UTTAR PRADESH TEXTILE TECHNOLOGY INSTITUTE, KANPUR

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TOPIC	:UNIT 5 : NiTi Alloy
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CONTENTS

INTRODUCTION

- In the early 1960s, a nickel–titanium alloy was developed by **William F. Buehler** for the space programme at the Naval Ordnance Laboratory in Silver Springs, Maryland, USA.

- The thermodynamic properties of this intermetallic alloy were found to be capable of producing a shape memory effect when specific, controlled heat treatment was undertaken.

- Nitinol- an acronym for the elements from which the material was composed**;** ***ni* for nickel, *Ti* for titanium and *nol* from the Naval Ordnance Laboratory.**

- Nitinol- family of intermetallic alloys of nickel and titanium which have been found to have unique properties of **shape memory and super-elasticity.**

- Super-elastic behaviour means that on unloading they return to their original shape before deformation.

- Greater strength and a lower modulus of elasticity compared with stainless steel- use of NiTi instruments during the preparation of curved root canals- because the files will not be permanently deformed as easily as would happen with traditional alloys

METALLURGY OF NICKEL–TITANIUM ALLOYS

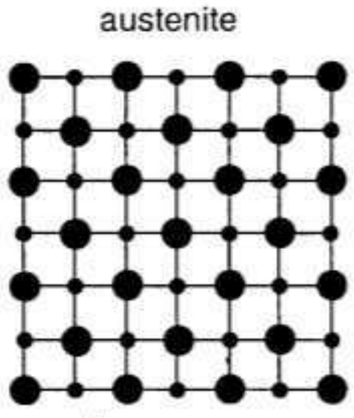
- The nickel–titanium alloys used in root canal treatment contain approximately **56% (wt) nickel and 44% (wt) titanium.**

- In some NiTi alloys, a small percentage (<2% wt) of nickel can be substituted by cobalt.

- Generic term- **55-Nitinol** (inherent ability to alter their type of atomic bonding- unique and significant changes in the mechanical properties and crystallographic arrangement of the alloy.

- These changes occur as a function of temperature and stress.

- The two unique features that are of relevance to clinical dentistry- ***shape memory* and *super-elasticity*** (occur as a result of the austenite to martensite transition in the NiTi alloy).



STRUCTURE OF NICKEL–TITANIUM

- The crystal structure of NiTi alloy at high temperature ranges (100°C) is a stable, body-centred cubic lattice which is referred to as the *austenite phase* or parent phase.

- 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 electric resistivity as a result of changes in electron bonding.

- By reducing or cooling the temperature through this range, there is a change in the crystal structure which is known as the *martensitic transformation*; the amount of this transformation is a function of the start (Ms) and finish (Mf) temperature.

- The phenomenon causes a change in the physical properties of the alloy and gives rise to the *shape memory* characteristic.

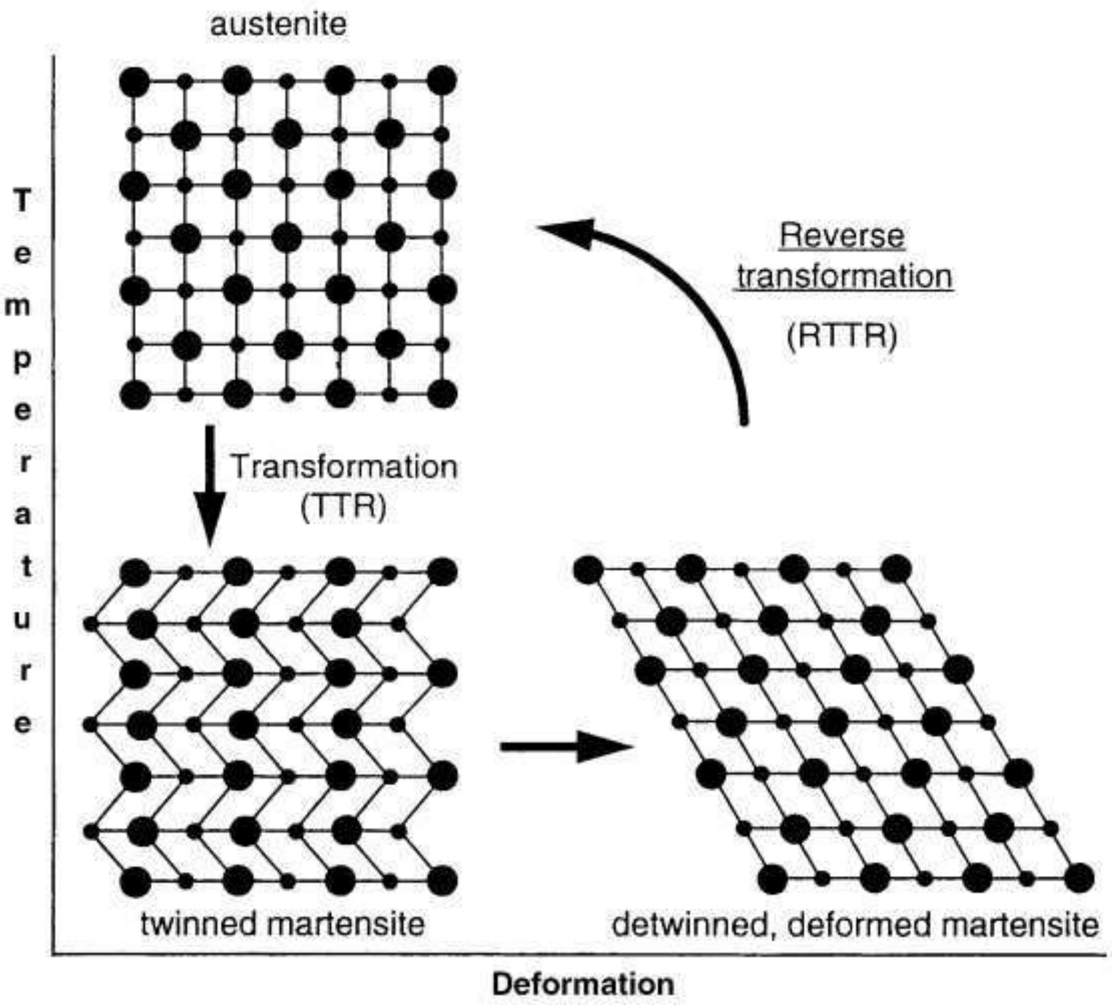


Figure Diagrammatic representation of the martensitic transformation and shape memory effect of NiTi alloy.

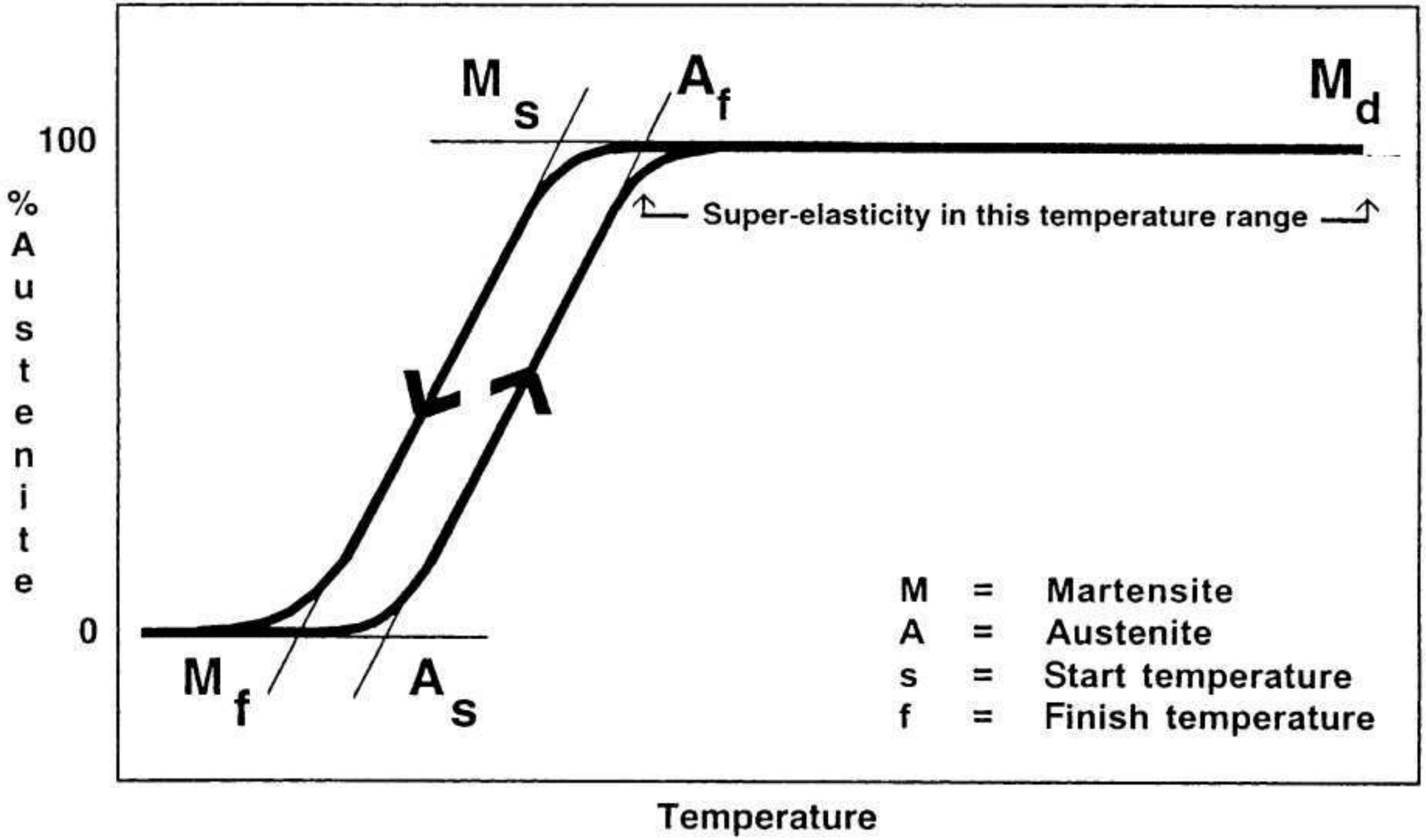
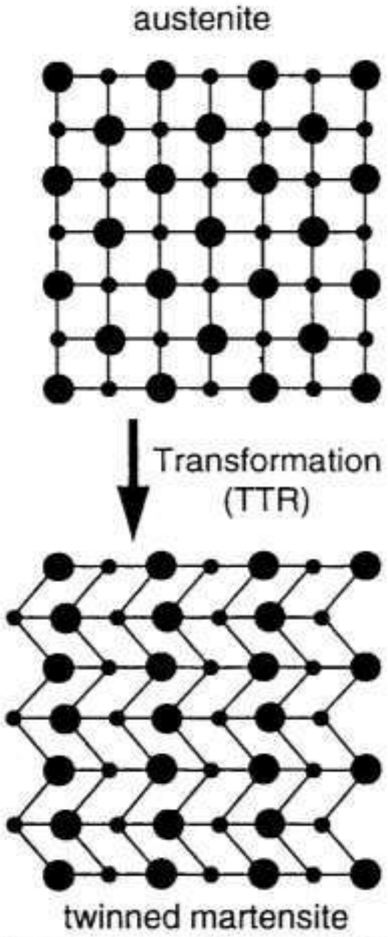
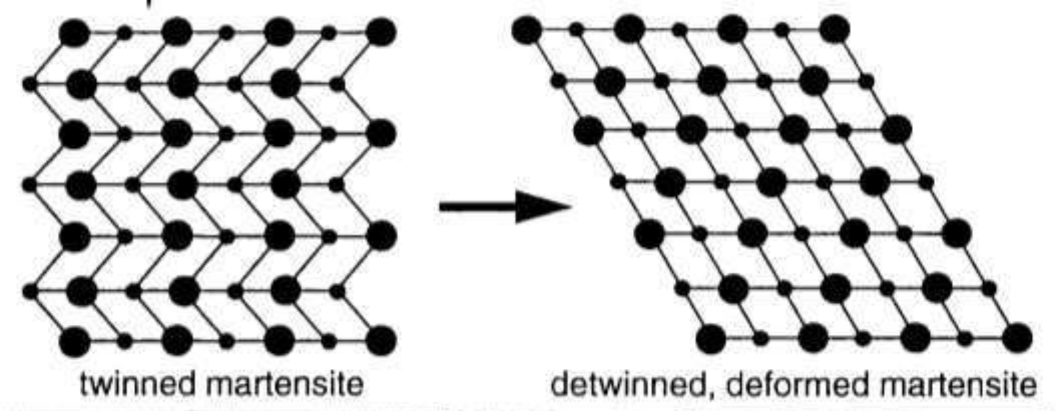


