files and three finishing files. This set is increased by two larger finishing files and a set designed for retreatment procedures. In the cross-section, ProTaper shows a modified K-type file with sharp cutting edges and no radial lands; this creates a stable core and sufficient flexibility for the smaller files. The cross-section of finishing files F3, F4, and F5 is slightly relieved for increased flexibility. The difference in the design of this system is the varying tapers along the instruments' long axes. The three shaping files have tapers that increase coronally, and the reverse pattern is seen in the five finishing files. Shaping files #1 and #2 have tip diameters of 0.185 mm and 0.2 mm, respectively, with 14-mm-long cutting blades. The diameters of these files at D14 are 1.2 and 1.1 mm, respectively. The finishing files (F1-F5) have tip diameters of 0.2, 0.25, 0.3, 0.4, and 0.5 mm, respectively, between D0 and D3, and the apical tapers are .07, .08, .09, .05, and .04, respectively. The finishing files have rounded noncutting tips.



The convex triangular cross-section of ProTaper instruments reduces the contact areas between the file and the dentin. The greater cutting efficiency of this design has been improved by balancing the pitch and helix angle, preventing the instruments from threading into the canal. ProTaper instruments can be used with 250 to 300 rpm.

Two usage characteristics are recommended for the ProTaper system:

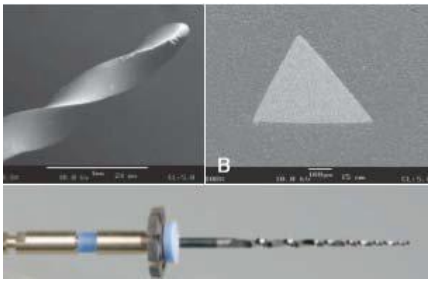
1- The preparation of a glide path.
2- The use of a more lateral "brushing" working stroke. Such a stroke allows the clinician to direct larger files coronally away from danger zones and counteract any "threading-in" effect.

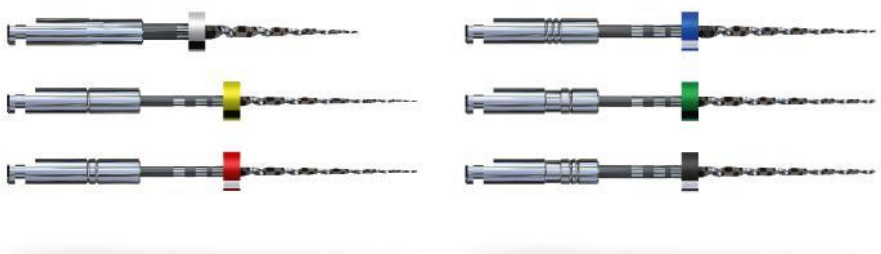


No. of instruments/ set	Tip sizes	Size increments	r.p.m. (recommended)	Lengths
6 (3 shaping files; SX, S1, S2; 3 finishing files; F1, F2, F3)	19-30	Vary along the working part of an individual instrument	150 to 350 minimal axial force, low to medium torque to fracture, varying working torque	19, 21,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

- **RaCe, Bio Race**

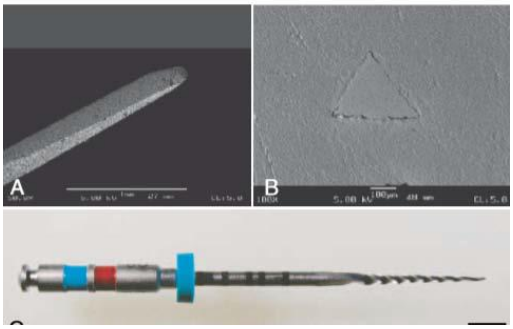
The RaCe has been manufactured since 1999 by FKG. The name stands for a reamer with alternating cutting edges. This design aimed at reducing the tendency to thread the file into the root canal. Cross sections are triangular or square for #.02 instruments with size #15 and #20 tips. The surface quality of RaCe instruments is achieved by electropolishing. The tips are round and non-cutting.





