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New Rotary Instrument

A graduation Project
Submitted to
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College Of Dentistry, University Of Baghdad

By:

Athraa Ahmed Ibrahim

Supervised by:

Ass.Prof. Dr. Samer A. Thyab

B.D.S. Msc. Conservative

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Certification of the Supervisor

I certify that this project "new rotary instrument " was prepared by the fifth-year student by Athraa Ahmed under my supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervisor's name: **Ass. Prof. Samer A. Thyab**

Date:

Dedication

To the kindest heart in my life my mother who give me all the support and care in my life

To the closest person to me my sisters Mariam and Jehan who have been my constant source of inspiration. They have given us the drive and discipline to tackle an task with enthusiast and determination. without their love and support this project would not have been made possible

To my friend Teba who have always encouraged me and helped me to complete this journey successfully.

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for his endless support, kind efforts, time, advice and scientific opinions and I‟m really proud to be one of his students.

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List of contents

Subject	Page No.
Introduction	6-8
Nickel Titanium in Endodontics	8
• History	8
• Advantage	9
• Disadvantages	9
Properties of NiTi Endodontic Rotary Instruments	11-15
• Mechanical	15-18
• Metallurgical	
Controlled memory (CM)NiTi alloys	19,20
Generations of the NiTi rotary instruments	20-27
	21
• First	22
• Second	23
• Third	24
• Fourth	25
• Fifth	246,27
• New generation (NiTi,Blue)	
Advanced in rotary endodontics(Revo S)	27-29
Recently introduced NiTi file systems	29,30
Causes and prevention of fractures of NiTi instruments	31,32
Conclusion	33
References	34-41

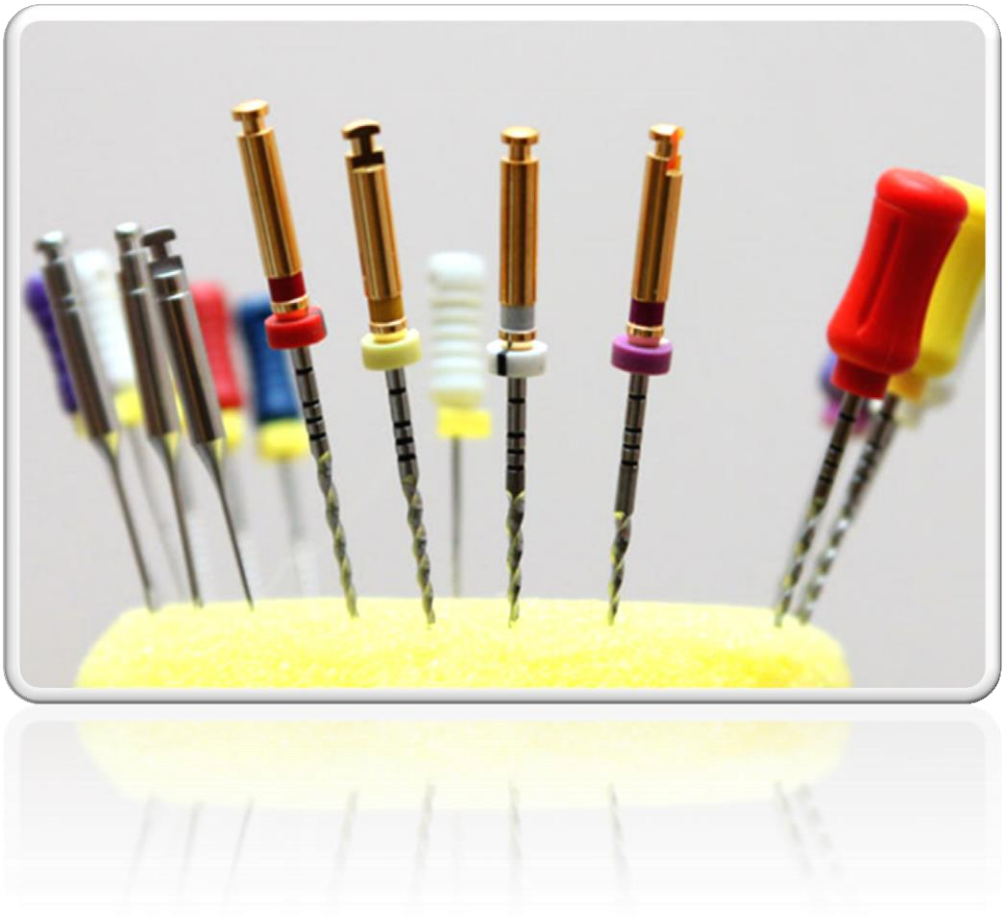
List of figures

Figure No.	Description	Page No.
1	The apparatus for the cantilever bending test.	13
2	SEM image of fractured surface after cyclic fatigue testing.	14
3	SEM image of fractured surface after torsional testing.	15
4	Martensitic transformation:	18
5	Temperature hysteresis in NiTi alloys.	19
6	Comparison of austenitic (ProTaper Next) and martensitic NiTi files (CM wire)	21
12	Revo S nickel–titanium rotary system	30
13	Revo S The instrument works in a cyclic way.A Customized Treatment Using 3 Instruments.	31
7	First generation	22
8	Second generation	23
9	Third generation	25
10	Fourth generation	26
11	Fifth generation	27

List of table

Table number	Subject	Page number
1	Composition, properties,and recommended use of	33

	different NiTi systems	



Introduction

With emerging technology, we see endodontics being swept away in the latest wave of technization. There are a plethora of different systems available, and a large number of studies have focused on various physical and chemical aspects of NiTi files. Various proprietary methods and treatments have been introduced to enhance the cutting ability and file design**(Shubhashini N.et al,2016)**. Files with the austenite phase have super elastic properties and are recommended to be used in straight or mildly curved canals, whereas those instruments composed of the martensite phase possess high flexibility along with increased resistance to cyclic fatigue and are recommended to be used while preparing canals with complex curvatures**(Lopes H. et al,2015)**.

Successful endodontic treatment depends on accuracy of diagnosis and on adequate mechanical preparation of the pulp space for restoration. The armamentarium of endodontics has grown in complexity over the past 40 years. Different techniques of root canal preparation have been described in the related literature. Stainless steel (SS) instruments have been traditionally used for canal preparation**(Shen Y.et al,2016)**.

Introduction of rotary instrumentation has revolutionized the art and science of endodontic practice in the last decade with predictable success. The rotary files have been subjected to constant evolution in the form of metallurgy, design features, and the manner in which these instruments are driven (rotary/reciprocation), etc., resulting in revolution, both within the canal and in the area of contemporary endodontics**(Murray P et al,2015).**

The first endodontic files were made of carbon steel, whose hardness greater than dentin, prevent its use in curved canals and could cause iatrogenic such as: deformation of the apical foramen, anatomical deviation of the canal and perforations, that is due to the greater filing on the curved wall. They were manufactured without scientific criteria. Among its advantages, resistance to

fracture and high cutting capacity could be highlighted, but diminished by being highly corrosive due to the joint action of chemical substances such as sodium hypochlorite, negatively affecting the resistance of the file**(Murray P et al,2015 ,Gutmann JL,2012).**

The replacement of carbon steel for stainless steel instruments used today solved the corrosion problem. In 1955 John Ingle, a professor at the University of Washington USA, introduced the standardization of instruments; together with Levine in 1961. They published the first work on standardized instruments, as well as the gutta-percha and silver cones accordingly**(Gutmann JL,2012)**

Its (Niki) introduction, in fact, has thoroughly changed the instrumentation procedures of endodontic root canal systems, so as to be considered as a technological revolution which established the beginning of the modern endodontics. The exact moment of this passage corresponds to the publishment by Walia et al. of the article titled "An initial investigation of the bending and torsional properties of Nitinol root canal files", in which for the first time the Authors proposed the NiTi alloy as a material for the manufacturing of endodontic instruments, considering the great success that this alloy was having in orthodontics**(Short et al,1997).**

In fact, the most remarkable limitation of NiTi instrumentation is the possibility of instrument failure during shaping procedures. As thoroughly demonstrated, the two main causes of this are undoubtedly the cyclic fatigue and the excessive torsional loads exerted on instruments during the dentinal cutting in curved canals. With the purpose of reducing failures and increasing the speed and the predictability of root canal treatments, researchers and engineers have focused their attention on the factors related to the geometry and design of the instruments that are able to influence their mechanical resistance, both in terms of torsional and cyclic fatigue **(Sattapan B.et al,2000)**.

