ARCH WIRES USED IN ORTHODONTICS

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Terminology

Force: It is defined as an act upon a body that changes or tends to change the state of rest or the motion of that body.

Newton's 1st law of motion: A particle subjected to a balanced system of concentrated forces will remain at rest, if originally at rest, or will move with constant speed in a straight line if originally in motion.

2nd law indicates that if the particle is subjected to an unbalanced system of forces, the particle will accelerated in the direction of the net force exerted.

3rd Law states that, the paired active and reactive forces are equal in magnitude but are directly opposite to one another and are exerted on adjacent particles.

Stress: Force per unit area

Strain: The change in dimension is called a strain change in length / unit length.

Strain could be

i) Plastic
ii) Elastic

Tensile stress:

Caused by a load that tends to stretch or elongate a body. It is always accompanied by Tensile strain.

Compressive stress:

If a body is paced under a load that tends to compress or shorten it, the internal resistance to such a force is called compressive stress; it is accompanied by compressive strain.

Shear stress:

A stress that tends to resist a twisting motion or a sliding of one portion of body over another is called shearing stress.

The elastic limit: of a material is the greatest stress to which a material can be subjected, such that it will return to its original dimensions when the forces are released.

Proportional limit:

The stress at the point P on the stress-strain graph at which the curve digresses from a straight line is known as proportional limit.

Yield strength:

The yield strength is the stress required to produce the particular offset chosen (plastic strain).

Modulus of elasticity:

If any stress value equal to or less than proportional limit is divided by its corresponding strain value, constant of proportionality is obtained.

Resilience: Can be defined as the amount of energy absorbed by a structure when it is stressed not to exceed its proportional limits.

Strength is the maximal stress required to fracture a structure. It is called tensile strength, compressive strength or shear strength.

Toughness:

Property of being difficult to break. It can be defined as the energy required to fracture a material.

Brittleness:

A brittle material is apt to fracture at or near its proportional limit.

Ductility:

The ability of a material to withstand permanent deformation under a tensile load without rupture.

Malleability:

The ability of material to withstand permanent deformation without rupture under compression as in hammering or rolling into sheet.

Relaxation:

After a substance has been permanently deformed, there are trapped internal stresses. These displaced atoms may be said to be ‘Uncomfortable’ and wish to return to their normal regular relative position. Given time for diffusion they will ---------- their equilibrium relationship. The result is a change in shape or rearrangement of atomic or molecular positions.

The material is said to wrap or distort. Such a relief of stress is known as relaxation.

Friction:

Two materials touching one another share a contact area. The resistance to movement tangent to this area of one material to the other is known as friction.

The resistance that precludes actual motion is termed static friction that which exists during motion is called dynamic friction.

Classification of archwire

A) According to material used:
   a. Gold archwires
   b. Stainless steel archwires
   c. Chrom-cobalt archwires
   d. Nickel-Titanium archwire
      i. Martensitic
      ii. Austenitic
         1. Superelastic
         2. Japanese NiTi
         3. Chinese NiTi
         4. Alpha NiTi
         5. Reverse curve NiTi
         6. Copper NiTi
   e. TMA - β Titanium
   f. Ceramic coated / optiflex archwires

B) According to cross-section
   a. Round
   b. Rectangular
   c. Rounded rectangular
   d. Square
   e. Braided
   f. Stranded

Properties:

Optimum orthodontic tooth movement is produced by light, continuous force. The challenge in designing and using an orthodontic appliance is to produce a force system with these characteristics, creating forces that are neither too great nor too variable over time. It is particularly important that light forces do not decrease rapidly, decaying away either because the material itself loses its elasticity or because a small amount of tooth movement causes a large change in the amount of force delivered. Both the behavior of elastic materials and mechanical factors in the response of the teeth must be considered in the design of an orthodontic appliance system through which mechanotherapy is delivered.

The basic properties of elastic materials

The elastic behavior of any material is defined in terms of its stress-strain response to an external load. Both stress and strain refer to the internal state of the material being studied.

Stress is the internal distribution of the load, defined as stress per unit area, whereas strain is the internal distortion produced by the load, defined as deflection per unit length.

