ORTHODONTIC MATERIALS

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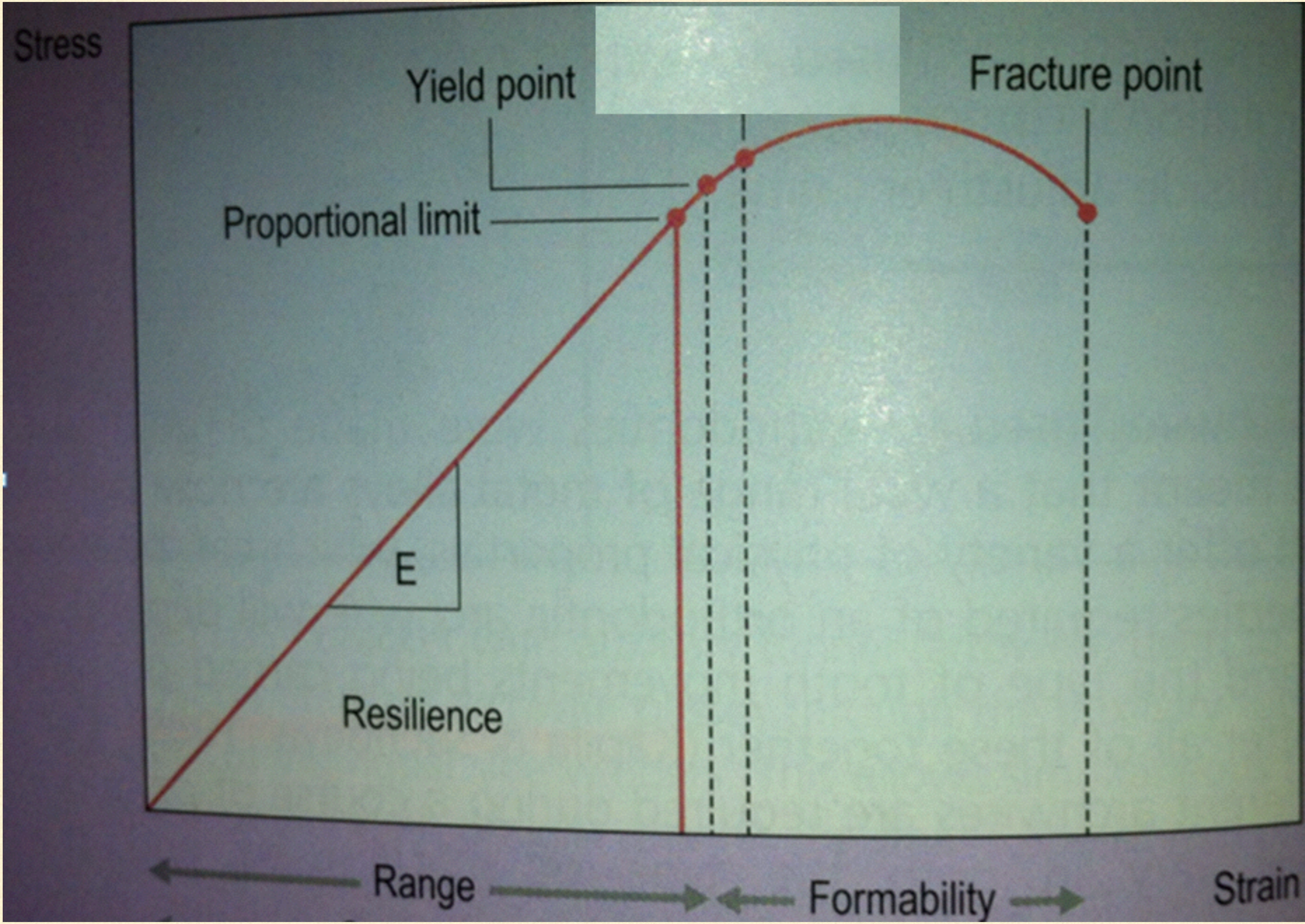
WIRES CHARACTERISTICS:

- **Stiffness (α E)**
  - Force delivered by a wire and is proportional to the modulus of elasticity (E)
  - The resistance of a wire to deformation (within the elastic range)
- **Springback (range of deflection) α 1/E**
  - How far a wire can be deflected without undergoing permanent deformation.
- **Range (working range)**
  - Amount of deflection that a wire can achieve within proportional limit.
  - The distance wire bends elastically before permanent deformation.
- **Formability**
  - Ability to bend wire into desired form
  - The distance between the proportional limit
- **Resilience**
  - Energy stored in wire to move teeth when it is deformed
  - Area in stress/strain curve under the proportional limit.


Stress
Yield point
Fracture point
Proportional limit
E
Resilience
Range
Formability
Strain

- Stress strain curve:
- The y-axis label is stress, which is the force applied per unit area of the wire (N/m2). The x-axis label is strain, which is the change in length relative to the original length of wire and so is expressed as a percentage.