1- Nickel Titanium in Endodontics

The introduction of nickel–titanium (NiTi) alloys in the late 1980s led to a revolution in endodontics as these files were shown to have considerable advantages over stainless steel (SS) files, especially in relation to the safety of instrumentation **(Walia HM. et al,1988)** . NiTi files were able to overcome the issue of rigidity and low resistance to cyclic fatigue associated with stainless steel instruments. Other than the advantage of increased flexibility and shorter treatment time, NiTi wires also resulted in fewer procedural errors such as zipping, ledges, or transportation due to their superelasticity, compared with SS files **(Liu SB. et al,2006)**. NiTi wires have gained special commercial applications in dentistry because of their shape, memory effect, and corrosion resistance. These properties of the alloy occur as a result of transition from the austenite to martensite form. This transformation requires "twinning," which is a reversible atomic process that divides the lattice into two symmetric parts at an angle and allows reduction of strain during the transformation phase **(Wayman CM.et al,1998).**

1.1 History:

A new generation of endodontic instruments, made from a remarkable alloy – nickel and titanium, has added a striking new dimension to the practice of endodontics. The super elasticity and shape memory of nickel-titanium (NiTi), the properties that allow it to return to its shape following significant deformation, differentiate it from other metals, such as stainless SS that sustain permanent deformation and retain the shape change **(Thompson S.A. el al,200)** These properties make NiTi endodontic files more flexible and better able to conform to the canal curvature, resist fracture, and wear and tear less than SS files. In the early 1960s, the super elastic property of NiTi alloy, also known as

Nitinol, was discovered by Buehler and Wang at the US Naval Ordnance Laboratory**(Shubhashini N.et al,2016).**

1.2 Rotary instrumentation has the following advantages over hand instrumentation:

- Enhanced ability to collect and remove debris from the canal system.
- Continuous clockwise rotation will convey debris only in a coronal direction from the canal ramifications and apical foramen(**Zanza A.et al,2021).**
- Mechanical rotation provides a more constant 360° engagement of the file tip in the canal that forces it to follow the canal and results in better control for maintaining the central axis of the canal, reducing the incidence of ledging or perforation.
- The most obvious benefit for continuous rotation is the reduction in the time required for instrumenting the canal.
- Produces greater taper in canal preparation**(Shubhashini N.et al,2016).**

1.3 Disadvantages include:

- Conventional NiTi instruments in rotary movement one, subjected to structural fatigue that if continued will lead to fracture.
- Increased canal preparation and increased microcrack**(Shubhashini N.et al,2016).**

1.4 Advantages in Using NiTi Rotary Instruments:

- Reduction in time of endodontic treatments

Instrumentation technique with manual SS files requires a larger number of tools and longer operating times. Instead, the increased cutting efficiency of NiTi rotary instruments and the use of increased taper instruments allow clinicians to improve these parameters of endodontic treatment **(Zupanc J.et al,2018)**.

- Simplification of instrumentation procedures

The special properties of the NiTi instruments have made it possible to considerably simplify the instrumentation technique compared to the traditional procedural steps carried out through the use of SS files . Thanks to the better mechanical characteristics of rotary instruments than manual ones, it's possible to shape the root canals respecting their original trajectories not altering their original anatomy **(Schäfer E.et al,2021).**

- Increase of predictability and effectiveness of endodontic treatments

The superelasticity of NiTi alloy ensures the use of endodontic instruments with an increased taper without an excessive risk of fracture due to bending or cyclic fatigue, im- proving the process of root canal shaping and therefore of root canal filling . For all these reasons, the success rates of endodontic treatments performed with NiTi rotary instruments is significantly greater than those performed with SS manual instruments**(Grande N.M.et al,2017)**.

The success behind the NiTi alloy resides in its biological and mechanical properties that make the NiTi alloy unique and particularly suitable for the manufacturing of endodontic rotary instruments: biocompatibility , corrosion resistance , shape memory effect and superelasticity **(Zanza,A.et al,2021)**.

2 Properties of NiTi Endodontic Rotary Instruments

2.1 Mechanical Properties

The introduction of Nickel-Titanium as the alloy of choice for the manufacturing of endodontic instruments has significantly revolutionized the shaping procedure and, thus, the root canal treatments. Nevertheless, the intracanal separation of endodontic rotary instruments remains one of the most concerns for endodontists. However, it has been demonstrated that the presence of a fractured instrument in itself does not definitely compromise the outcome of endodontic therapy, but surely requires a large investment of time and resources **(Daneshmand S.et al,2013)**.

- **Flexibility**

Flexibility of endodontic instruments is a fundamental requirement because it allows appropriate canal enlargement while maintaining the instrument centered within the canal , causing fewer undesirable changes in the shape of curved canals. The high flexibility of NiTi endodontic instruments comes from the combination of the low elastic modulus and unique superelastic properties **(Sattapan, B. et al 2000)**, which means that NiTi files can undergo significant deformation without reaching their elastic limits and still return to their original form. Flexibility is influenced by chemical composition and heat treatment as well as geometric configuration . In laboratory studies, it is usually evaluated by the bending test because bending is the most representative loading caused by the curvature of the root canals **(Pruett, J.P. et al,1997)**.

The flexibility is characterized by the bending moment at 45° using a testing apparatus built according to ISO 3630-1 specifications or studied by load-deflection curves during the loading and unloading process using a cantilever bending apparatus, as shown in [Figure1]. Low bending moment and high flexural stiffness is indicative of the high flexibility **(Viana AC et al,2010)**.