Figure Hysteresis of martensitic transformation.

- The transformation induced in the alloy occurs by a shear type of process to a phase called the ***martensitic* or daughter phase,** which gives rise to *twinned martensite* that forms the structure of a closely packed hexagonal lattice.

- Almost no macroscopic shape change is detectable on the transformation, unless there is application of an external force.



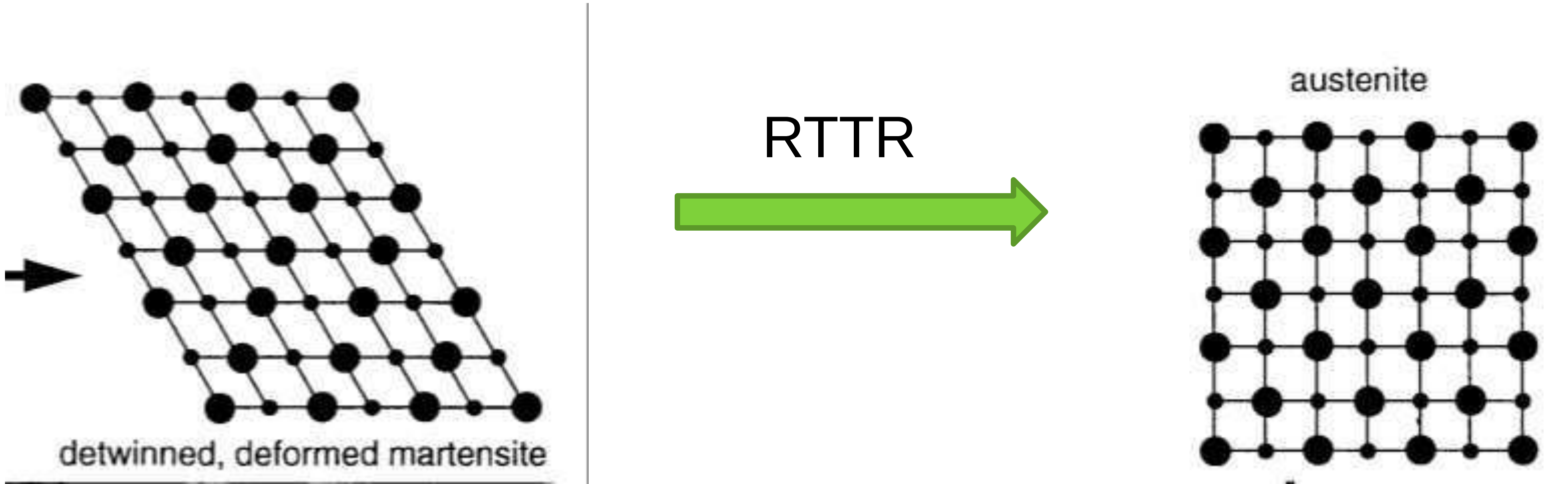


- The martensite shape can be deformed easily to a single orientation by a process known as de-twinning to *detwinned martensite*, when there is a ‘flipping over’ type of shear.

- The NiTi alloy is **more ductile in the martensitic phase** than the austenite phase.

- The deformation can be reversed by heating the alloy above the TTR (reverse transformation temperature range or RTTR).

- The alloy resumes the original parent structure and orientation as the body-centred cubic, high temperature phase termed *austenite* with a stable energy condition.



- The total atomic movement between adjacent planes of atoms is less than a full interatomic distance when based on normal atomic lattice arrangements.

- This phenomenon is termed ***shape memory.***

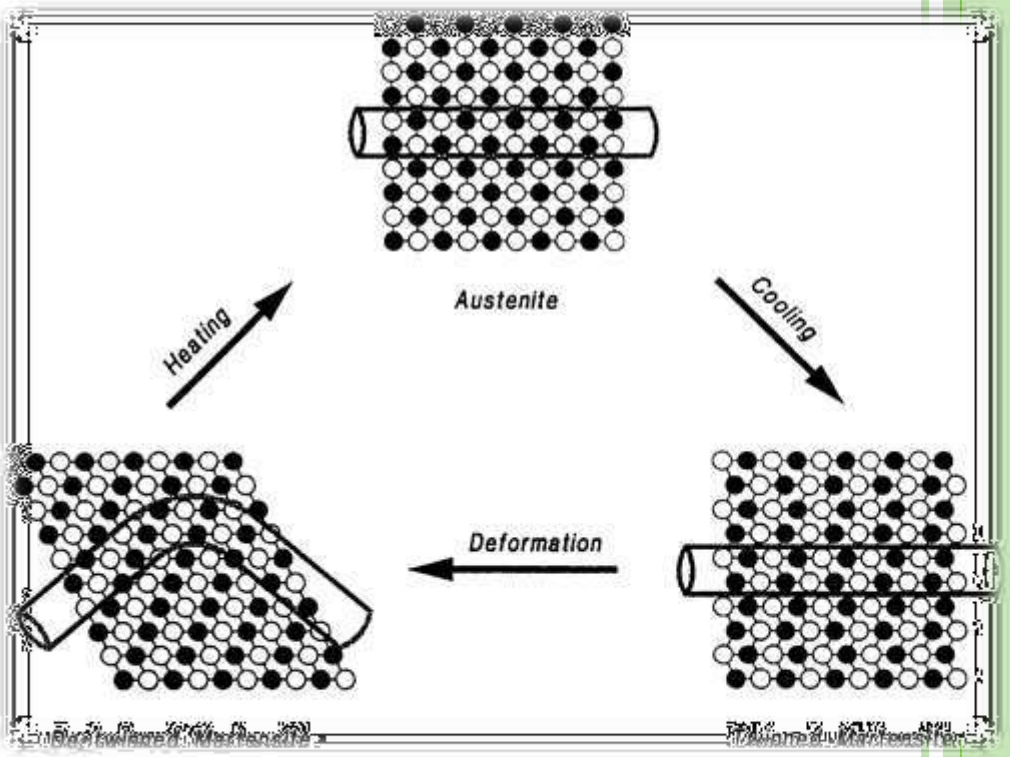


Figure Diagrammatic representation of the shape memory effect of NiTi alloy.

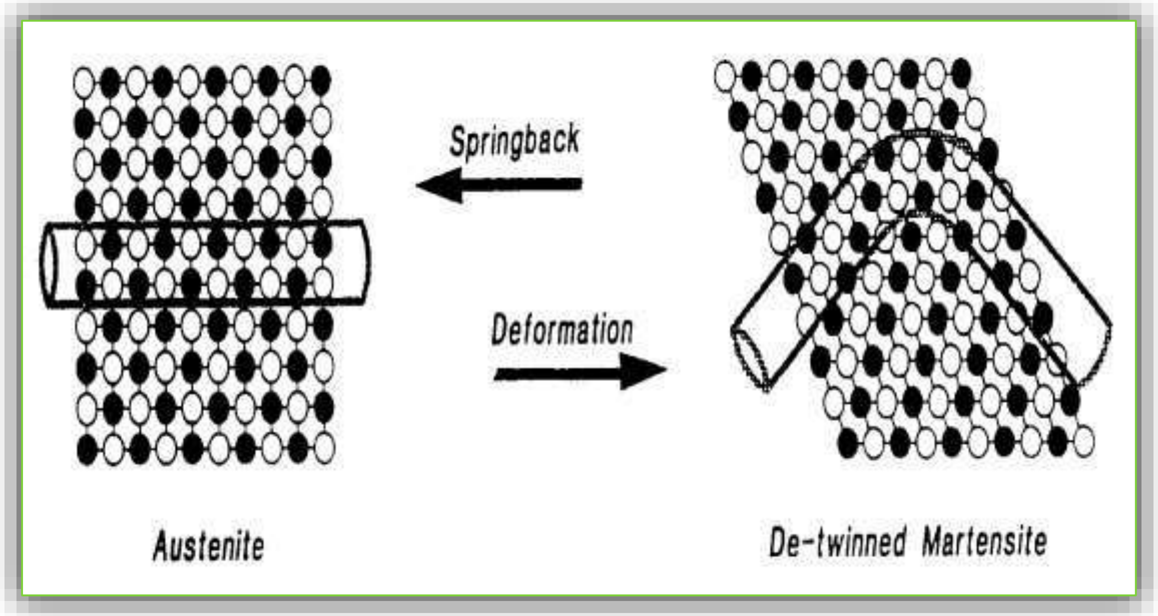


Figure Diagrammatic representation of the super elasticity effect of NiTi alloy.