- **Biocompatibility & environmental stability:**
  - Corrosion resistance
  - Tissue tolerance to the wire
- **Jointability**
  - Able to attach/ weld auxiliaries
- **Friction**
  - Low friction at the bracket/wire interface
- **Ductility**
  - Ability to undergo a large permanent deformation under tensile stress without failer .
- **Proportional Limits:**

The point at which the permanent deformation is first observed.

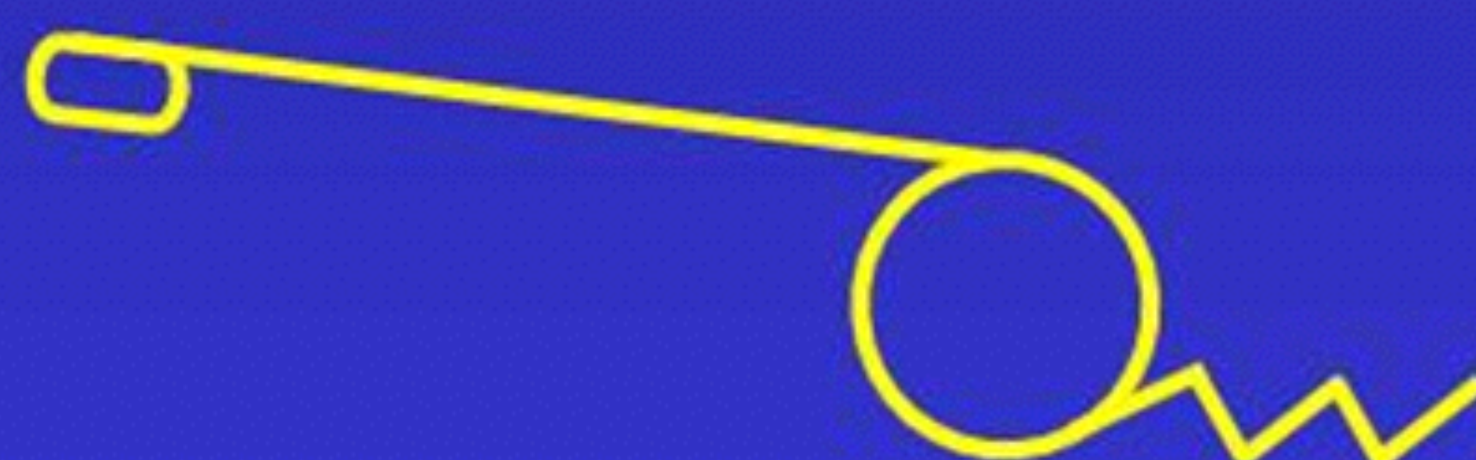
- **Yeild strength**:

Point at which 0.1 % deformation is measured.

- Elastic or Young's modulus - this property depends on the chemical composition and so will be the same for all wires of the same composition. This modulus (E) can be determined from the slope of the stress strain graph where the wire undergoes linear elastic deformation between zero and the elastic limit.

For a cantilever spring

$$\text{Force} \propto \frac{dr^4}{l^3}$$



d = deflection

r = radius

l = length

TYPES OF ORTHODONTIC WIRES

- Stainless steel.
- Nickel titanium.
- Titanium molybdenum alloy.