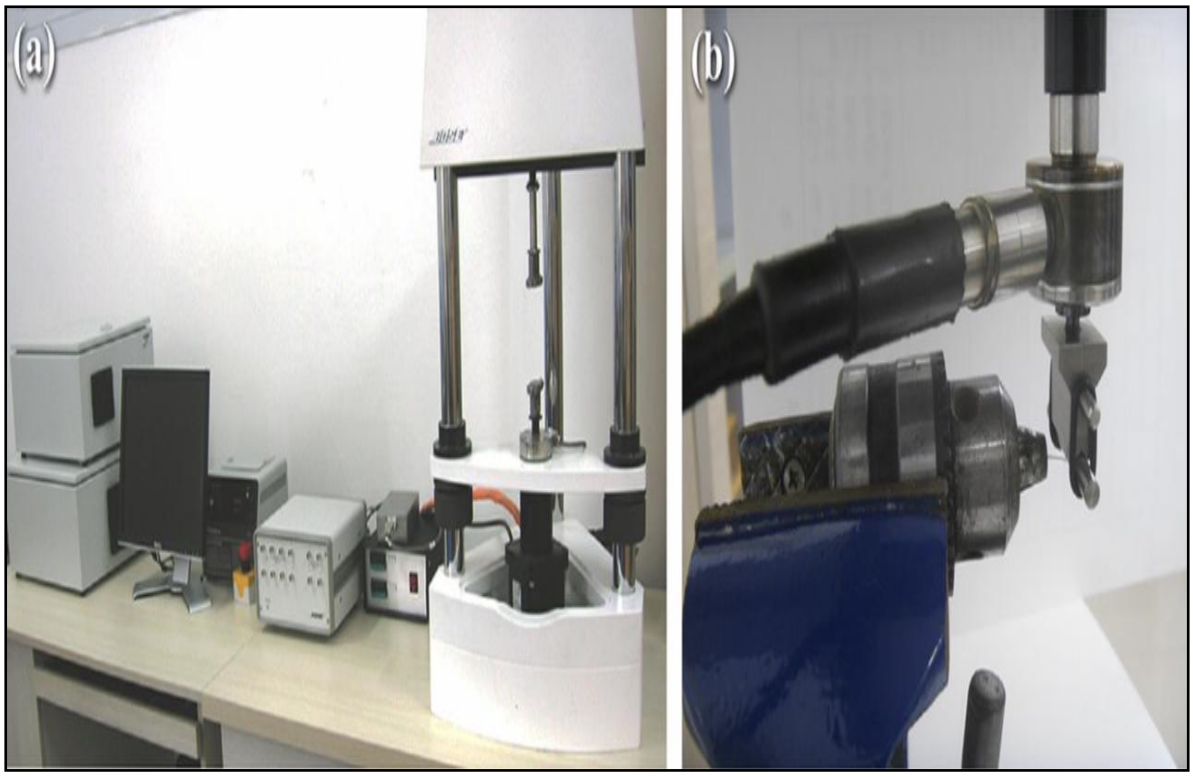


Fig. 1: The apparatus for the cantilever bending test. (a) Biomechanical performance test system (ElectroForce 2300, Bose Corporation ElectroForce Systems Group). (b) Set-up of the cantilever bending test.

As reported by Sattapan et al. The two main causes of intracanal separation of NiTi endodontics instruments are cyclic fatigue and torsional stresses .

- **Cyclic Fatigue Resistance**

The cyclic fatigue accumulation is an unavoidable consequence of tension–compression strain cycles to which the instrument is subjected to the point of maximum curvature [Figure2] . As a result, the risk of fracture due to flexural fatigue can never be zeroed, but only limited, until these instruments are used in continuous or alternating rotation in curved canals**(Pruett, J.P. et al,1997).**

Fig.2: SEM image of fractured surface of a F2 EdgeTaper Platinum (Albuquerque, NM, USA) in a transversal view at ×600 magnification after cyclic fatigue testing. Dimples and microvoids visibly spread on the fractured surface constitute a typical feature of ductile fracture, which origins from the external part of the instruments with visible crack (evidenced by yellow arrows).

- **Torsional Resistance**

Torsion is one of the primary mechanisms responsible for the intracanal separation of NiTi endodontic instruments. Torsional failure occurs when an apical part of the endodontic instrument, more frequently the tip, operating in continuous or alternating rotation, remains blocked in the dentinal wall and its coronal portion continues to rotate, causing its fracture [Figure3] **(Sattapan, B. et al 2000).**

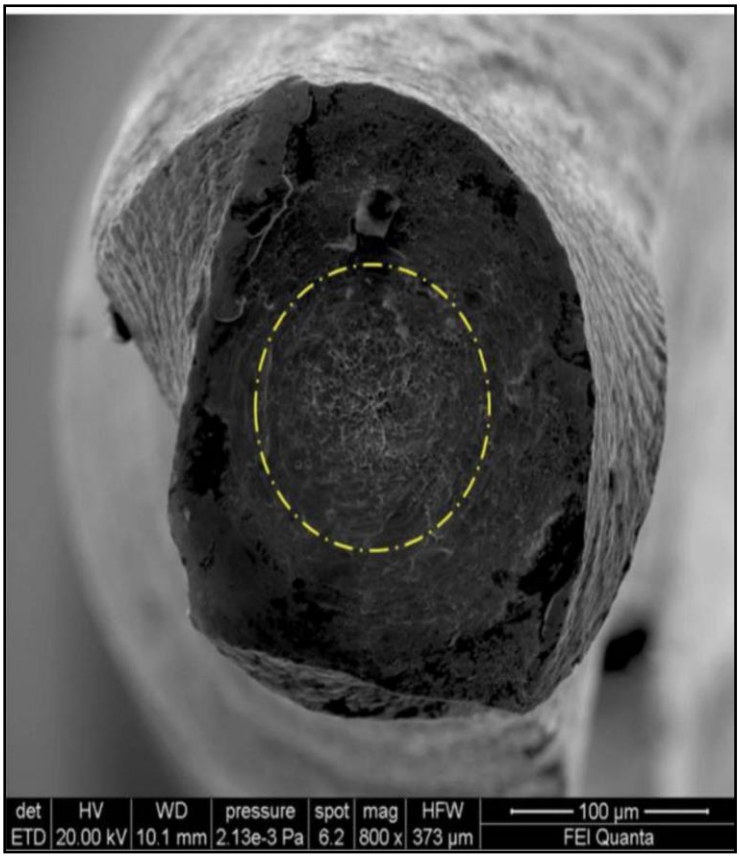


Fig.3 :SEM image of fractured surface of a F-One #20 (Fanta Dental, Shanghai, China) in a transversal view at ×800 magnification after torsional testing. The typical features of fracture arising from excessive torsional load, showing concentric circular abrasion marks and fibrous dimples near the center of rotation are evidenced by the round-shaped circumferential line.

- **Combined Torsional and Flexural Stresses**

Recently, greater attention has been focused on understanding the interaction between bending and torsional stress in order to better comprise the mechanical phenomena behind the root canal instrumentation **(Seracchiani et al,2021).** In fact, the NiTi endodontic rotary instruments during shaping procedure are always subjected to both flexural and torsional stresses and surely further studies are needed to eviscerate their reciprocal influence in more detail **(Zanza A. et al ,2021).**

2.2 Metallurgical challenges in endodontic instruments

It is generally accepted that metallurgical properties have a dramatic impact on the performance of NiTi instruments **Zanza A. et al ,2021).** These properties include the composition, microstructure, and phase constitution of NiTi instruments, and can be conveniently investigated by metallurgical laboratory techniques such as energy dispersive X-ray spectrometer (EDX), optical microscopy (OM), scanning electron microscopy (SEM), transmission electron microscopy (TEM), normal differential scanning calorimeter (DSC), temperature-modulated DSC (TMDSC), and X-ray diffraction (XRD) spectrum or micro-XRD spectrum**(Testarelli L et al,2011).**

- **Influence of composition**

Most of the NiTi alloys used for endodontic instruments are made in a nearly one-to-one atomic ratio of nickel to titanium, which equals approximately 56 wt% nickel and 44 wt% titanium . However, subtle adjustments in the ratio of these two elements cause a dramatic change in the transformation temperature, which has a significant effect on its mechanical properties **(Seracchiani et al,2021).** The nickel content of a NiTi alloy has a great influence on the transformation temperatures; an increase of 0.1% will lower the phase transformation temperature by 12°C [1a]. The chemical composition of NiTi endodontic files is usually examined by EDX, which is a semi-quantitative chemical analysis and has been employed for both conventional NiTi instruments and the most recently developed NiTi instruments **Zanza A. et al ,2021).**However, EDX is not sensitive enough to detect slight changes in the composition of the alloy that can result in a large difference in the mechanical properties [12]. Zinelis et al. evaluated the elemental composition of 10 brands of NiTi endodontic instruments and discovered that Hyflex X-files exhibit a lower percentage of nickel by weight (52 wt% Ni) than the common 54.5–57

wt% Ni shown in the great majority of commercially available NiTi rotary instruments. This lower nickel content exerts an influence on the transformation temperature, resulting in the Af temperature of over 47°C for Hyflex NiTi files **(ShenY.et al,2013).**