- **Twisted File**

In 2008, the first fluted NiTi file was introduced and manufactured by plastic deformation, a process similar to the twisting process that is used to produce stainless steel K-files. This is done when a thermal process allows twisting during a phase transformation into the "R-phase" of nickel-titanium. The instrument is available with size #25 tip sizes only, in taper .04 up to .12. This production process resulted in superior physical properties





- **Wave One single-file reciprocating system**

This system is a single-use, single-file system to shape the root canal. In most cases, the technique only requires one hand file followed by one single Wave One file to shape the canal completely using the reciprocating motion. The file is made with M-wire technology, which improves strength and resistance to cyclic fatigue by about four times that of traditional rotary NiTi files.

The system is composed of:

1- The Wave One small file: It is used in narrow canals. The tip has an ISO of 20 with a continuous taper of 6%.

2- The Wave One primary file: It is used in the majority of canals. The tip has an ISO of 25 with an apical taper of 8% that reduces towards the coronal end.

3- The Wave One large file: It is used in wide canals. The tip has an ISO of 40 with an apical taper of 8% that reduces towards the coronal end.

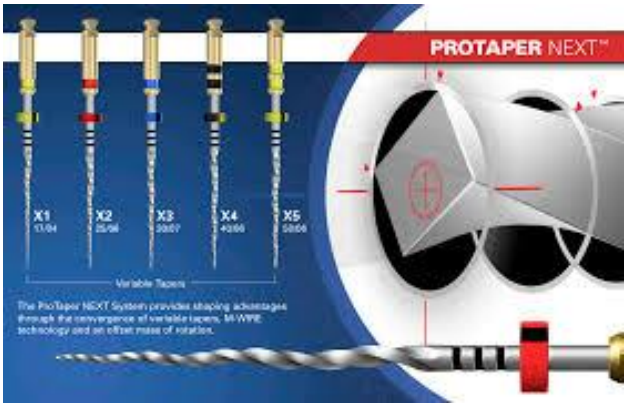
The instruments are designed to work with a reverse cutting action. All instruments have a modified convex triangular cross-section at the tip end and a convex triangular cross-section at the coronal end. This design improves instrument flexibility. The variable pitch flutes along the length of the instrument improve safety.

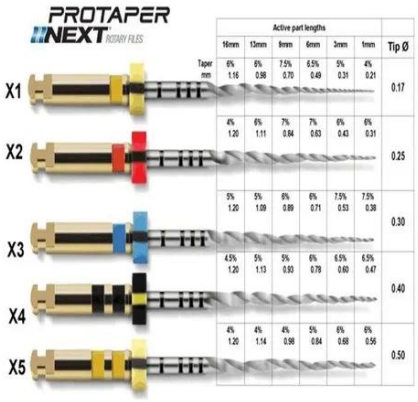




- **ProTaper Next**

This system is composed of 5 files, namely X1, X2, X3, X4, and X5. These files correspond to sizes 20/04, 25/06, 30/07, 40/06, and 50/06 respectively. The X1 and X2 have variable tapered designs, whereas X3-X5 files have a fixed taper from D1-D3 and then a decreasing percentage tapered design over the rest of their active portions.
This system has a rectangular cross-section that is centered, which allows 2 points of contact with the dentin wall, and the rest of the space is free for storing debris, which will be removed by the file swaggering motion.



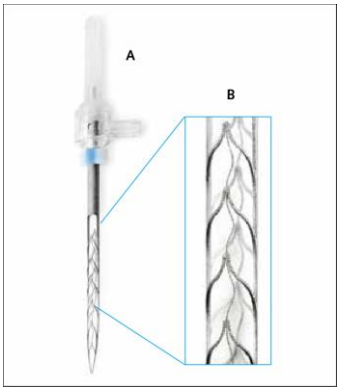


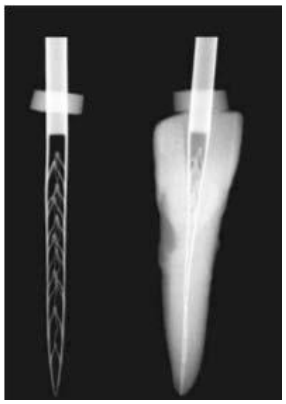
Group IV: Engine-Driven Three-Dimensionally