- It is possible using the shape memory effect to educate or place the NiTi alloy into a given configuration at a given temperature.

- This can be carried out at lower temperatures which deform the NiTi with a very low force and results in the ‘twins’ all occurring in the same direction.

- When the NiTi is heated through its transformation temperature it will recover its original ‘permanent’ shape.

- In terms of endodontology, this phenomenon may translate to the ability to remove any deformation within nickel–titanium instruments by heating them above **125°C.**

- The transition temperature range for each nominal 55-Nitinol alloy depends upon its composition.
- The TTR of a 1 : 1 ratio of nickel and titanium is in the range of –50 to +100°C.
- Reduction in the TTR can be achieved in several ways;
  - in the manufacturing process both **cold working and thermal treatment,**
  - altering the nickel : titanium ratio in favour of **excess nickel**, or
  - by substituting **cobalt** for nickel.

STRESS-INDUCED MARTENSITIC TRANSFORMATION

- The transition from the austensitic to martensitic phase can also occur as a result of the application of stress, such as occurs during root canal preparation.

- In most metals, when an external force exceeds a given amount mechanical slip is induced within the lattice causing permanent deformation; however, with NiTi alloys a *stress-induced martensitic transformation* occurs, rather than slip

This causes:

- a volumetric change associated with the transition from one phase to the other and an orientation relation is developed between the phases
- the rate of the increase in stress to level off due to progressive deformation even if strain is added due to the martensitic transformation. This results in the so-called *super-elasticity*.
- *Springback* when the stress decreases or stops without permanent deformation occurring. Springback is defined as load per change in deflection to the previous shape with a return to the austenite phase, provided the temperature is within a specific range.

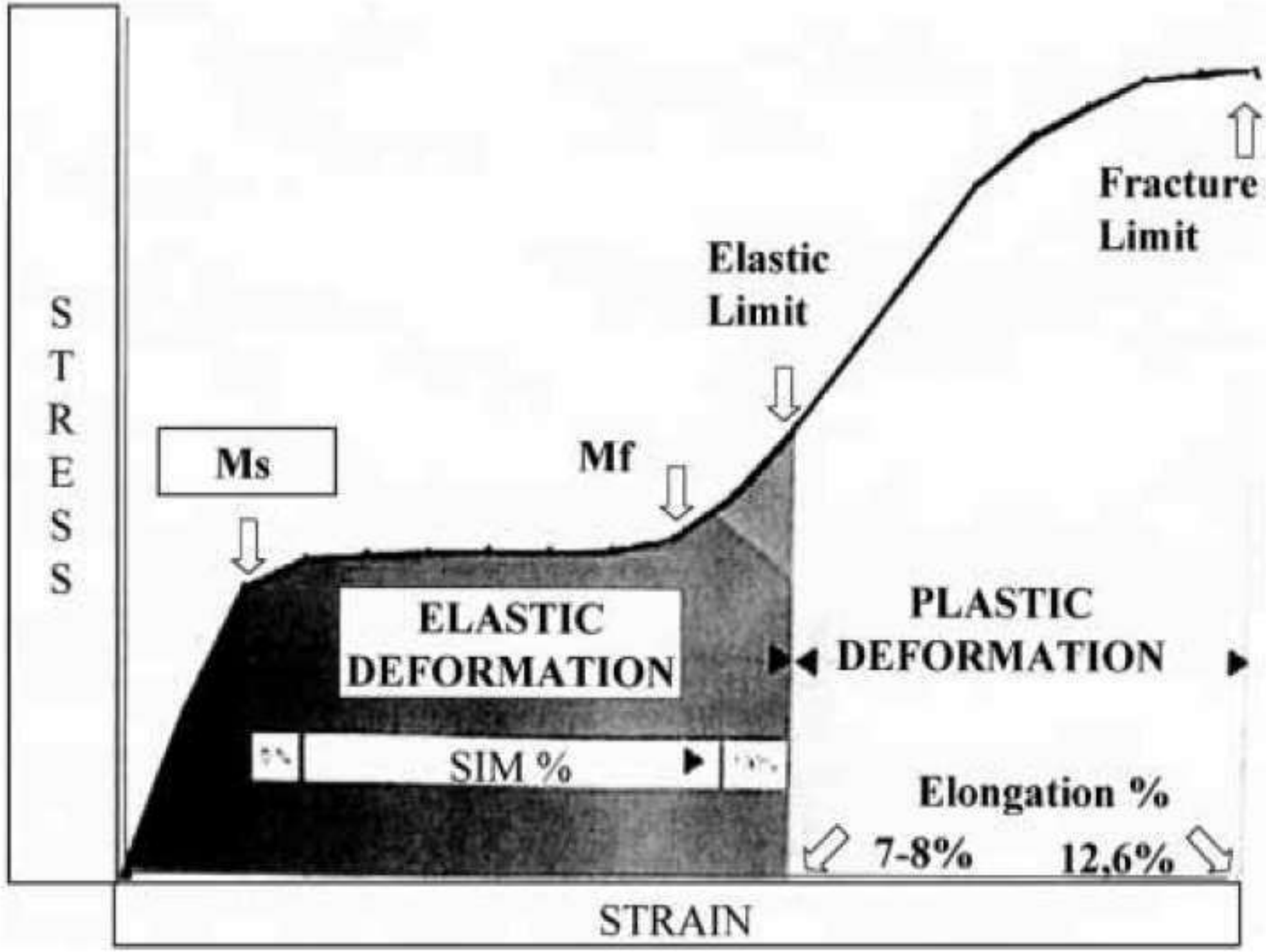


Figure NiTi phase transformation.

- The plastic deformation that occurs in NiTi alloys within or below the TTR is recoverable, within certain limits, on reverse transformation.
- It is this phenomenon of crystalline change which gives rise to the shape memory effect of the material and the superelastic behaviour.
- The part of the RTTR in which *'shape recovery'* occurs is termed the *shape recovery temperature range* (SRTR).

- This has also been termed ‘**mechanical memory**’.

- This is unlike conventional metallic stress-strain behaviour where elastic response in conventional alloys is recoverable, but is small in size; and where larger strains are associated with plastic deformation, that is not recoverable.

- The super-elasticity of nickel–titanium allows deformations of as much as 8% strain to be fully recoverable, in comparison with a maximum of less than 1% with other alloys, such as stainless steel.

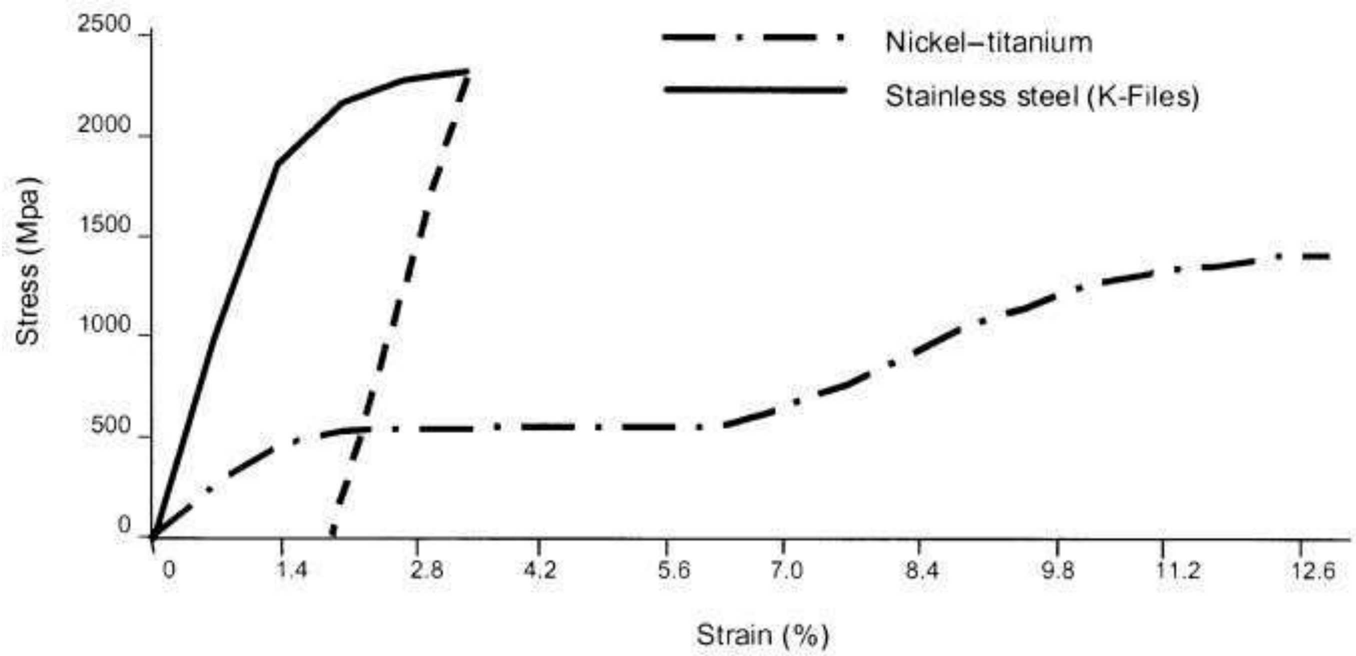
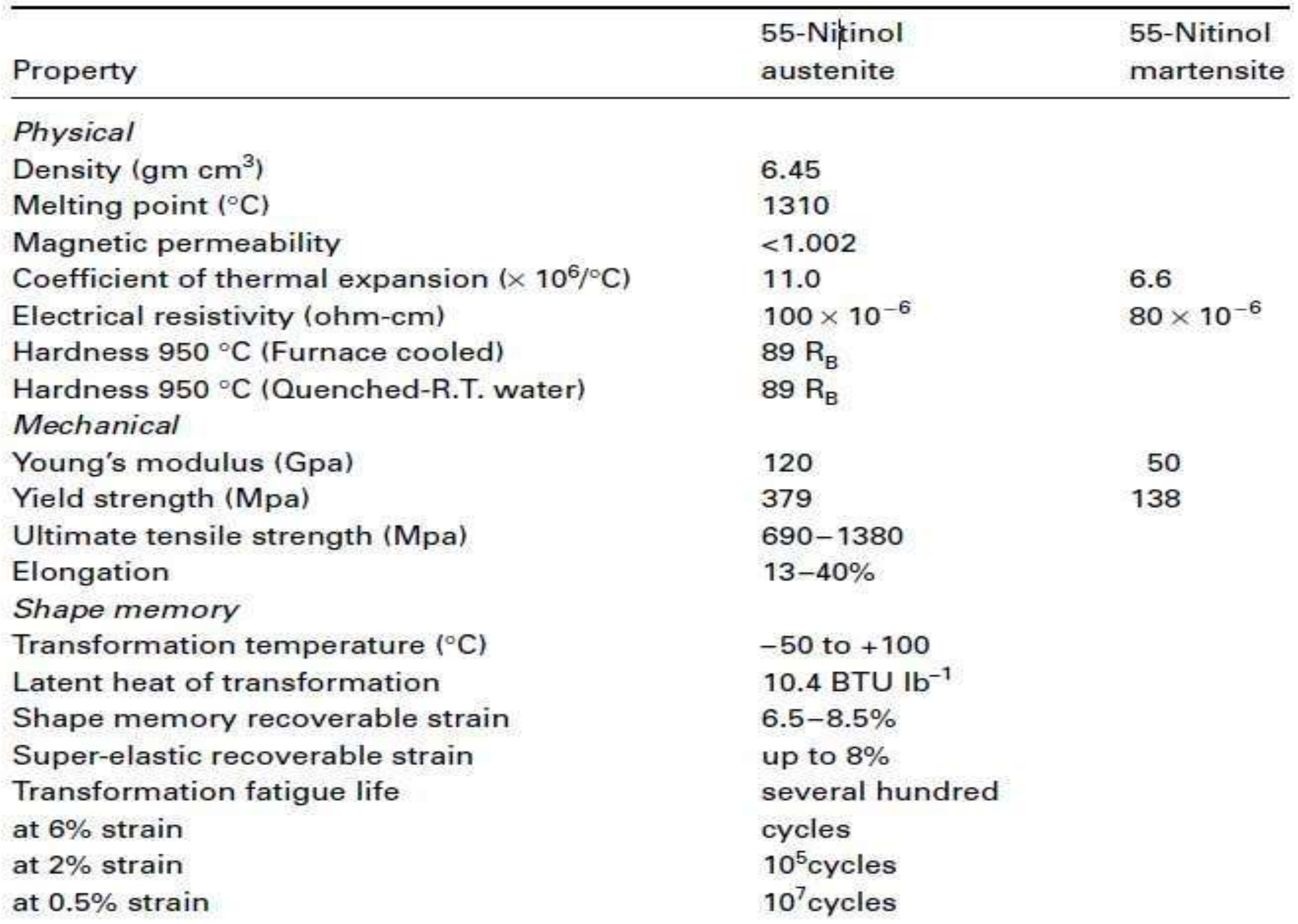