- **Influence of phase constitution**

The phase constitution of NiTi endodontic files under the service temperature plays an important role in determining the mechanical properties of the files. The NiTi alloys used for manufacturing of the endodontic instruments contain approximately 56% (wt) of nickel and 44% (wt) of titanium**(Wayman CM.et al,1998)**. However, even a 0.1% change in the composition of these alloys can result in a 10°C change in the transformation temperature, which can subsequently affect the mechanical characteristics of these alloys **(Zanza A et al,2021)**.At room temperature, these alloys are in the austenite form, which is a body-centered cubic structure**(Mohammadi Z.et al,2014)**. On cooling, the austenite form becomes a monoclinic structure called martensite because of a classic linear thermal contraction[fig.4].

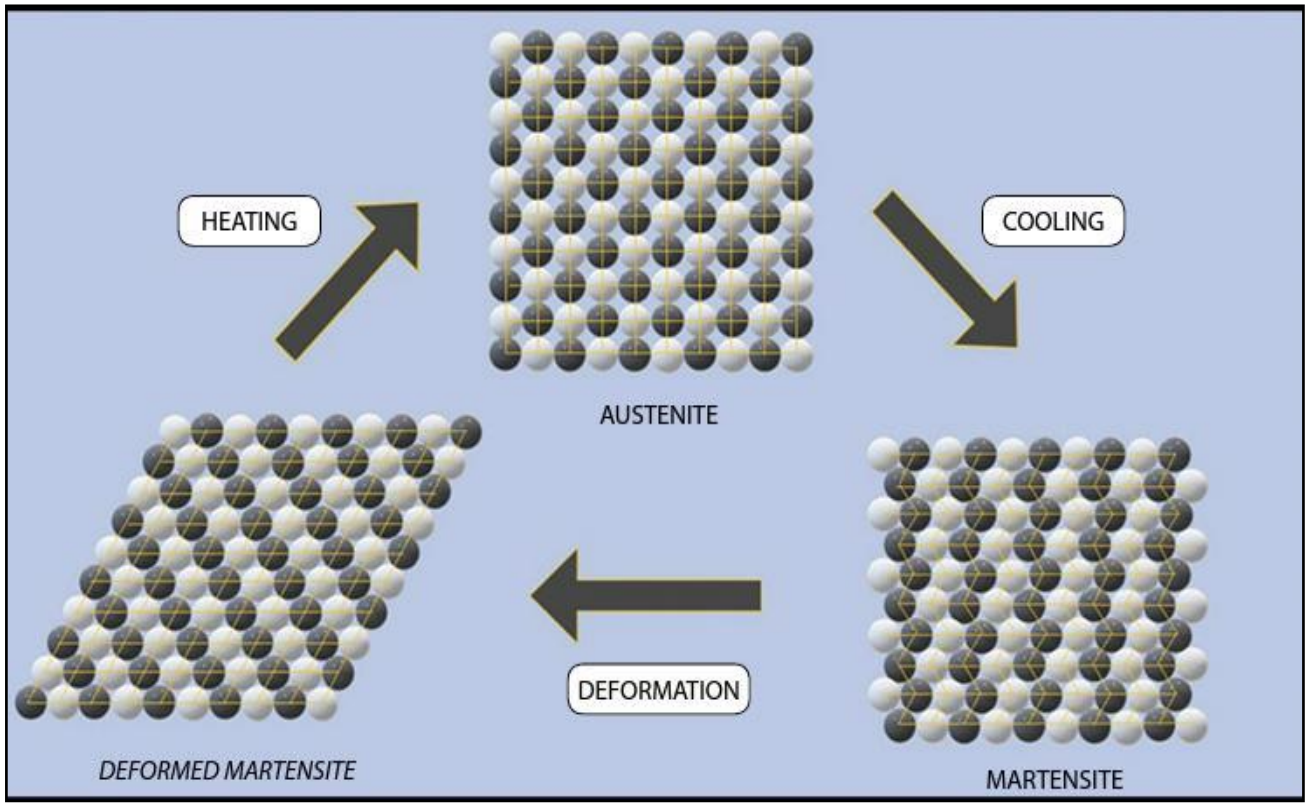


Fig.4: Martensitic transformation: Pseudoplastic behavior of NiTi is based on austenite and martensite crystal configurations, which depend on temperature.

Reheating this martensite phase will eventually reverse the process and yield an austenite form [Figure 5]. An intermediate phase, that is, the R-phase, or "Rhombohedral phase", occurs on cooling before the martensitic transformation is complete **(Yoneyama T.et al,2009).**

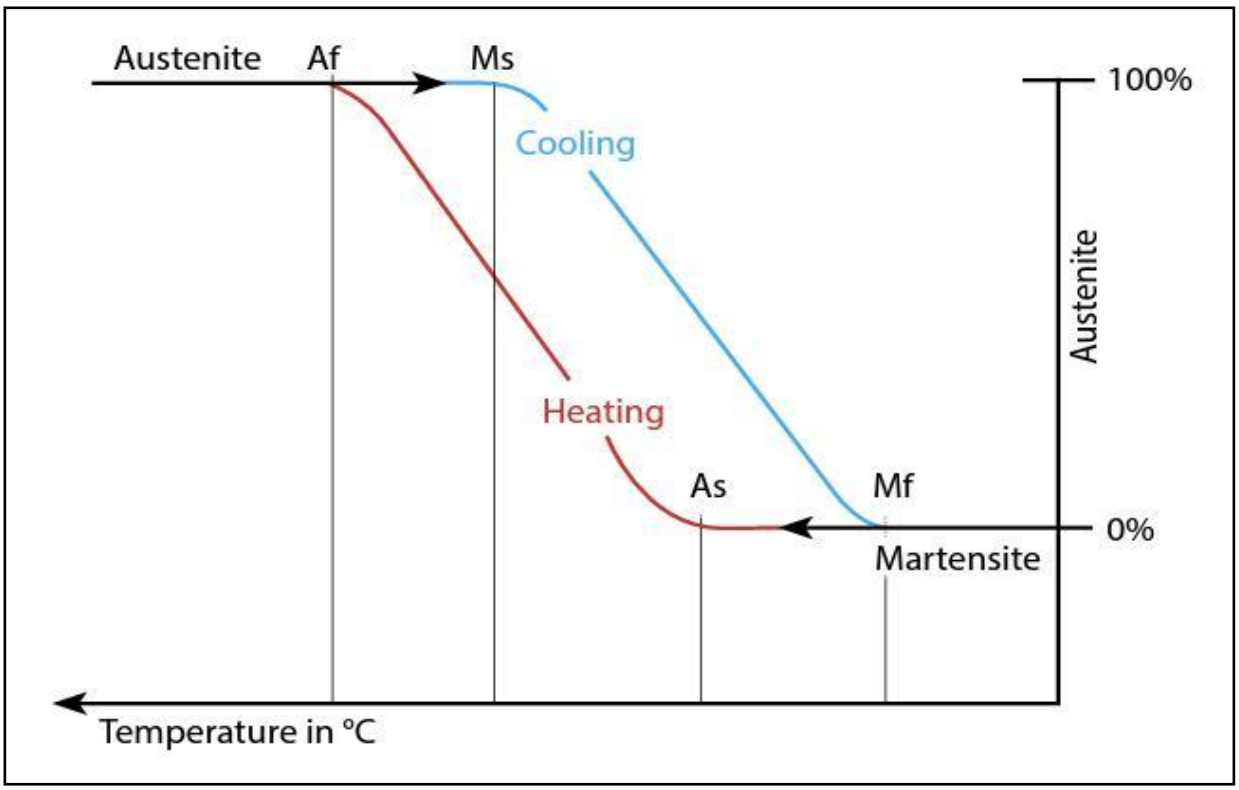


Fig.5 : Temperature hysteresis in NiTi alloys. (As) austenite start temperature; (Af) austenite finish temperature; (Ms) martensite start temperature; (Mf) martensite finish temperature.