- **Adjusting Files (Self-adjusting file)**

The self-adjusting file (SAF) represents a new approach to file design and mode of operation. The file is a hollow device, designed as a cylinder of thin-walled, delicate NiTi lattice with a lightly abrasive surface. An initial glide path is established with a #20 K file to allow the insertion of the SAF file. The file is proposed to be compressed from its 1.5 mm diameter into dimensions equivalent to those of a #25 K file. The handpiece generates in-and-out vibrations with 5000 vibrations per minute and 0.4 mm amplitude. The compressed file will adapt itself to the root canal walls, applying a uniform cutting action and gradually removing a uniform dentin layer from the canal walls. There is a continuous flow of irrigant, which removes the tissue debris and the dentin powder generated by the file.







Group V: Engine-Driven Reciprocating Instruments

Endo-eze reciprocating files. The Giromatic handpiece, a rotary instrument in use since 1969, delivers 3000 quarter-turn reciprocating movements per minute. Rasps and barbed broaches are most often used in Giromatic handpieces, but K-type and H-type instruments can also be used. The endo-eze file system (Ultradent) is a recently introduced addition for Giromatic handpieces.



The set has four instruments that are designed to clean the middle third of the canal. The sizes and tapers are 0.10 #0.25 taper, 0.13 #0.35 taper, 0.13 #0.45 taper, and 0.13 #0.06 taper. The use of stainless steel hand instruments is suggested for the apical third of the canal.

Group VI: Sonic and Ultrasonic Instruments

A very different way of instrumenting root canals was introduced when files or ultrasonic tips (of different shapes and sizes) were activated by electromagnetic ultrasonic energy. Piezoelectric ultrasonic units are also available for this purpose. These units activate an oscillating sinusoidal wave in the file with a frequency of about 30 kHz.

Two types of units, ultrasonic and sonic, are primarily available. Ultrasonic devices, which operate at 25 to 30 kHz, include the agnetostrictive (Cavi-endo) and the piezoelectric (Enac). Sonic devices operate at 2 to 3 kHz (Sonic Air MM 1500). Ultrasonic devices use regular types of instruments (e.g., K-files), whereas sonic devices use special instruments known as Rispi-Sonic, Shaper-Sonic, Trio-Sonic, or Heli-Sonic files.

Although similar in function, piezoelectric units have some advantages over the magnetostrictive systems. For example, piezoelectric devices generate little heat, so no cooling is needed for the electric handpiece. The magnetostrictive system generates considerable heat, and a special cooling system is needed in addition to the irrigation system for the root canal.

The file in an ultrasonic device vibrates in a sinus wave-like fashion. A standing wave has areas with maximal displacement (i.e., antinodes) and areas with no displacement (i.e., nodes). The tip of the instrument exhibits an antinode. Files must be used only for a short time, must remain passive within the canal, and the power must be controlled carefully.

Ultrasonic devices have proved very efficient for irrigating root canal systems.

During free ultrasonic vibration in a fluid, two significant physical effects are observed: cavitation and acoustic streaming. During oscillation in a fluid, a positive pressure is followed by a negative pressure, causing implosion. This is cavitation. Acoustic streaming creates small, intense, circular fluid movement around the instruments.



Generations of the NiTi rotary instruments

From the 1990s until now, NiTi rotary instruments have undergone revolutionary changes in terms of the construction and, as a result, physical characteristics of the NiTi instrument.

Furthermore, the design, shape, and number of instruments used in each group have been highly modified. The aim of modifying and improving these instruments is to develop a NiTi rotary instrument that cuts and removes the dentine strongly and is also resistant to fracture even in the most challenging, narrow, curved root canals. Another purpose of modifying and improving these instruments is to simplify the cleaning and shaping stage and to reduce the number of instruments, along with preserving the original shape of the prepared root canal.