Figure Stress-strain curve: stainless steel and nickel–titanium.

- A second group of Nitinol alloys can be formed if the NiTi alloy contains more nickel and as this approaches 60% (wt) Ni an alloy known as **60-Nitinol forms.**

- The shape memory effect of this alloy is lower, although its ability to be heat-treated increases.

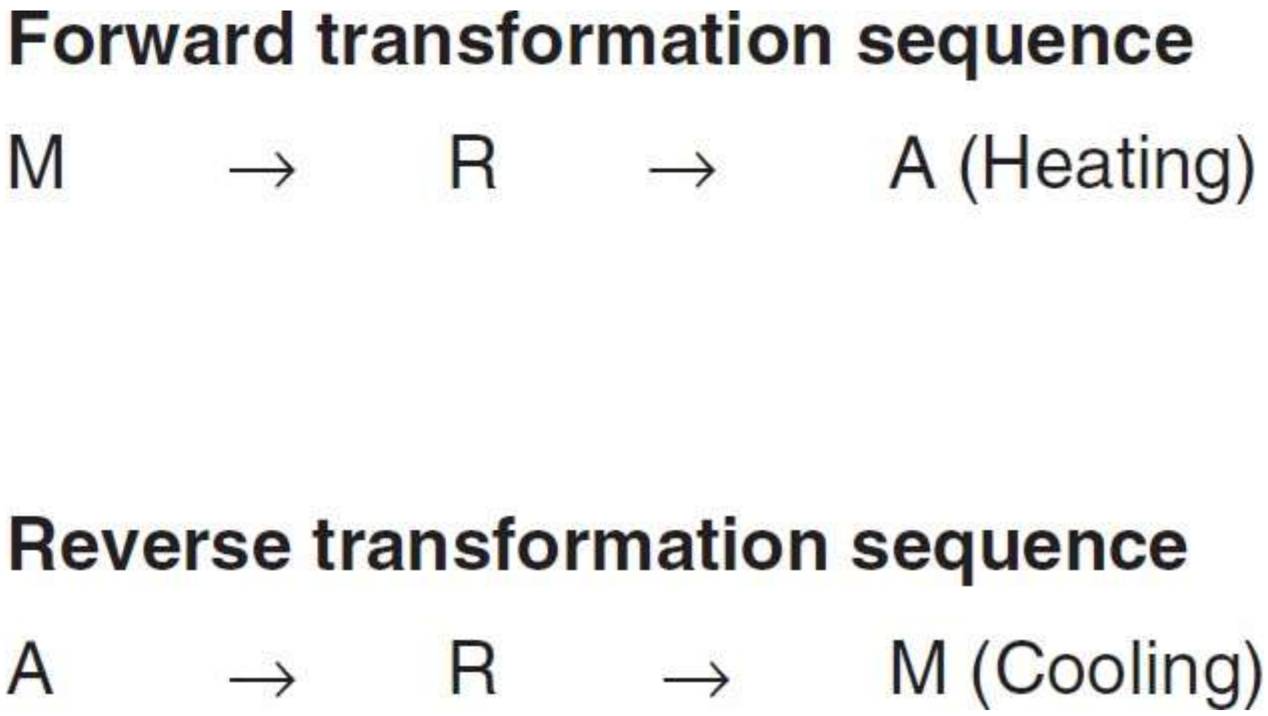
- Both 55 and 60- Nitinols are more resilient, tougher and have a lower modulus of elasticity than other alloys such as stainless steel, Ni–Cr or Co–Cr.



Property	55-Nitinol austenite	55-Nitinol martensite
Physical		
Density (gm cm^3)	6.45	
Melting point (°C)	1310	
Magnetic permeability	<1.002	
Coefficient of thermal expansion (× 10^6/°C)	11.0	6.6
Electrical resistivity (ohm-cm)	100×10^{-6}	80×10^{-6}
Hardness 950 °C (Furnace cooled)	89 R_B	
Hardness 950 °C (Quenched-R.T. water)	89 R_B	
Mechanical		
Young's modulus (Gpa)	120	50
Yield strength (Mpa)	379	138
Ultimate tensile strength (Mpa)	690–1380	
Elongation	13–40%	
Shape memory		
Transformation temperature (°C)	–50 to +100	
Latent heat of transformation	10.4 BTU lb^{-1}	
Shape memory recoverable strain	6.5–8.5%	
Super-elastic recoverable strain	up to 8%	
Transformation fatigue life	several hundred	
at 6% strain	cycles	
at 2% strain	10^{5}cycles	
at 0.5% strain	10^{7}cycles	

R PHASE

- It is an intermediate phase with a rhombohedral structre.



Forward transformation sequence

M → R → A (Heating)

Reverse transformation sequence

A → R → M (Cooling)

- R-phase possesses lower shear modulus than martensite and austenite, and the transformation strain for R-phase transformation is less than one-tenth of that of martensitic transformation.

CONTROLLED MEMORY(CM) WIRE

- Made from a NiTi wire subjected to proprietary thermomechanical processing.
- Have superior fatigue resistance than conventional NiTi rotary instruments made from superelastic wire.

M WIRE

- Developed with the objective of producing superelastic NiTi wire blanks that contains substantial stable martensite under clinical conditions
- Developed through a proprietary thermomechanical processing.
- It has significantly improved cyclic fatigue resistance.
- Contains all 3 crystalline phases, including deformed and microtwinned martensite, R-phase, and austenite.

MANUFACTURE OF NITINOL ALLOY

- Nickel–titanium alloy production is a very complex process that consists of:
  - vacuum melting/casting
  - press forging
  - rotary swaging
  - rod/wire rolling