When the external stresses are placed on a NiTi wire, the austenite form is converted to martensite (stress-induced martensite) form, which can accommodate greater stress without increasing the strain (up to 8%). As a result, a NiTi file has transformational elasticity, also known as superelasticity, or the ability to return to its original shape after being deformed**(Ye J.et al 2012).**

A stress-induced change without permanent deformation for up to 8% strain is possible in NiTi alloys, as opposed to 1% in stainless steel **(Aoki T.et al,2004).** On releasing the stress, the martensite form reverts back to the original shape, that is, the austenite form **(Metzger Z et al,2017).**

3 Controlled memory (CM)NiTi alloys

CM wires were introduced in 2010. They have a lower nickel content (52% wt.), as compared to other NiTi files. To incorporate extreme flexibility, these files undergo special thermo-mechanical treatment that also improves the shape memory effect of these files **(Zanza, A. et al,2021)**. Consequently, they do not have the rebound effect after unloading, and their original shape is restored after heat application or autoclaving procedure. Clinically, this incurs the benefit of pre-bending this file before placing it in a curved canal, especially with patients with limited mouth opening. The CM wire has a stable martensite phase because the austenite finishing temperature is above the working temperature. This implies that thermally processed controlled memory alloys would mostly or totally be in the martensite phase at body temperature **(Shen Y. et al , 2011)** [Figure 6]. CM instruments also have increased resistance to cyclic fatigue (300%–800% more fatigue resistant) because of their unique manufacturing process as they do not rebound to their original shape **(Peters OA. et al,2012).** However, they have one major drawback of increased tendency of permanent plastic deformation during use. Due to this weakness, these instruments are recommended for single use only . Some commercial brands of CM files include Hyflex CM, Typhoon Infinite Flex NiTi Files, VTaper 2H, and Hyflex electrical discharge machining (EDM).Heat-treated and controlled memory NiTi alloys are being used widely nowadays These newer designs have increased flexibility and reduced shape memory property. When used clinically, these instruments can better penetrate**(Hulsmann M. et al,2005).**

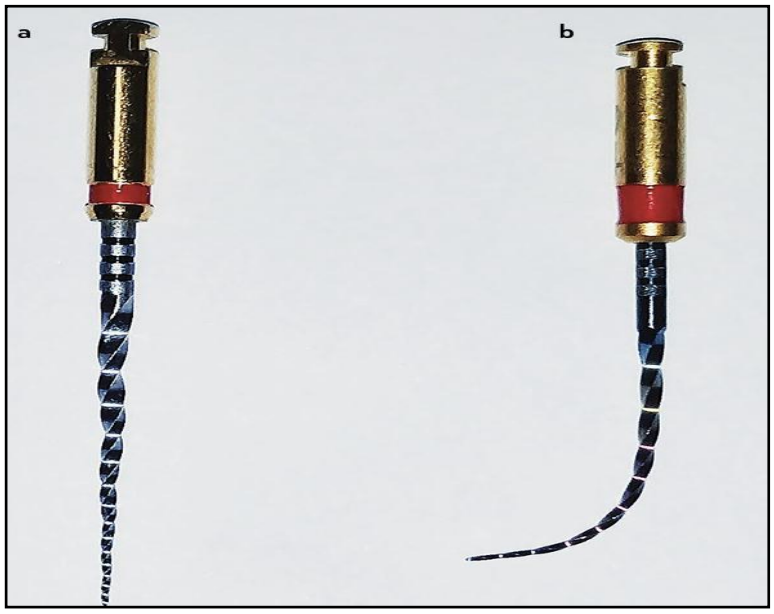


Fig.6 : Comparison of austenitic (ProTaper Next) and martensitic NiTi files (CM wire). (a) The austenitic NiTi file cannot be bent at room temperature; (b) The martensitic file can be bent at room temperature.

4 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**(Hulsmann M. et al,2005).** 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 which cuts and removes the dentin strongly and also is 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 using instruments along with preserving the original shape of the prepared root canals**(Bryant ST et al,1999).**

4.1 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 lengths**(Martins J.N.R. et al,2021).** The main important NiTi rotary instruments within this category are LightSpeed Endodontics (1992), Profile-Dentsply (1993), Quantec-SybronEndo (1996), and GT system-Dentsply (1998)**(Hata G. et al,2002).** Several researches showed that all first-generation rotary instruments created smooth root canal walls which centered in the middle and caused low procedural errors. The main deficiency of this generation of NiTi rotary instruments was requiring numerous files to achieve these goals and complexity**(Yun HH.et al,2003).**

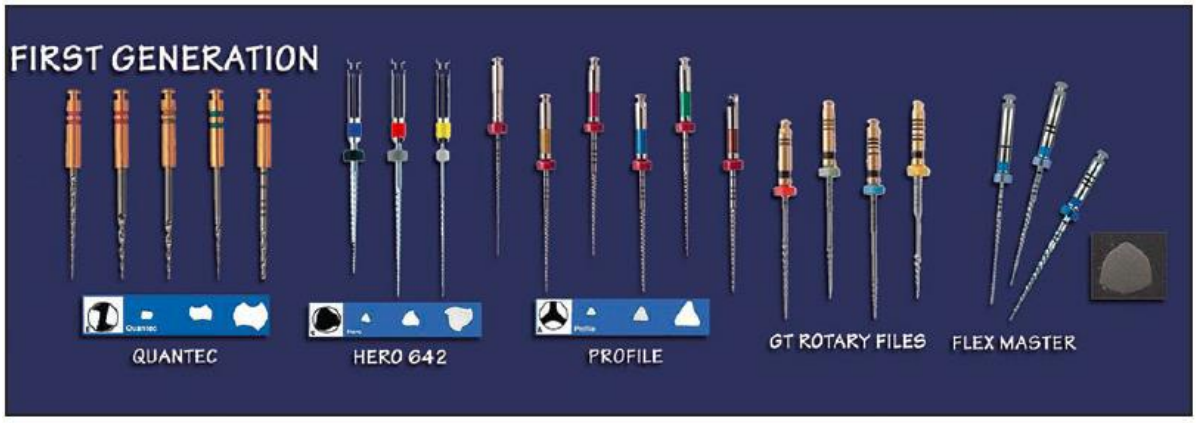


Figure.7 :first generation systems.(Shivakumar and Kalgeri, 2016)

- 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; poor cleaning in flattened root canals.