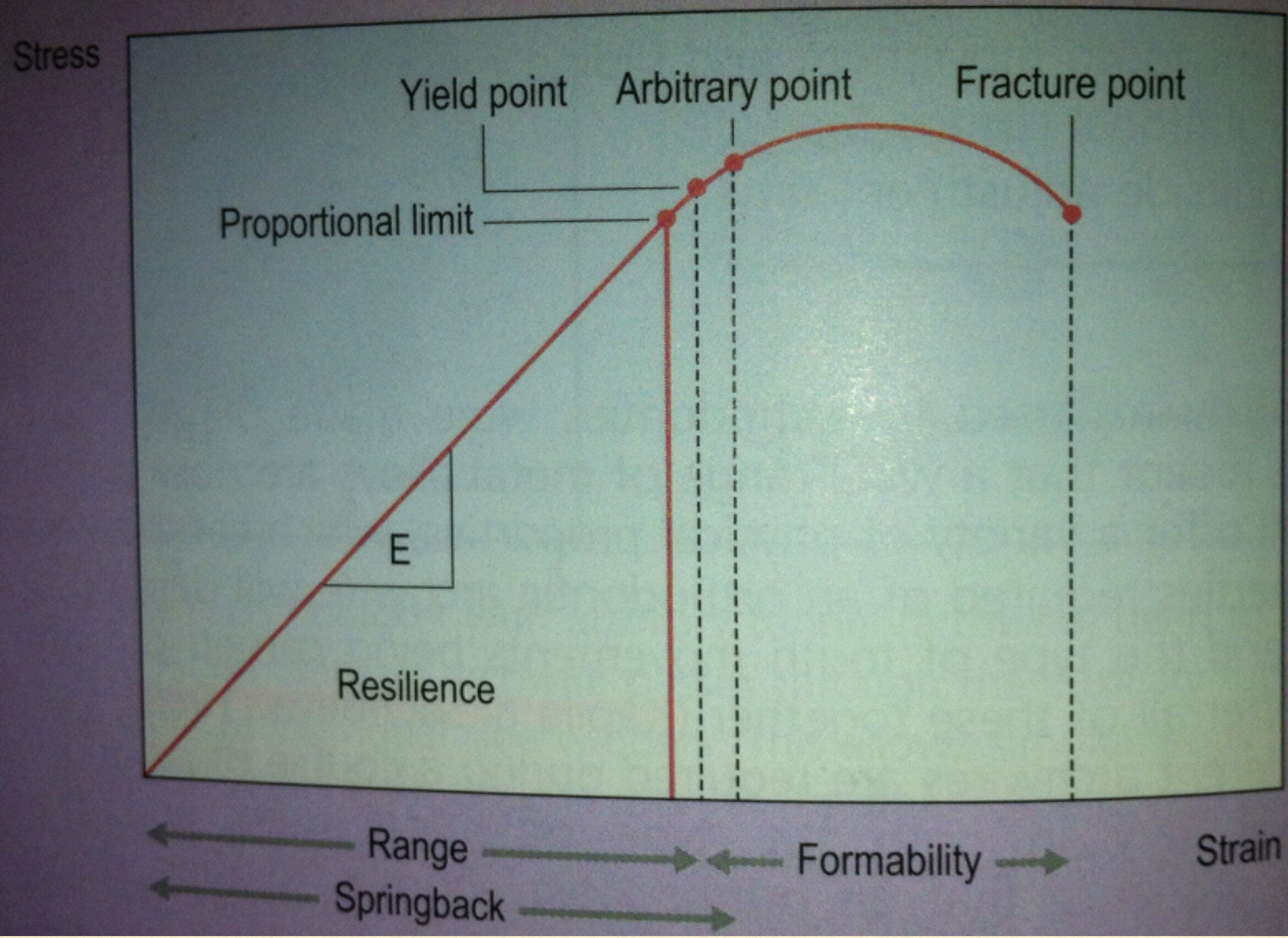
STAINLESS STEEL

- **1- Stainless steel:**
- The S.S used in orthodontics is Austenitic steel. These are commonly designated as 18-8 stainless steel because of the percentages of chromium (18%) and nickel (8%) in the alloys.
- It is formed of 71% Fe, 18% Cr, 8% Ni, <.2% Carbon.

- Chromium:
  - Improves corrosion resistance (surface of chromium oxide)
  - Must be removed before soldering with flux (Potassium fluoride flux)
- Nickel:
  - Increases ductility
- Carbon:

Increase the modulus of elasticity, but it increases brittleness.

- **Properties:**
- High stiffness, large modulus of elasticity, advantage in resisting deformation by extra and intra oral forces but disadvantage of aligning displaced teeth.
- Low springback
- Low stored energy compared with NiTi & TME, SS produces high forces that dissipate over shorter periods of time, require more frequent activations
- Formable
- weldable
- Low friction
- Environmentally stable
- Corrosion resistance.
- low cost .


Stress
Yield point
Arbitrary point
Fracture point
Proportional limit
E
Resilience
Range
Formability
Strain
Springback

Work hardening:

If a wire is strained beyond the elastic limit, it will undergo plastic deformation.

If then unloaded the stress will return to zero.