1. First Generation

This category of NiTi rotary instruments were first introduced to the market during the mid- 1990s. The most important characteristic of the first-generation NiTi rotary files is having passive cutting radial lands along with fixed 0.04– 0.06 tapers over the full working length.

The most important NiTi rotary instruments within this category are Light Speed Endodontics (1992), Profile-Dentsply (1993), Quantec-SybronEndo (1996), and GT system-Dentsply (1998). Several studies showed that all first-generation rotary instruments created smooth root canal walls that centered in the middle and caused low procedural errors. The main deficiency of this generation of NiTi rotary instruments was the requirement for numerous files to achieve these goals, and the complexity.

- **Advantages:**

Optimum flexibility is the ability of the instrument to accompany the curvature of a root canal, avoiding the formation of steps, perforations along the root canal or at the apical level; cutting efficiency; reduced working time for the operator, greater comfort for the patient, and a lower incidence of postoperative pain.

- **Disadvantages:**

They generate costs for the operator since they must be used only once; possibility of instrument fracture, and poor cleaning in flattened root canals.

2. Second Generation

The second generation of NiTi rotary files was introduced into the market in 2001. These instruments had active cutting edges with greater cutting efficiency, so the number of instruments required to achieve complete cleaning and shaping was almost less in comparison with the previous generation. Notable systems in this generation are ProTaper Universal-Dentsply, K3-SybronEndo, Mtwo-VDW, Hero Shaper-Micro-Mega, I Race, and I Race Plus- FKG Dentaire.Several studies have also approved the efficiency of these systems in fast preparation and also preserving the original shape of canals, even in curved and calcified challenging cases, although some researchers have reported some degrees of canal transportation along with a tendency for breakage during usage.

- **Advantages:**

High resistance to cyclic and torsional fatigue, lower fracture index, greater cutting efficiency, offers a shorter working time, providing a

reduction of stress for the professional, lower incidence of postoperative pain, therefore, in greater comfort for the patient.

- **Disadvantages:**

They generate costs to the operator since they must only be used once, with the possibility of fracture, but with a lower incidence than with the first generation instruments The NiTi Alloy Phase R was also used in the manufacture of the Oscillating (Asymmetric) Systems, usually called Reciprocants, Oscillating Systems (Reciprocants) TF Adaptive (2013) (SybronEndo Kerr Group).

3. Third Generation

It was in late 2007 that the manufacturers started to apply the heating and cooling technologies to NiTi alloys to improve the safety of these instruments, especially in the curved root canals. In making the third generation of the NiTi rotary files, the manufacturers have highly focused on metallurgical properties of the NiTi alloy using heating and cooling procedures on wires, which results in a reduction of the cyclic fatigue of the files and also a reduction of the separation risk of the instruments, which is highly demanded by the practitioners. Applying M-wire and R-phase technologies and electrical discharge methods makes instruments with high memory shapes and a low risk of separation. K3 XF Files-SybronEndo, Profile GTX Series–Dentsply, controlled memory (CM) Files (HyFlex CM)– Coltene, and Vortex Blue (Dentsply Tulsa) are notable files in this group, which have been exposed to heat treatments to increase flexibility and safety. The CM property helps the instrument to save the shape of the canal when it is moved out of the canal. Flex files (NeoEndo) have been predisposed to gold thermal treatment, which increases their cutting efficiency along with cyclic fatigue resistance.

- **Advantages:**

High resistance to cyclic and torsional fatigue, lower fracture index when used more than once, greater cutting efficiency, greater flexibility compared to first generation (15% more flexible), less working time for the professional, greater comfort for the patient, lower incidence of post operative pain.

- **Disadvantages:**

They generate higher costs, because according to the manufacturer, they must be used only once; possibility of fracture, but with a lower incidence compared to the instruments of the previous generation.