4.2 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 **(Schäfer E.et al,2004).** 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 transportations along with tendency for breakage while usage**(Kuzekanani M.et al,2018).**

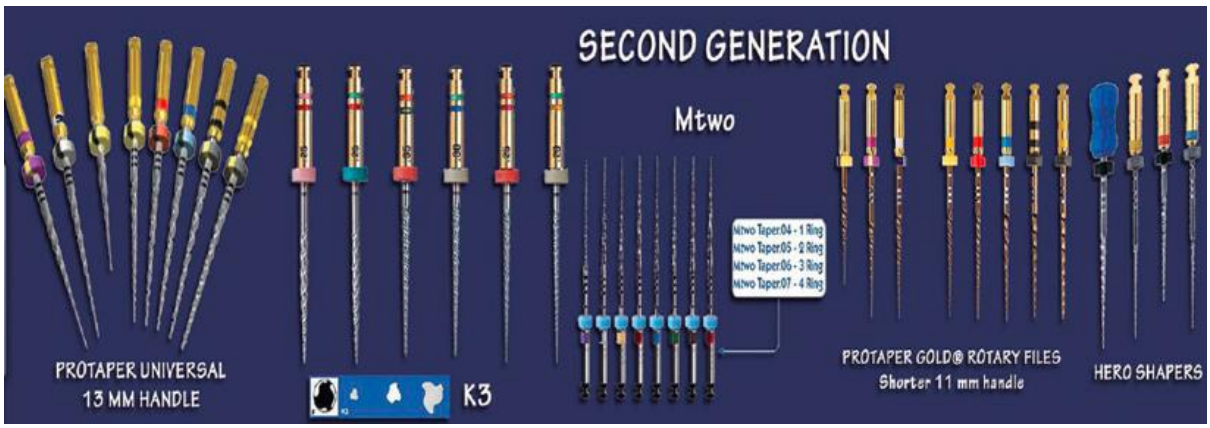


FIG.8 : second-generation instruments(Shivakumar and Kalgeri, 2016).

- 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 **(Flores aG .et al,2019)**

- Disadvantages

They generate costs to the operator since they must only be used once, 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 **(Flores AG .et al,2019)**

Oscillating Systems (Reciprocants)

TF Adaptive (2013) (SybronEndo Kerr Group)

4.3 Third Generation

It was in late 2007 that the manufacturers started to apply the heating and cooling technologies on NiTi alloys to improve the safety of these instruments, especially in the curved root canals **(Ruddle CJ.et al,2013).**

In making third generation of the NiTi rotary files, the manufacturers have highly focused on metallurgic properties of the NiTi alloy using heating and cooling procedures on wires which results in reduction of the cyclic fatigue of the files and also 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 make instruments with high memory shapes and low risk of separation **(Peters OA.et al,2012)**

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) files

have been predisposed to gold thermal treatment which increases their cutting efficiency along with cyclic fatigue resistance**.(Schäfer, E.et al (2022).**

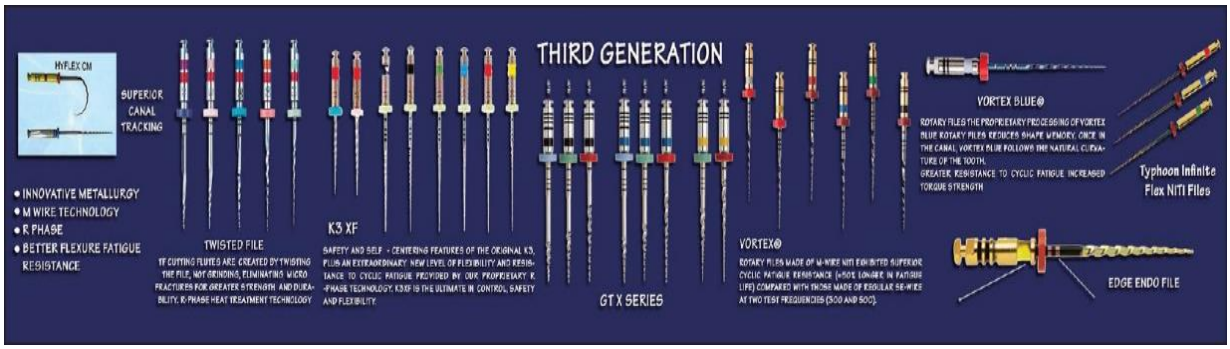


Figure 9third-generation instruments(Shivakumar and Kalgeri, 2016)

- 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 **(Nabeshima CK.et al,2014).**

- 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**(Nabeshima CK.et al,2014).**

4.4 Fourth Generation

Reciprocation which is described as any repetitive back and forth or up and down motion is another philosophy in canal preparation which 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**(Duke F.et al,2015).** The reciprocation theory of canal preparation has led to 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 fourth generation**(Nabeshima CK.et al,2014).**

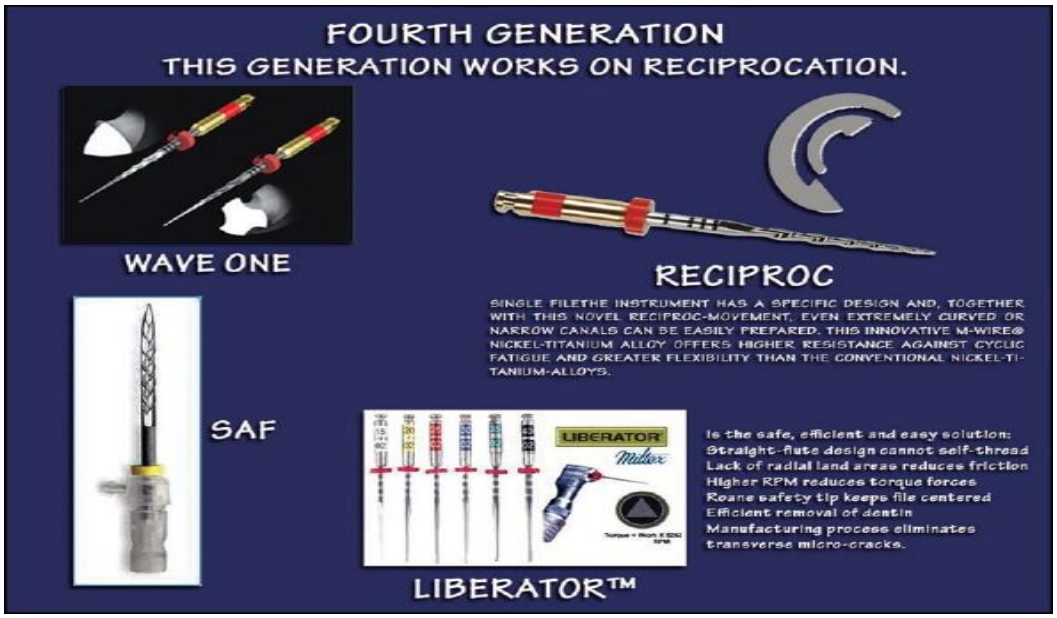


Figure 10 fourth-generation instruments(Shivakumar and Kalgeri, 2016)

- 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, greater patient comfort **(Nabeshima CK.et al,2014).**