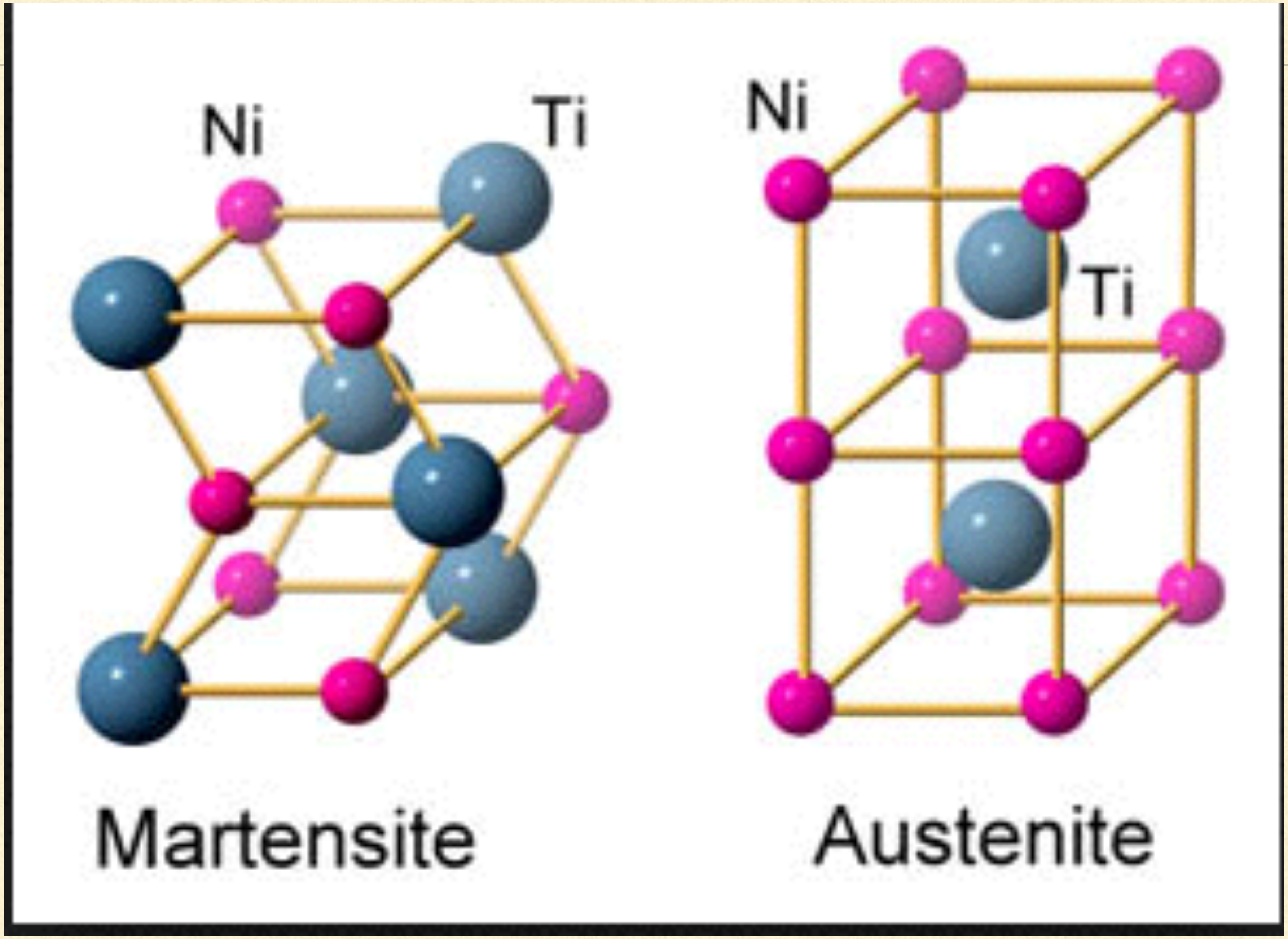
If it is subsequently reloaded, the work hardening that has taken place will have the effect of raising the yield strength and the elastic limit. However, the distance on the stress strain curve between the yield strength and ultimate tensile stress will be reduced.

There is therefore less opportunity to plastically deform the wire to create a desired shape, such as a spring or crib, without the wire breaking in the process.

NICKEL TITANIUM ALLOY

- There are essentially three types of commercially available nickel titanium wires (Kusy 1997):
- Martensitic stable (conventional alloy)
- Austenitic active (pseudoelastic)
- Martensitic active (thermoelastic)