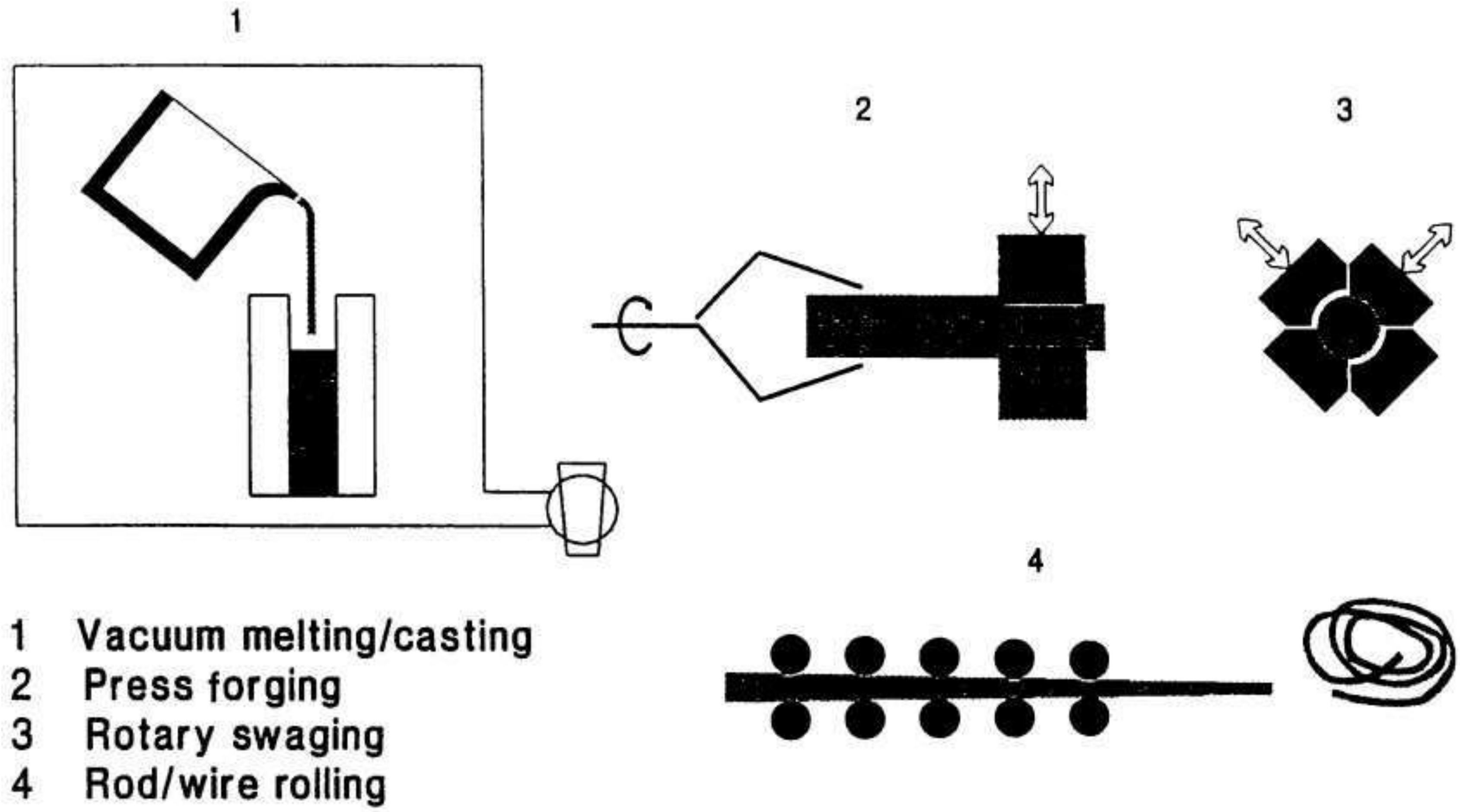
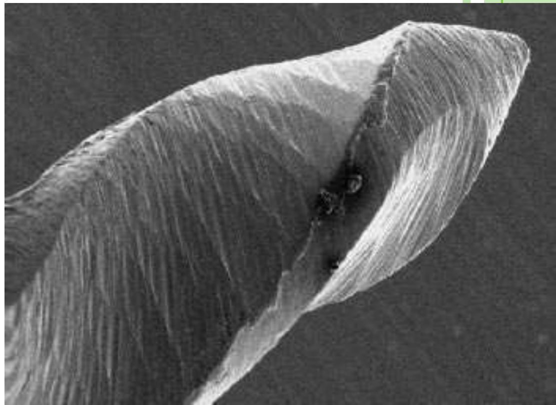


Figure Diagrammatic representation of the manufacturing process of Nitinol alloy.

CONSTRUCTION OF ROOT CANAL INSTRUMENTS

- The manufacture of NiTi endodontic instruments is more complex than that of stainless steel instruments, as the files have to be machined rather than twisted.
- The super-elasticity of the alloy means that it cannot maintain a spiral as the alloy undergoes no permanent deformation.
- Attempts to twist instruments in a conventional way would probably result in instrument fracture

- The instrument profile (design) has to be ground into the Nitinol blanks.
- Further difficulties during production include elimination **of surface irregularities (milling marks) and metal flash (roll-over)** on the cutting edges that may compromise the cutting ability of these instruments and potentially cause problems with corrosion.



- The composition of Nitinol used to construct endodontic instruments is 56% (wt) nickel and 44% (wt) titanium.

- It is possible to vary the composition of NiTi alloy in order to give rise to wires with two different characteristics; either to be a super-elastic alloy or to have the shape memory property.

- Ideally, for the manufacture of root canal instruments the **ultimate tensile strength of the alloy should be as high as possible** to resist separation, whilst the **elongation parameters must be suitable for instrument flexibility**, thereby decreasing canal transportation, and to allow high resistance to fatigue.

- Once the alloy has been manufactured, it undergoes various processes before the finished wire can be machined into a root canal instrument.
- Essentially, the casting is forged in a press into a cylindrical shape prior to rotary swaging under pressure, to create a drawn wire.
- The wire is then rolled to form a tapered shape with even pressure from a series of rollers applied to the wire.

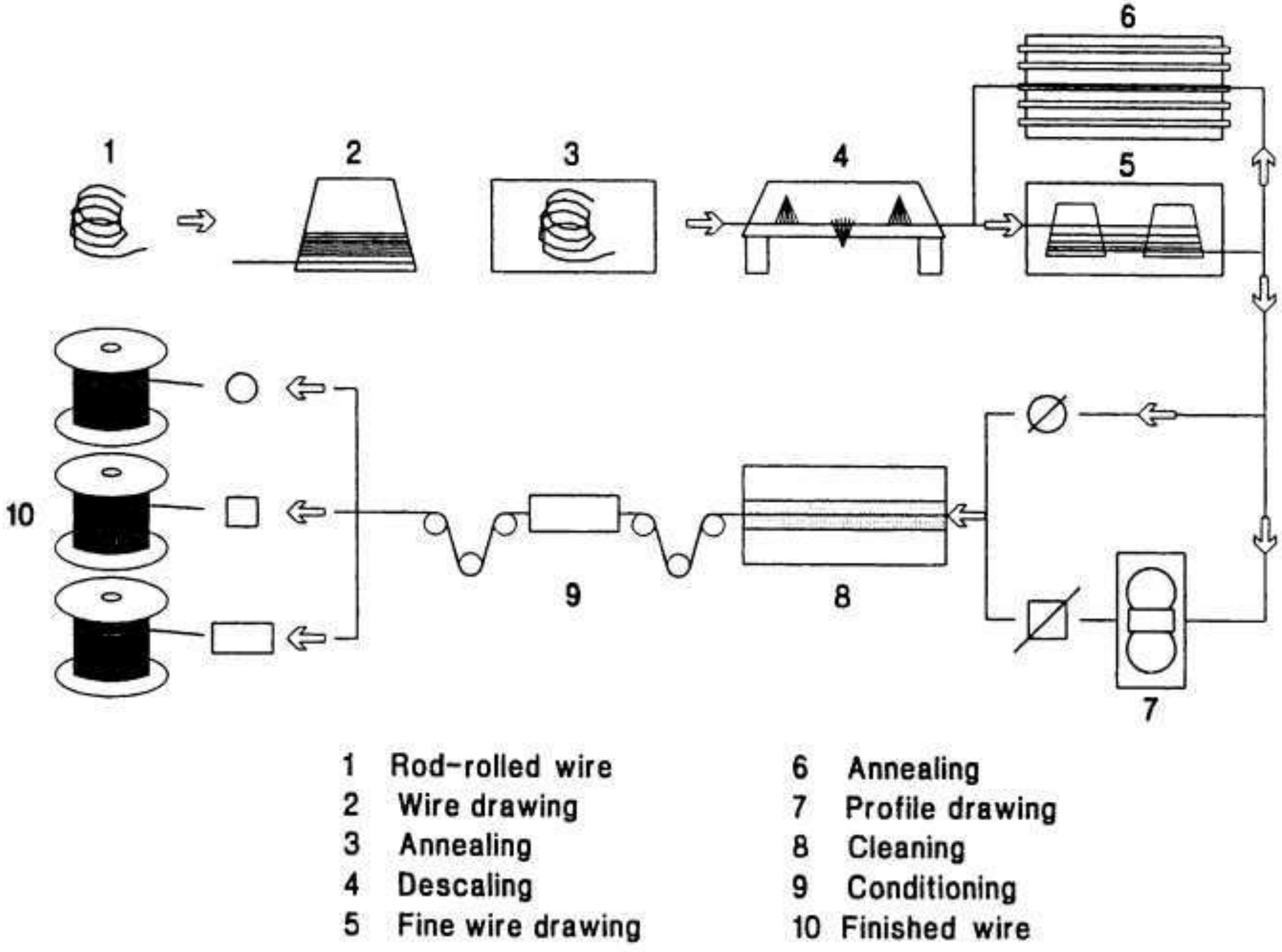


Figure Diagrammatic representation of the production of finished Nitinol wire.

NITI FRACTURE

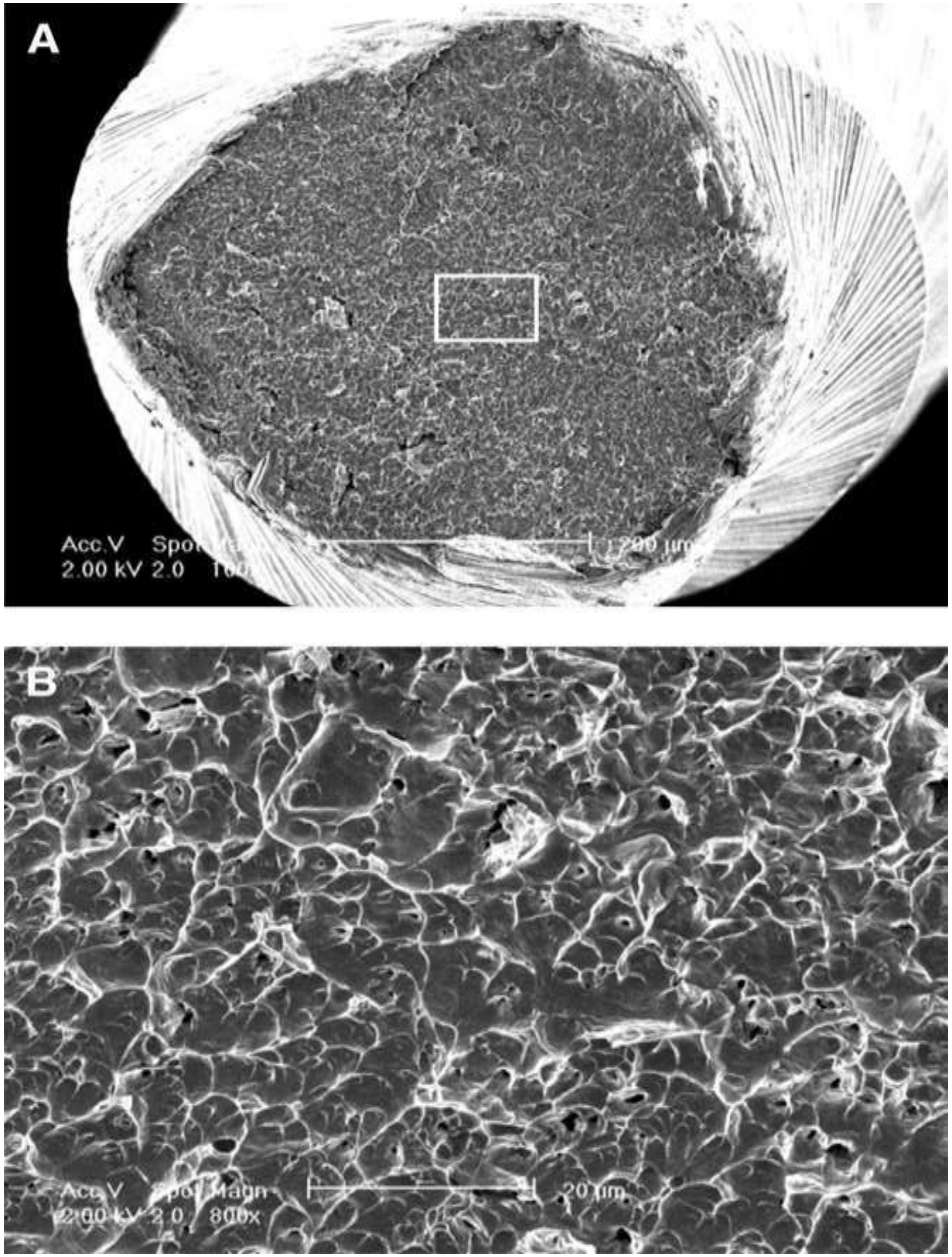
- In general fracture can be classified as either brittle or ductile.
- Ductility refers to the ability of a material to undergo plastic deformation before it breaks.
- Brittle fractures are associated with little or no plastic deformation.
- Hence, brittle fractures usually occur in metals with poor ductility.