- Disadvantages

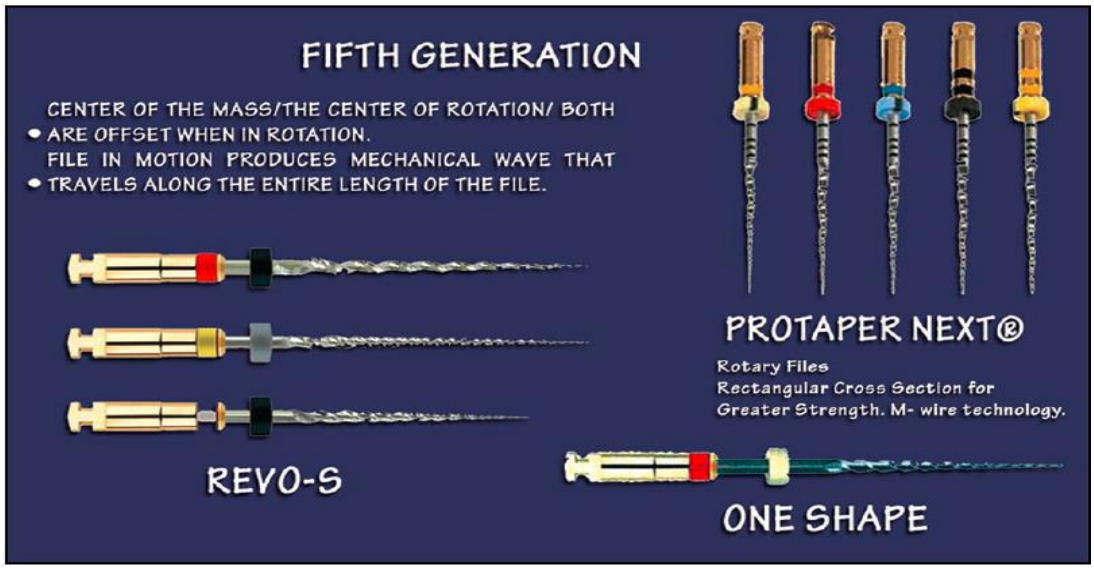
Contraindicated for wide or relatively wide and straight ducts **(Nabeshima CK.et al,2014).**

4.5 Fifth Generation

In this generation, the efficiency of canal shaping has been improved by offsetting the center of rotation**(Duke F.et al,2015).** The offset designed files produce a mechanical wave of motion that distributes along the full length of the NiTi file which improves cutting and removing 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**(Nabeshima CK.et al,2014).**

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. Taper instrument with asymmetrical cross section along the entire blade has variable cross section and longer pitch. Using the glide path, the instrument is optional in 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**(Tabassum S et al,2019).**



Figue 11 fifth-generation instruments.(Shivakumar and Kalgeri, 2016)

- 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 **(Zana A.et al,2021)**.

4.6 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) manufactured with Nitinol 508 and consisting of a blue titanium oxide layer, not seen in traditional super-elastic NiTi instruments **(Zana A.et al,2021).**

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 **(Nabeshima CK.et al,2014)**.

- 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), greater resistance to torsion, offers 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 a less resistance of the instrument when introduced into the root canal **(Zana A.et al,2021).**

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 conventional nickel titanium alloy. Torsion resistance is also affected by the cross-sectional design, the metal mass and the properties of the alloy **(Nabeshima CK.et al,2014).** Shen Y, et al. , conducted a study where they compared the Profile Vortex (M-Wire) and Vortex Blue systems after their clinical use. Each system was used up to three times, except in very curved or calcified ducts, they were discarded at their first use. They concluded that the fracture rate in that study was too low for a difference between the two systems **(Zana A.et al,2021).**

5 Advanced in rotary endodontics

- **Revo-S:**

This new sequence with only 3 nickel-titanium instruments simplifies the initial endodontic treatment and optimizes the cleaning. The asymmetrical cross section of the Revo-S facilitates penetration by a “snake-like” movement, and offers a root canal shaping which is adapted to the biological and ergonomic imperatives**(Duke F.et al,2015)**. This sequence has a cutting, debris elimination and cleaning cycle, which optimizes the root canal cleaning by improving the upward removal of the generated dentine debris**(Zana A.et al,2021).** It also offers the choice of an apical finishing (AS30, AS35 and AS40), which is most closely adapted to the anatomical and ecological criteria of the canal. The Advantages of Revo-S is it enables a better root canal penetration due to a “snake- like” movement = better progression of the instrument toward the apical region of the root canal. Facilitates the elimination of debris upward the coronal thanks to the increased available volume for debris.Avoids the grooves to be obstructed and thus avoids the extrusion of debris beyond the instrument tip and apical foramen. Reduces the stress on the instrument thanks the rippling movement of the file along the canal walls: no screwing effect, more flexibility, and better ability to negotiate curves **(Stephen Buchanan et al ,2009).**

The Revo-S NiTi rotary system also manufactured by Micro-Mega simplifies and optimizes the cleaning and shaping of the root canals with only three NiTi instruments. The asymmetric cross section of the Revo-S facilitates penetration by a snake-like movement and offers a root canal shaping adopted to the biological and ergonomic imperatives[Figure7]**(Gorni, F.G.et al,2004).**