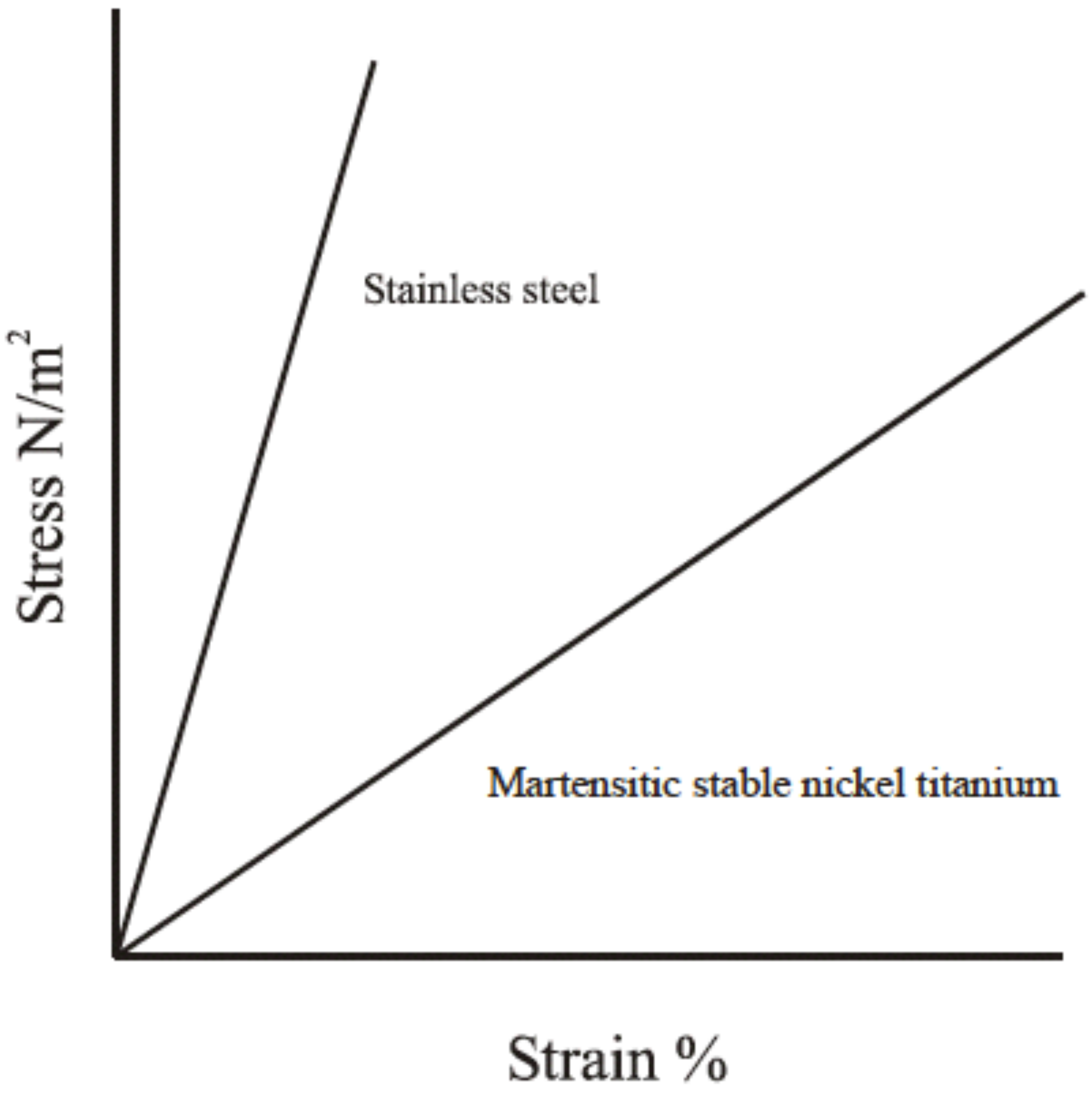
- Martensite: low temperature phase of NiTi with body centered structure.
- Austenite: High temperature phase of NiTi with phase centered structure.
- Austenitic wire is less flexible than the martensitic one
- Active alloy: Alloy that is able of phase transformation.
- Stabilised alloy: incapable of undergoing phase transformation.


Ni
Ti
Ni
Ti
Martensite
Austenite

NICKEL TITANIUM ALLOY-MARTENSITIC STABLE:

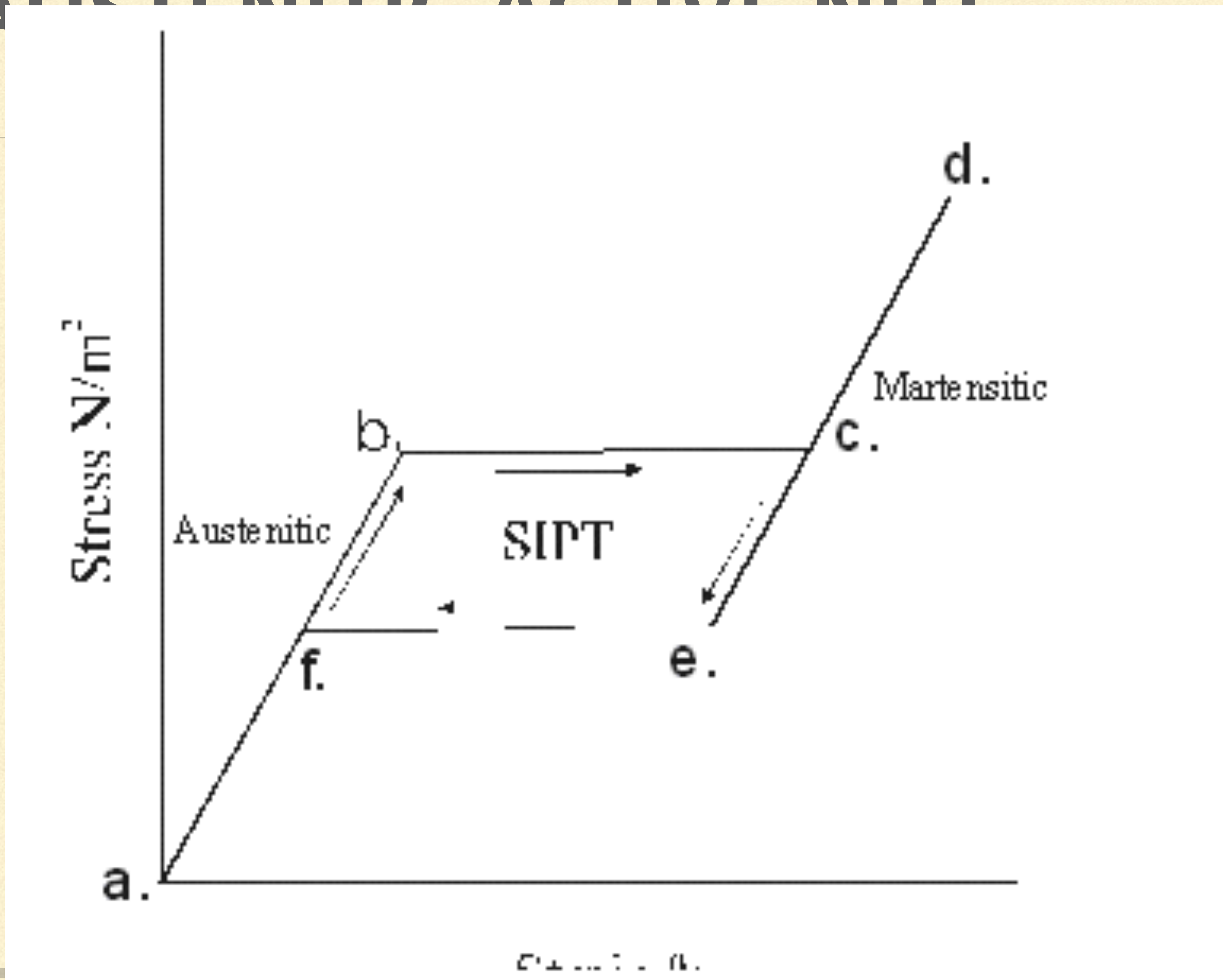
- Composition: 52 % Ni, 43% Ti.
- **Characteristics:**
- 1-Low stiffness, so that for any given activation (deflection), the force applied by a nickel titanium wire is between one-fifth and one sixth of that applied by an equivalent dimension stainless steel wire (Goldberg et al. 1983)
- 2- High spring back, Larger recoverable energy than SS. The strain that can be applied to the wire before it reaches its yield strength is much greater than stainless steel. This means that a nickel titanium wire can move a tooth with a lighter force and for a longer period of time than a stainless steel wire of equivalent size.

- 3-Cannot be welded or soldered
- 4- Friction is higher than S.S but less than TMA.
- 5- **No shape memory or superelastic properties**



Idealised stress strain graph showing the relative stiffness of stainless steel and nickel titanium alloy. Stainless steel is approximately 5 - 6 times stiffer.

AUSTENITIC ACTIVE NITI



- This type of behaviour is best explained by considering the stress strain curve. This curve is very much an idealised version of the behaviour of the wire in the mouth. Before it is placed under load, by tying the wire into the brackets, it is said to have an austenitic structure. As the wire is placed under stress (loaded), being pushed into the bracket slot on a malaligned tooth, it initially demonstrates linear elastic behaviour, i.e. from points a. to b., the plot following a straight line in a similar fashion to that seen with the other alloys so far discussed. As the orthodontist continues to push the wire into the bracket, the wire then begins to undergo a change in its crystal structure towards the martensitic phase. During this time the stress within the wire remains the same, which gives the plateau effect seen on the stress strain graph, i.e. from points b. to c.. The changes in the crystal structure that take place are known as stress induced phase transformations.

- Eventually the alloy has reached the martensitic phase throughout and begins to demonstrate linear elastic behaviour once more i.e. points c. to d.. If the wire is now fully displaced into the bracket slot and has been tied in place, a force will be applied to the tooth and it will begin to move. As it does so, the stress within the wire will reduce i.e. points d. to e.. With continued tooth movement, the stress within the wire will begin to plateau once again as the alloy transforms back to the austenitic phase i.e. points e. to f.. For the orthodontist, the most important part of the stress strain curve is this unloading plateau from points e. to f., since this will mean a light continuous force is applied to the tooth, even though it is moving and the deflection (strain) of the wire is reducing. Eventually the stress induced phase transformation will have been reversed and the austenitic structure will have returned. With continued unloading, linear elastic behaviour will once again be demonstrated by the wire, i.e. points f. to a..

superelasticity

the martensite-austenite phase transformations, generated by mechanical stress or heat, which result in a segment of the loading curve for nickel titanium alloys in which stress is independent of applied strain. It only exists when both phases of the alloy are present.