For analysis purpose, orthodontic archwires and springs can be considered as beams, supported either only on one end or on both ends. If force is applied to such a beam, its response can be measured as the deflection produced by the force. Force and deflection are external measurements. In tension, internal stress and strain can be calculated from force and deflection by considering the area and length of the beam.

For orthodontic purposes, three major properties of beam materials are critical in defining their clinical usefulness – strength, stiffness and range.

Each can be defined by appropriate reference to a force deflection or stress-strain diagram.

Three different points on a stress-strain diagram can be taken as representative of the strength of the material. Each represents in somewhat different way, the maximum load that the material can resist. The most conservative measure is proportional limit, the point at which any permanent deformation if first observed. A more practical measure is the point at which deformation of 0.1% is measured, this is defined as yield strength. The maximum load the wire can sustain. The ultimate tensile strength is reached after some permanent deformation and is greater than yield strength. Since this ultimate tensile strength determines the maximum force the wire can deliver if used as a spring, it is important clinically, especially since yield strength and ultimate tensile strength differ much more for newer titanium alloys than for steel wires.

Strength is measured in stress units (gm/cm^2) stiffness and springiness are reciprocal properties

Springiness = 1 / stiffness

Each is proportional to the slope of the elastic portion of force-deflection curve. The more horizontal the slope, the springier the wire, the more vertical the slope, the stiffer the wire.

Range is defined as the distance that the wire will bend elastically before permanent deformation occurs. This distance is measured in millimeters. If the wire is deflected beyond its yield strength, it will not return to its original shape, but clinically useful springback will occur unless the failure point is reached. In many clinical situations, orthodontic wires are deformed beyond their elastic limit. Their springback properties in the portion of the load deflection curve between the elastic limit and the ultimate strength therefore, are important in determining clinical performance.

These three major properties have an important relationship:

Strength = Stiffness × Range

Two other properties of some clinical importance also can be illustrated with a stress strain diagram – resilience and formability. Resilience is the area under the stress-strain curve out to the proportional limit. It represents energy storage capacity of the wire, which is a combination of strength and springiness. Formability is the amount of permanent deformation that a wire can withstand before failing. It represents the amount of permanent bending the wire will tolerate before it breaks.

The properties of ideal wire material for orthodontic purposes can be described largely in terms of these criteria. It should possess

i) High strength
ii) Low stiffness
iii) High range
iv) High formability
    - In addition, the material should be weldable or solderable.
    - It should also be reasonable is cost

No archwire meets all these requirements and the best results are obtained by using specific archwire material for specific purposes.

The orthodontic archwire dimensions are specified in thousands of an inch i.e. 0.016 inch or 0.018 inch. This is also written as 16 mils or 18 mils respectively. To know the diameter in millimeters – dividing the dimensions in mils by 4 and placing a decimal point in front i.e. 16 mils = 0.4mm.

Review or literature

According to Angle, first importance in evolution of fixed orthodontic appliance was the bow of 'Fauchard of France' in 1728. This arch wire was flat piece of metal scalloped out for the ideal position of the teeth.

Magill, was according to Angle, first to use a plain band cemented to tooth, by oxychloride of zinc cement.

In 1887, Dr. Angle introduced the round labial arch wire which was supported by clamp bands on the molar teeth. It was also an expansion arch. If molar expansion was desired, the arch wire was expanded. The appliance is commonly referred to as the 'E' (expansion) arch.

The E arch gave way to the flat wire 0.022" × 0.036" placed flatwise against the teeth, the ribbon arch. This flat flexible wire was molded to fit the malocclusion.

Later the flat wire was narrowed from 0.036" to 0.028" and turned on edge to engage the teeth edgewise by way of a new bracket that opened buccally, thus edgewise appliance was introduced by Dr. Angle in 1928.

The Johnson twin wire 1934 used two 0.010 wires, parallel and in contact, to again from a ribbon like arch but possessing greater possibilities because of the vertical flexibility of archwires.

In 1937 Atkinson's universal appliance was introduced using one rectangular and one round wire, which was designed to bring about every tooth movement possible.