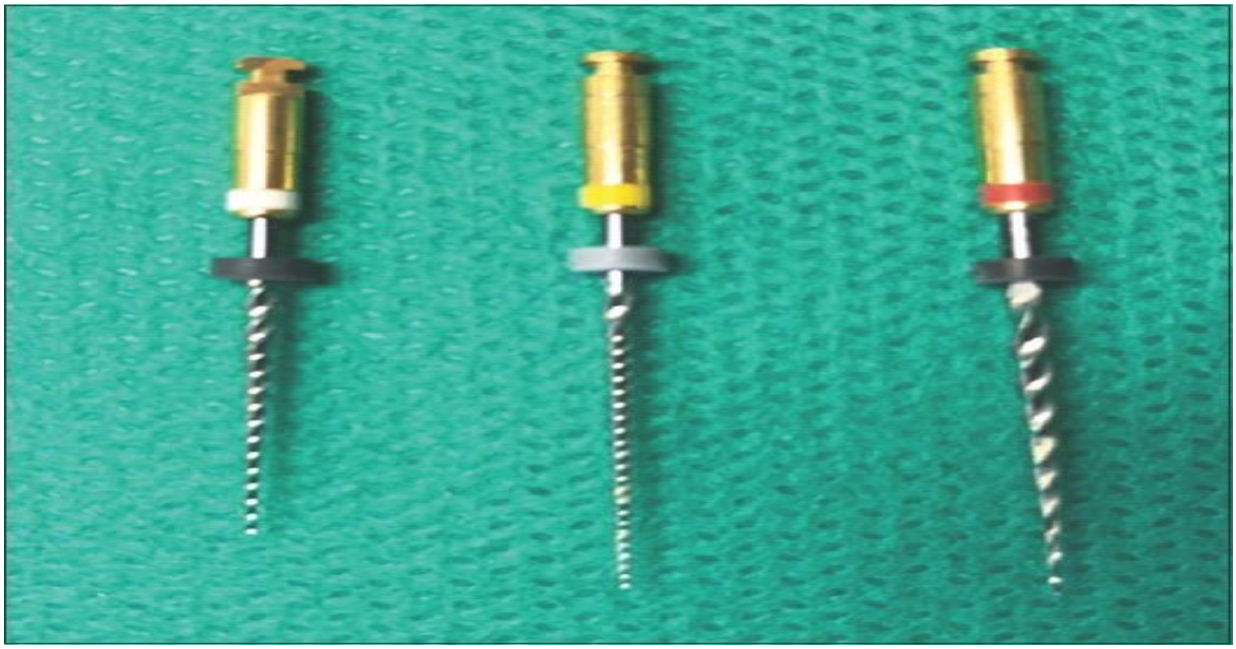


Fig12 : Revo S nickel–titanium rotary system

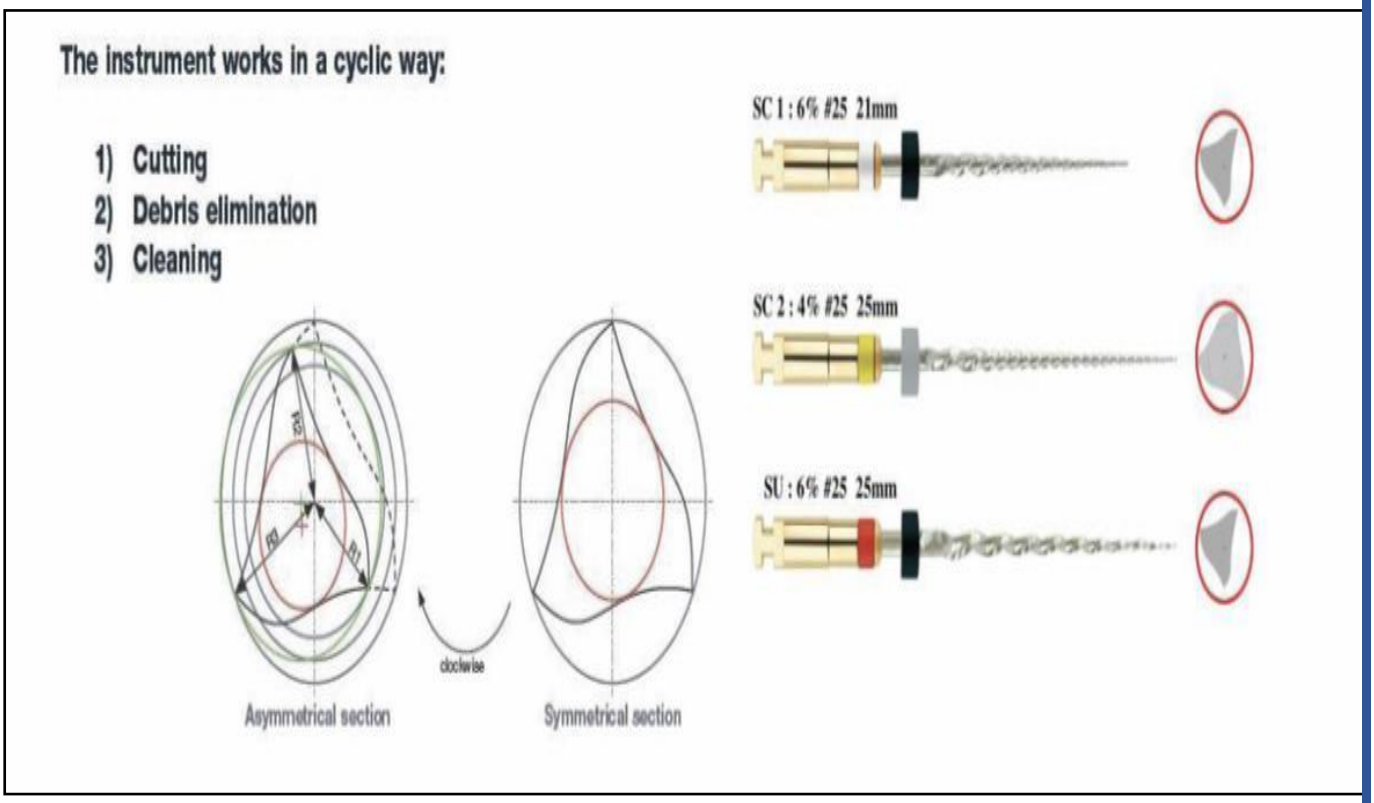


Fig13: Revo S The instrument works in a cyclic way.A Customized Treatment Using 3 Instruments.

6 Recently introduced NiTi file systems

The composition, alloy, properties, and recommended use of these new systems are summarized in Table 1**(Tabassum S et al,2019).**

TABLE 1: Composition, properties, and recommended use of different NiTi systems

NiTi System	**Alloy**	**Composition**	**Properties**	**Recommended use**
Hyflex CM	CM wire	Martensite with different amounts of austenite and R-phase	•No superelasticity •High resistance to cyclic fatigue •Increased flexibility	• Severely curved canals •Bypassing ledges
Hyflex EDM	CM wire; EDM technology	No austenite phase	•Increased cutting efficiency • Increased cyclic fatigue resistance	•Straighter canals •Used in combination with Hyflex CM in severely curved canals
BT-RaCe	Conventional NiTi	Austenite-Electropolished	•Triangular cross section • Booster tip	•Conservative instrumentation of all types of canals •Original canal shape maintained
Vortex Blue and ProTaper Gold	M-wire	Martensite TiO2 layer on surface	•Shape memory • Super elasticity • Increased cyclic fatigue resistance	•Severely curved canals •Bypassing ledges

7- Causes and prevention of fractures of NiTi instruments

The most common accident in the use of nickel titanium instruments is fracture, which determines a great difficulty in removing a separate instrument from inside the root canal. These causes of separation or fracture of the instruments can be grouped in clinical and metallographic form.

- Clinical causes

Lack of previous elimination of cervical and coronal interferences: The elimination of interferences constitutes an indispensable aspect in the preparation of the root canal either using stainless steel or nickel titanium instruments to access in a direct way to the canal**(Leonardo MR.et al,2017).**

- Prior patent absent

It is a requirement to carry out the previous probing or catheterization with stainless steel manual K files in the segment of the root canal that will be subjected to the action of the rotary instruments, in this way the difference between the diameter of the tip is reduced or equalized of the instrument and that of the duct. That is, mechanized instruments are preceded by manual instruments**(Gutiérrez JF.et al,2015).**

- Metallographic causes

Inadequate Kinematics in NiTi instruments. They occur when the instrument rotates inside of the root canal and suffers two types of stress or fatigue, by torsion and flexion**(Lopes HP.et al,2016).**

- Torsional fatigue

It occurs when a segment of the instrument, usually the tip locks in the walls of the root canal and is immobilized without being able to overcome the resistance of the dentin to produce the cut; The other end of the instrument is subjected to the axial torque generated by the motor when turning**Gutiérrez JF.et al,2015).**A stress is then created that exceeds the limit of elasticity of the metal, producing a plastic deformation followed by the unwanted fracture of the instrument . In summary, the fracture occurs if the section of the canal is smaller than the tip of the instrument impeding cutting the dentin**(Leonardo MR.et al,2017).**

- Flexural fatigue

Flexural stress is directly related to the curvature of the root canals, the diameter of the instrument and the speed of rotation, which are variables that determine the lifespan of the instrument .

Cyclic fatigue is the altered repetition of tension-compression cycles on a point of the instrument when it rotates in a curved root canal. An instrument with less conicity will withstand flexural stress better than an instrument with greater conicity **(Gutiérrez JF.et al,2015).**

Conclusion

With emerging technology, we see endodontics being swept away in the latest wave of technization. There is plethora of different systems available, and a large number of studies have focused on various physical and chemical aspects of NiTi files. Various proprietary methods and treatments have been introduced to enhance the cutting ability and file design. Files with the austenite phase have super elastic properties and are recommended to be used in straight or mildly curved canals, whereas those instruments composed of the martensite phase possess high flexibility along with increased resistance to cyclic fatigue and are recommended to be used while preparing canals with complex curvatures. Heat-treated and controlled memory NiTi alloys are being used widely nowadays as reflected by the current literature. These newer designs have increased flexibility and reduced shape memory property. When used clinically, these instruments can better penetrate the entrance of the canals as they can be pre-bent to maintain the flexed shape.

The knowledge of the properties of NiTi alloy and an in-depth understanding of the mechanical behavior of endodontic instruments during instrumentation procedure is mandatory in order to improve techniques, instrument design and their clinical use. Intracanal separation of NiTi endodontic rotary instruments is still one of the major concerns of endodontists, even if the success rate of root canal therapy is high. Reducing the percentage of instrument failure is a fundamental future perspective and a deep comprehension of The NiTi alloy and stresses acting on the endodontic instruments during shaping procedures are needed to achieve this goal.

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