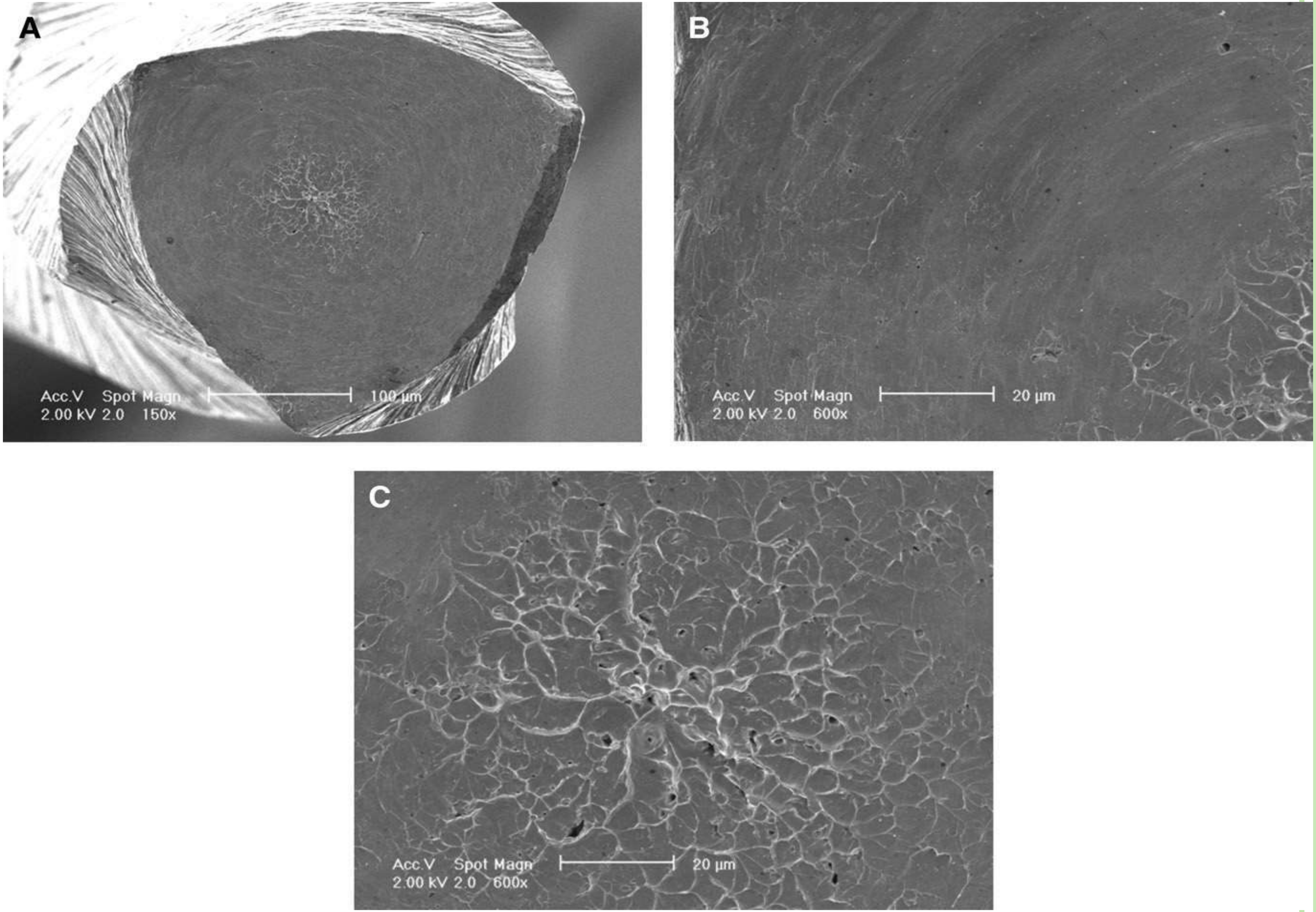
- Typically there is an initiation of cracks at the surface of the metal, and stress concentration at the base of the crack results in its propagation either along grain boundaries (intergranular) or between specific crystallographic planes (cleavage fracture).

- The crack thus behaves as a stress-raiser, because an applied load, instead of being spread over a smooth surface, will be concentrated at one point or area.

- In ductile fractures microvoids are produced within the metal and nucleation, growth, and microvoid coalescence ultimately weaken the metal and result in fracture.

- The fracture surface is characterized by a dull dimpled surface.


A
Acc.V Spot Magn
2.00 kV 2.0 100
200 µm
B
Acc.V Spot Magn
2.00 kV 2.0 800x
20 µm


A
Acc.V Spot Magn
2.00 kV 2.0 150x
100 µm
B
Acc.V Spot Magn
2.00 kV 2.0 600x
20 µm
C
Acc.V Spot Magn
2.00 kV 2.0 600x
20 µm

- Metal fatigue results from repeated applications of stress, leading to cumulative and irreversible changes within the metal.
- It may be caused by tensile, compressive, or shear forces as well as corrosion, wear, or changes produced by thermal expansion and contraction .
- Fatigue crack growth can be identified by striation marks on fracture surfaces, and has been demonstrated in fractured rotary NiTi instruments

- Fractured rotary NiTi instruments have been classified into those that fail as a result of ***cyclic flexural fatigue*** *or* ***torsional failure*** *or a combination of both.*

- Fracture caused by fatigue through flexure occurs because of metal fatigue.

- As an instrument is held in a static position and continues to rotate, one half of the instrument shaft on the outside of the curve is in tension, whereas the half of the shaft on the inside of the curve is in compression.

- This repeated tension-compression cycle, caused by rotation within curved canals , increases cyclic fatigue of the instrument overtime and may be an important factor in instrument fracture.

- Torsional fracture occurs when an instrument tip or another part of the instrument is locked in a canal while the shank continues to rotate.
- When the elastic limit of the metal is exceeded by the torque exerted by the handpiece, fracture of the tip becomes inevitable.
- Such fractured instruments shows specific sign such as plastic deformation.

FACTORS PREDISPOSING TO FRACTURE

A) **Instrument Design:**

- Both cross sectional area and file design may affect an instruments resistance to fracture when subjected to flexural and torsional load.

- Instruments with larger diameters have been found to succumb to flexural fatigue earlier than those with smaller diameters, and they appear to have greater internal stress accumulation.

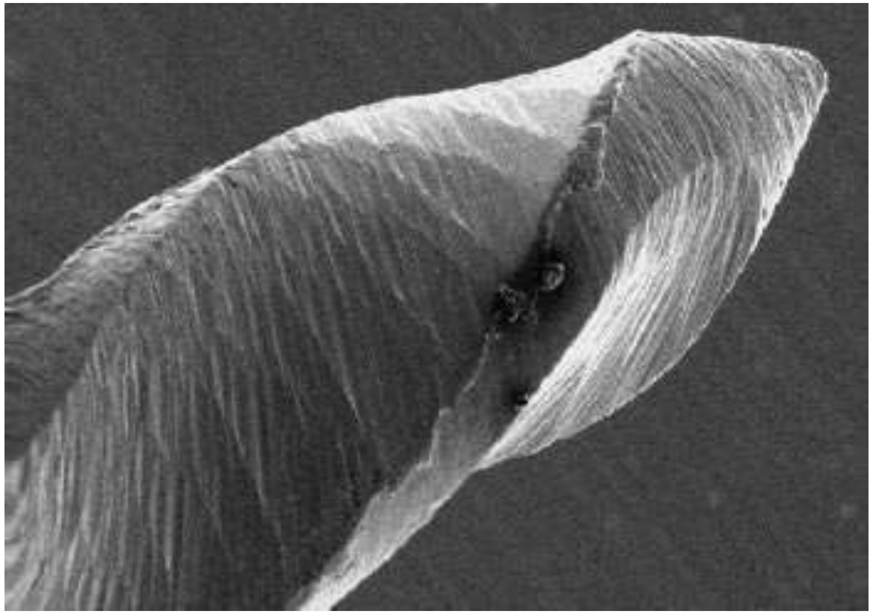
- However, an increase in instrument diameter and corresponding increase in cross-sectional area may contribute to increased resistance to torsional failure.
- Other design factors that may affect instrument fracture include brand of instrument (i.e. alloy composition), instrument size, and taper

B) **Manufacturing Process**

- During the manufacture and processing of NiTi alloy, a variety of inclusions, such as oxide particles, may become incorporated into the metal resulting in weaknesses at grain boundaries.