- Characteristics :
- 1- Superelasticity (Psuedoelasticity).
- 2- Shape memory:
- The ability of the wire to undergo deformation and then return to its prior shape when it is triggered by thermal or mechanical stimulus.

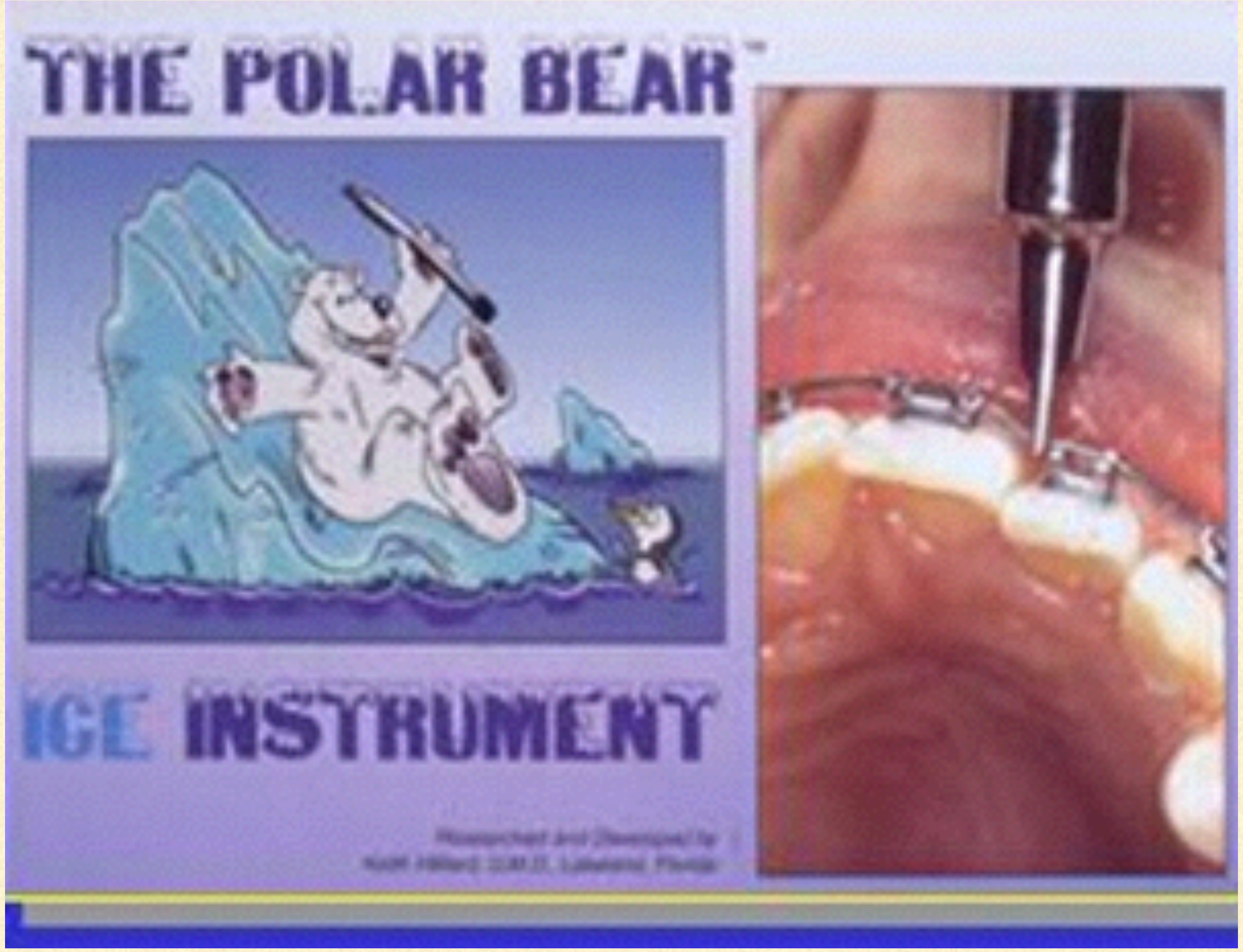
MARTENSITIC ACTIVE NITI

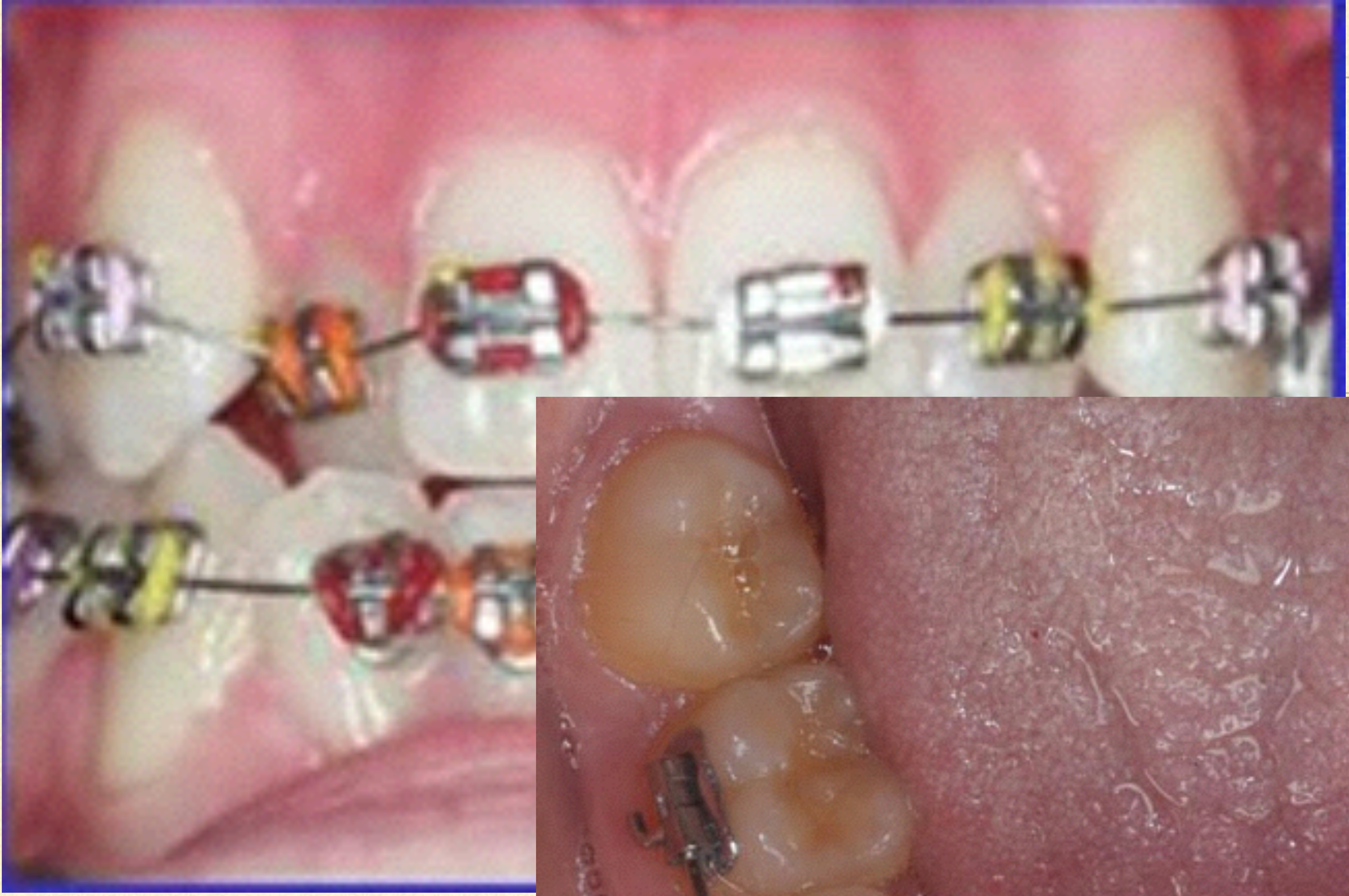
- Not only undergoes the stress induced phase transformation of its crystal structure, as seen with the austenitic active wire, but also demonstrates a change in crystal structure with a change in temperature.
- These wires are frequently referred to as thermally active, heat activated or thermoelastic nickel titanium wires.
- The temperature at which the phase change occurs is not a point temperature, but a temperature range referred to as the temperature transition range (TTR). Below the TTR the wire is in the martensitic phase with a low modulus of elasticity and it can be deformed (strained) very easily. It is therefore easy to ligate the wire to a misplaced tooth when cooled below the TTR.

- As the temperature rises towards mouth temperature, the wire begins its transition from the martensitic to the austenitic phase and the modulus of elasticity increases. The wire then returns to its original shape, increasing the loading on the tooth and encouraging it to move.

- It is now possible to purchase wires with predetermined TTRs of 27°C, 35°C and 41°C

- Characteristics :
- 1- Superelasticity (Thermoelasticity).
- 2- Shape memory:
- The ability of the wire to undergo deformation and then return to its prior shape when it is triggered by thermal or mechanical stimulus.


THE POLAR BEAR™
ICE INSTRUMENT




TITANIUM MOLYBDENUM ALLOYS (TMA)

- Compose of 79% Ti, 11% Mo.
- Stiffness of TMA is approximately twice that of the original martensitic stable nickel titanium alloy and one third that of the equivalent size stainless steel wire
- *TMA could be bent into shape quite easily (formable) and could also be welded, but not soldered.
- * High coefficient of friction when compared with nickel titanium and stainless steel Wires
- Wire of choice for finishing.

Thank you