4. Fourth Generation

Reciprocation, which is described as any repetitive back-and-forth or up-and-down motion, is another philosophy in canal preparation that was first introduced by Blanc, a French dentist, in the late 1950s. Instead of full rotation, the reciprocating NiTi rotary instruments have movements in which clockwise and counterclockwise degrees of rotation are quite equal. The reciprocation theory of canal preparation has led to the development of the fourth generation of NiTi rotary instruments. The use of a single file technique to achieve a thorough cleaning and shaping goals at this phase was another success which was also derived from the reciprocating philosophy in cleaning and shaping the root canal systems Many studies have shown that the Wave One and the One Shape single-file systems can efficiently reduce the bacterial number in the root canal along with preserving the original shape of it. Wave One-Dentsply, self-adjusting file (SAF)-ReDent Nova, and Reciproc-VDW are featured instruments of the fourth generation.

- **Advantages:**

Is indicated for root canals with severe anatomical complexity. High resistance to cyclic fatigue, lower fracture index. (300% more resistant), Greater cutting efficiency, greater flexibility, 80% more flexible than conventional instruments, offers less working time, lower incidence of postoperative pain, and greater patient comfort.

- **Disadvantages:**

Contraindicated for wide or relatively wide and straight ducts.

5. Fifth Generation

In this generation, the efficiency of canal shaping has been improved by offsetting the center of rotation. The offset-designed files produce a mechanical wave of motion that distributes along the full length of the NiTi file, which improves cutting and removes the debris in comparison

with a centered mass rotating instrument. Furthermore, this offset design reduces the taper lock or the screwing effect, which causes instrument separation. HyFlex/electrical discharge machining (EDM)-Coltene, Revo-S-Micro-Mega, One Shape Micro-Mega, and ProTaper Next-Dentsply are important files of the fifth generation.

The Revo-S and the One Shape systems of the fifth generation, both manufactured by the Micro-Mega Company, offer proper root canal shaping by continuous clockwise rotation of the instruments inside the root canal system.

One Shape which is just a single number 25/0.06. A taper instrument with an asymmetrical cross-section along the entire blade has a variable cross-section and longer pitch. Using the glide path, the instrument is optional in the One Shape instrumentation strategy. Micro-Mega also offers optional using apical finishing files. These sterile single-use NiTi-finishing files are used after root canal shaping with One Shape in order to enlarge the root canal diameter.

- **Advantages:**

They are 80% more flexible than the files of conventional rotary systems, more resistant to cyclic fatigue by 150% compared to the Universal Protaper System, shorter working time.

6. New generation system (NiTi Blue)

New generation system (NiTi, Blue): They are manufactured with NiTi Alloy with Blue Treatment. NiTi Vortex BlueTM instruments (Dentsply/Sirona-United States) are manufactured with Nitinol 508 and consist of a blue titanium oxide layer, not seen in traditional superelastic NiTi instruments. This relatively hard surface layer of Vortex Blue instruments can compensate for the loss of hardness compared to Profile Vortex M-Wire. Vortex Blue and shape memory technologies use special thermal processes to control the transition of extreme temperatures, making the instruments highly flexible.

- **Advantages:**

Indicated for root canals that present a severe anatomical complexity. They follow the natural curvature of the root canal due to its great

flexibility, greater resistance to cyclic fatigue (65% higher in relation to instruments manufactured with M-Wire® NiTi and 99% in relation to the First-generation NiTi instruments offer greater resistance to torsion, which results in a lower working time, a reduced memory effect of the instrument (that is, it can be pre-curved slightly and not return to its original position), generating less resistance of the instrument when introduced into the root canal.

Vortex Blue instruments have improved material properties within creases, fatigue resistance, and flexibility compared to Profile Vortex (M-Wire) instruments. However, both NiTi Blue and M-wire alloy show better fatigue resistance compared to the conventional nickel-titanium alloy. Torsion resistance is also affected by the cross-sectional design, the metal mass, and the properties of the alloy.