- Some surface voids are presumed to be because of small amounts of oxygen, nitrogen, carbon, and hydrogen dissolving in the alloy to form various precipitates.

- The manufacture and machining of rotary NiTi instruments often results in an instrument having an irregular surface characterized by milling grooves, multiple cracks, pits, and regions of metal rollover.



C) Dynamics of Instrument Use

- The speed at which instruments operate seems to have no effect on the number of cycles to fracture, but higher speeds reduce the period of time required to reach the maximum number of cycles before fracture.

- Light apical pressure and brief use of instruments may contribute to prevention of fracture of rotary NiTi instruments, as may a continuous pecking motion.

D) Canal Configuration

- Instruments subjected to experimental cyclic stress fracture at the point of maximum flexure, which corresponds to the point of greatest curvature within the tube.

- A reduction in the radius of curvature similarly reduces the instrument’s ability to resist torsional forces.

- The effect of double curvatures has not been reported but the consequences of stresses on the instrument intuitively would be the same as for single curvatures although occurring at more than one site.

E) **Preparation/ Instrumentation Technique**

- During canal preparation, taper lock and the familiar clicking sound may be produced by the repeated binding and release of the rotary instruments during canal preparation could subject these instruments to higher torsional stress.

- Schrader and Peters have found that varying instrumentation sequences and using combinations of different tapers seemed to be safer regarding torsional and fatigue failure, but necessitates using a greater number of instruments.
- Importantly preflaring of the root canal with hand instruments before use of rotary NiTi instrument is a major factor in reducing the fracture rate of rotary NiTi instruments.

F) **Number of Uses**

- Svec and Powers found signs of deterioration of all instruments in their study after only one use.
- However, others have reported that rotary NiTi instruments may be used up to ten times, *or to prepare four molar teeth*, with no increase in the incidence of fracture.

- Furthermore, no correlation has been found between number of uses and frequency of file fracture.

- Therefore, it can be concluded from these differing findings and recommendations that the number of uses of rotary NiTi instruments will depend on a number of variables including *instrument properties, canal morphology, and operator skill*.

G) **Cleaning and Sterilization Procedures**

- The issue of influence of sterilization of the instruments on their resistance to fracture is still uncertain, with the literature not reaching a consensus, but it seems not to be an important factor in the fracture of NiTi instruments.

- Dry heat and steam autoclave decreased the flexibility of stainless steel and NiTi files, but the values satisfied International Standards Organization specifications.

Canaldi-Sahli C, Brau-Aguade´ E, Sentis-Vilalta J. The effect of sterilization on bendingvand torsional properties of K-files manufactured with different metallic alloys*. Int Endod J 1998;31:48–52*.

- Clinical use with sodium hypochlorite (NaOCl) and repeated sterilization “did not lead to a decrease in the number of rotations to breakage of the files”

Yared GM, Bou dagher FE, Machtou P. Cyclic fatigue of ProFile rotary instruments after clinical use. *Int Endod J 2000;33:204–7.*

- In addition, for NaOCl , there is a hint of pitting corrosion after sterilization and exposure to 5% NaOCl.
- After 30 to 60 minutes, statistically significant amounts of titanium were dissolved from the tested LightSpeed (LightSpeed Endodontics, San Antonio, Texas) instruments.
- Such contact times are never reached under clinical conditions and, therefore, are thought to be irrelevant.

Busslinger A, Sener B, Barbakow F. Effects of sodium-hypochlorite on nickel-titanium LightSpeed instruments. *Int Endod J 1998;31:290–4*.

RATIONALE FOR THE USE OF LOW-TORQUE ENDODONTIC MOTORS IN ROOT CANAL INSTRUMENTATION

- The use of slow-speed high-torque NiTi rotary instrumentation has been accepted in the last decade by manufacturers, clinicians and researchers , leading to many iatrogenic errors.
- Ideally it should now be changed to slow-speed low-torque or, preferably, right-torque motors, since each instrument has a specific ideal (right) torque.

- The values are usually low for the smaller and less tapered instruments, and high for the bigger and more tapered ones.
- To minimize the risk of intracanal breakage the instruments should be operated in a range between the martensite start clinical stress values and the martensite finish clinical stress values, which is a safe and efficient load

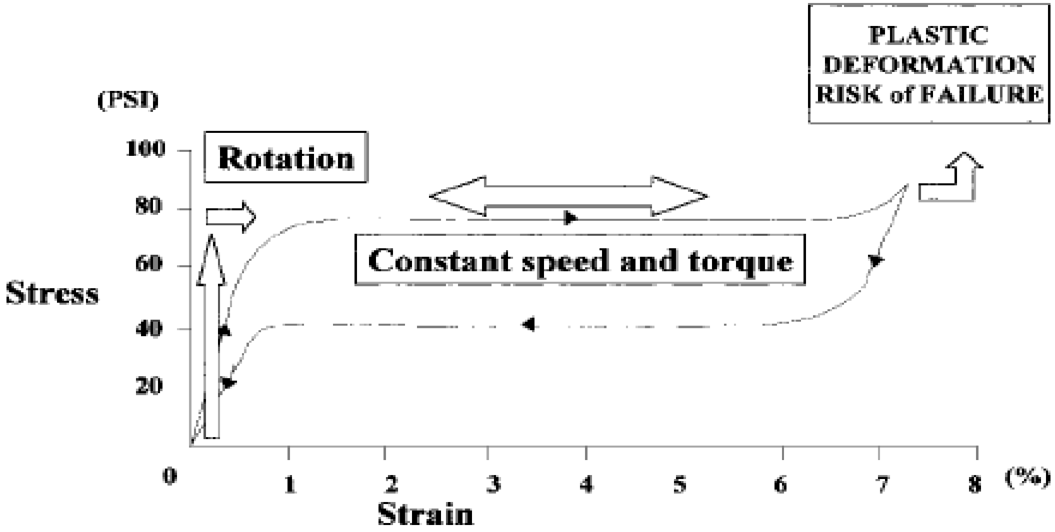


Fig. 2. Superlastic behaviour of NiTi alloy.

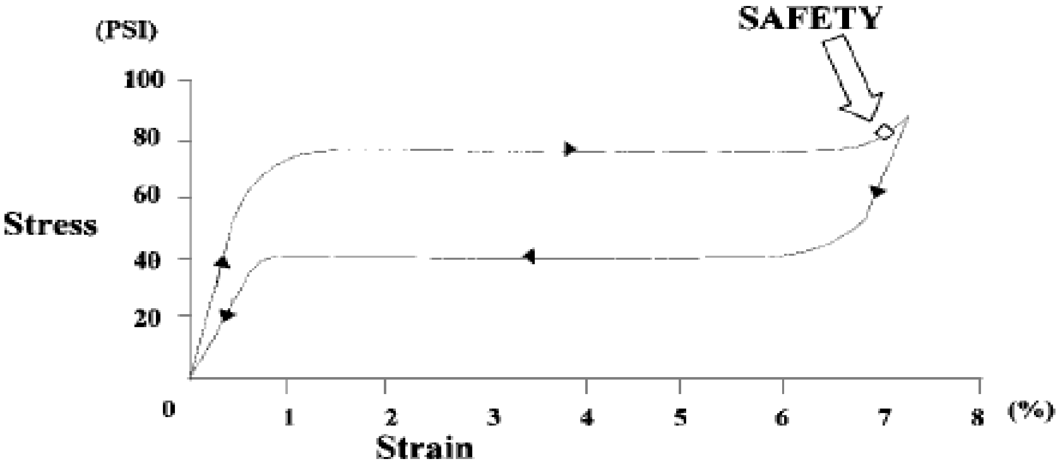


Fig. 3. Suggested low-torque setting (safety), slightly lower than the limit of elasticity.

- Right torque value for each individual instrument must be calculated by the manufacturers to obtain optimum cutting performance while minimizing risks of failure.
- Moreover, motors must have a very precise, fine-adjusted control of torque values, in order to take advantage of these concepts of not exceeding the limit of elasticity and consequently avoiding plastic deformation and intracanal breakage.

In summary, to minimize the risk of fracture in clinical practice, the following guidelines are recommended:

- Always create a glide path and patency with small (at least #10) hand files.
- Ensure straight line access and good finger rests.
- Use a crown-down shaping technique depending on the instrument system.
- Use stiffer, larger, and stronger files (such as orifice shapers) to create coronal shape before using the narrower, more fragile instruments in the apical regions.

- Use a light touch only, ensuring to never push hard on the instrument.
- Use a touch-retract (i.e. pecking) action, with increments as large as allowed by the particular canal anatomy and instrument design characteristics.
- Do not hurry instrumentation, and avoid rapid jerking movements; beware of clicking.
- Replace files sooner after use in very narrow and very curved canals.

- Examine files regularly during use, preferably with magnification.
- Keep the instrument moving in a chamber flooded with sodium hypochlorite.
- Avoid keeping the file in one spot, particularly in curved canals, and with larger and greater taper instruments.
- Practice is essential when learning new techniques and new instruments.

VARIOUS SURFACE TREATMENTS OF NITI INSTRUMENTS

- The surface of NiTi instrument mainly consists of oxygen, carbon, and titanium oxides ($TiO2$) and smaller amounts of nickel oxides (NiO and $Ni2O3$) and metallic nickel (Ni).
- Ni may dissolve more easily than titanium (Ti) because its oxide is not so stable.

- Attempts to enhance the surface of NiTi instruments, minimize or eliminate their inherent defects, increase the surface hardness/flexibility and improve the resistance to cyclic fatigue and cutting efficiency of endodontic instruments have resulted in a variety of strategies

Table : Key studies on the ion implantation (II) of NiTi rotary instruments

Authors	Results
Gavini et al.	Ion-implanted instruments reached significantly higher cycle numbers before fracture compared to annealed and non-implanted files.
Wolle et al.	Argon II improved the performance of S1 files moderately, whereas nitrogen ion-implanted files performed worse in the fatigue test.

Table: Key studies on the thermal nitridation (TN) of NiTi rotary instruments

Authors	Results
Shenhar et al.	TN improved the corrosion resistance of Ti and/or Ti alloys in corrosive environments.
Huang et al.	TN improved the corrosion resistance of Ti and/or Ti alloys in corrosive environments.
Li et al.	TN of NiTi instruments at various temperatures increased cutting efficiency and corrosion resistance.
Lin et al.	TN significantly increased the corrosion resistance

Table : Studies on the cryogenic treatment (CT) of NiTi rotary instruments

Authors	Results
Kim et al.	Cryogenically treated specimens had a significantly higher microhardness than the controls.
Vinothkumar et al.	Deep dry CT increased the cutting efficiency of NiTi instruments, significantly.
George et al.	Deep CT improved the cyclic fatigue resistance of NiTi rotary files, significantly.

Table: Studies on the electropolishing (EP) of NiTi rotary instruments

Authors	Results
Herold et al.	EP did not inhibit the development of microfractures in EndoSequence rotary instruments.
Anderson et al.	EP prolonged the fatigue life of rotary NiTi endodontic instruments.
Bui et al.	EP significantly reduced resistance to cyclic fatigue but did not affect torsional resistance and cutting efficiency, however, the angle at failure and amount of unwinding were decreased.
Cheung et al.	EP did not enhance low cyclic fatigue life of NiTi instruments subjected to rotational bending. In addition, EP did not improve the resistance to corrosion of strain-cycled instruments.
Boessler et al.	EP of ProTaper shaping instruments led to increased torque during preparation of simulated root canals.
Tripi et al.	The electropolished race instrument demonstrates an increased resistance to fatigue failure.
Praisarnti et al.	Low cyclic fatigue failure of a RaCe NiTi instrument rotating with a curvature in a corrosive environment enhanced by a magneto EP process.
Lopes et al.	The EP of BioRace endodontic instruments significantly increased the number of cycles to fracture under rotating-bending conditions within an artificial curved canal.

ALLERGY

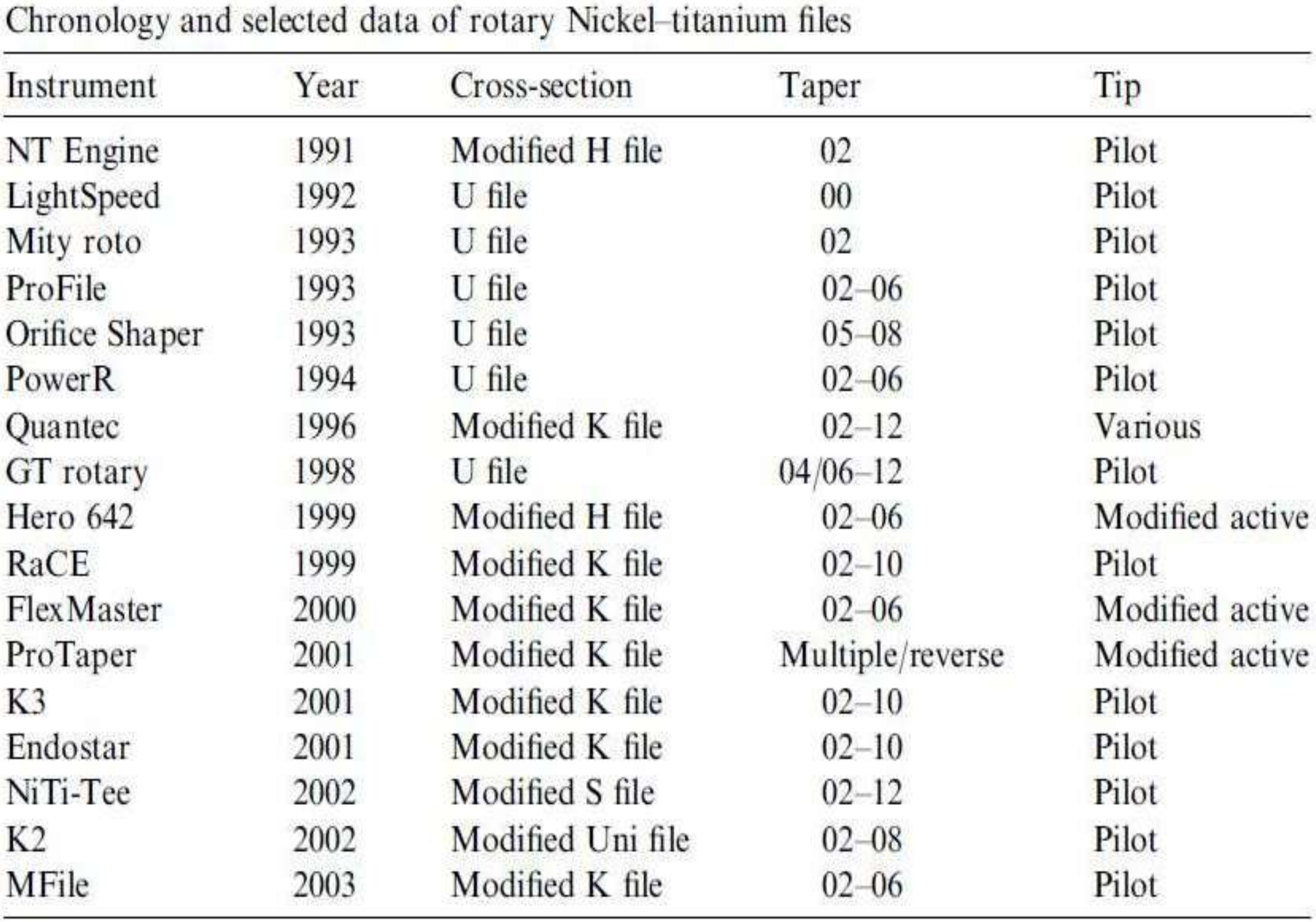
- Nickel is the most widespread allergen in the industrial nations because of its usage in fashion jewelry and consumer products.
- Nickel **hinders the mitosis of human fibroblasts** but nickel seems to lack this effect and show good biocompatibility.

CHRONOLOGY OF NITI USE IN ENDODONTICS

- When the Gates–Glidden (GG) bur was invented in 1885, rotating instruments in endodontics and dentistry in general were very rare.
- The first contra angle with a whole circle rotation is attributed to Rollins in 1899—about 1 century ago.

- “Modern” instruments were not developed until the 1930s when Endocursor was designed.
- 1958 - **Racer** was introduced
- 1964 –**Giromatic** was developed
- 1980s – **Canal finder** was developed

- The discovery of NiTi alloys enabled a steadily accelerating development of NiTi files.
- First developed and designed for hand instrumentation—enabled a whole range of permanent rotating systems now available in a wide range of types and brands.



Chronology and selected data of rotary Nickel–titanium files

Instrument	Year	Cross-section	Taper	Tip
NT Engine	1991	Modified H file	02	Pilot
LightSpeed	1992	U file	00	Pilot
Mity roto	1993	U file	02	Pilot
ProFile	1993	U file	02–06	Pilot
Orifice Shaper	1993	U file	05–08	Pilot
PowerR	1994	U file	02–06	Pilot
Quantec	1996	Modified K file	02–12	Various
GT rotary	1998	U file	04/06–12	Pilot
Hero 642	1999	Modified H file	02–06	Modified active
RaCE	1999	Modified K file	02–10	Pilot
FlexMaster	2000	Modified K file	02–06	Modified active
ProTaper	2001	Modified K file	Multiple/reverse	Modified active
K3	2001	Modified K file	02–10	Pilot
Endostar	2001	Modified K file	02–10	Pilot
NiTi-Tee	2002	Modified S file	02–12	Pilot
K2	2002	Modified Uni file	02–08	Pilot
MFile	2003	Modified K file	02–06	Pilot

NITI GENERATIONS

First generation

- **Passive cutting radial lands and fixed tapers of 4 and 6 %** over the length of their active blades.
- Numerous files for achieving the preparation objectives.
- From the mid- to late 1990s, **GT files** (DENTSPLY Tulsa Dental Specialties) became available that provided a **fixed taper on a single file of 6, 8, 10, and 12 %.**
- The most important design feature of first-generation NiTi rotary files was passive radial lands, which helped a file to stay centred in canal curvatures during work.

Second generation

- The second generation of NiTi rotary files reached dental markets in 2001.
- **Active cutting edges** and thus require fewer instruments to prepare a canal fully.
- **EndoSequence (Brasseler) and BioRaCe (FKG Dentaire)-** fixed taper-provided file lines with alternating contact points- prevent taper lock and the resultant screw effect.
- The clinical breakthrough occurred when **ProTaper Universal** (DENTSPLY Tulsa Dental Specialties) utilised multiple tapers of an increasing or decreasing percentage on a single file- limits each file's cutting action to a specific region of the canal and affords a shorter sequence of files to produce deep Schilderian shapes safely.

- Excessive inward pressure, especially when utilising fixed-taper files, promotes taper lock, the screw effect and excessive torque on a rotary file during work.
- In order to offset deficiencies in general, or inefficiencies resulting from electropolishing, cross-sectional designs have increased and rotational but dangerous speeds are advocated.

Third generation

- In 2007, some manufacturers began to focus on using heating and cooling methods for the purpose of reducing cyclic fatigue in and improving safety with rotary NiTi instruments used in canals that are more curved.
- The intended phase-transition point between martensite and austenite was identified as producing a more clinically optimal metal than NiTi.
- Significantly reduced cyclic fatigue and, hence, broken files.
- Some examples of brands that offer heat treatment technology are Twisted Files (Sybron Endo), HyFlex (Coltène/Whaledent), and GT, Vortex, and WaveOne (all DENTSPLY Tulsa Dental Specialties).

Fourth generation

- Another advancement in canal preparation procedures was achieved with reciprocation, a process that may be defined as any repetitive up-and-down or backand- forth motion.
- This technology was first introduced in the late 1950s by a French dentist.
- Examples: **SAF, Reciproc, Wave One**

Fifth generation

- The latest generation of shaping files have been designed in such a way that the centre of mass or the centre of rotation, or both, are offset.
- This design minimises the engagement between the file and dentine.
- In addition, it enhances the removal of debris from a canal and improves flexibility along the active portion of the file.
- Examples : **Revo-S, One and ProTaper Next.**

CONCLUSION

- Because of their super-elasticity, nickel–titanium alloys are being used increasingly in the construction of endodontic instruments.
- It is important for clinicians to be aware of the metallurgy of NiTi alloy in order that the characteristics of instruments constructed from this alloy can be appreciated and to encourage research to maximize their clinical potential.

- Whilst NiTi root canal instruments are more flexible than stainless steel files and have the ability to prepare canals quickly and without undue aberrations there are important considerations such as their increased cost, the potential decrease in cutting ability due to wear and the ability to machine instruments with various designs and dimensions to a consistent size.

THANK YOU