It could be observed that in Angle's orthodontic appliance, the arch wire in each succeeding mechanism is thinner that in immediately preceding mechanism, so that the amount of force delivered for tooth movement becomes less in each later mechanism. This indicates that Angle was aware that the tooth moving forces delivered by his earlier forms of orthodontic appliance were too great. This reduction of teeth moving forces in each new orthodontic mechanism introduced by Angle permitted greater control of tooth movement, made it possible to move teeth more rapidly and reduced the pain experienced by patient.

Several different metals are used in orthodontic appliance:

Upto the 1930's the only orthodontic wire available were made of Gold.

Austenitic stainless steel with its greater strength, high modulus of elasticity, good resistance to corrosion and moderate costs was introduced as arch wire in 1929 and shortly gained popularity over gold.

Chrome cobalt alloys were developed in the mid century. This had physical properties very similar to stainless steel however they had advantage that they could be supplied in the softer and more formable state and then could be hardened by heat treatment.

In 1952 Dr. Begg in collaboration with Mr. A.J. Willcock sought to develop tensile wire materials that was thin enough to distribute force at an optimal level for tooth movement over a considerable period of time, over a long distance and with minimum loss of force intensity while doing so. The diameter of the wire was progressively reduced from 0.018" to 0.014" archwire. This is also called Australian wire.

Then came the Nitinol wire which was invented in 1960's by William F. Buchler, a research metallurgist at the Naval Ordinance Laboratoy in Silver spring Maryland. The name Nitinol is an acronym derived from the elements which comprise the alloy, Ni for Nickel, Ti for titanium and 'noi' for naval ordance laboratory.

In clinical orthodontics, Anderson and his associate were attracted by the unique properties inherent in NiTi alloy such as high elastic limit and the low elastic modulus. In 1971, they reported the results of their investigation for clinical sue. Unitek corporation has produced this wire for the profession under trade name of 'Nitinol'. It has excellent spring back but does not posses shape memory or super elasticity because it has been manufactured by a work hardening process.

NiTi a new superelastic orthodontic wire, was originally developed by Dr. Hau-Cheng Tien and collegues at general research institute for non-forrous metal in China in 1978.

In 1978, Furukawa electric Co. Ltd of Japan produced a new type Japanese NiTi alloy possessing all three properties (excellent springback shape memory and super elasticity).

Dr. Anderson, also tested then thermodynamic nitinolo wires in 1980, although they were introduced to clinical orthodontics only in the last few years essentially these wires can return to a previously set shape when heated to their transition temperature range.

At the same time in 1980, Charles J. Burstone and A Jon Goldberg, introduced new β-Titanium alloy as TMA alloy in clinical use. It has a unique balance of low stiffness, high spring back, formability and weldability.

In 1985, Dr. C.J. Burstone reported on the alloy, Chinese NiTi developed by Dr. Cheung in China.

A year later, in 1986, Miura Fetal, reported on Japanese NiTi, the alloy developed by Furukawa electric company in 1978. These two alloys have a basic austenitic grain structure and have the advantage of a transition in the internal structure without requiring a significant temperature change to accomplish this.

Mr. A.J. Wilcock Jr. of Australia has recently developed (1988) a much harder near alpha-phase titanium alloy comprising 6% aluminium and 4% vanadium for orthodontic purposes.

M.F. Thalass in 1992, introduced a new orthodontic arch wire called ‘optiflex’. It has unique mechanical properties with high aesthetic appearance. It is made of clear optical fiber.

Charles J. Bustone is 1995 demonstrated TMA with ion implatation. A low coefficient of friction is desirable in orthodontic archwire. However studies have shown that Nickel Titanium and TMA have higher coefficient of friction than stainless steel. In the case of TMA, the friction is probably due to its relative softness compared to harder stainless steel bracket. Ion implantation increases the hardness and reduce the coefficient of friction of TMA wire.

Recently in 1995 Rohit Sacchdeva and Suchio Miyasaki introduced copper-NiTi alloy in the family of NiTi. It is a quaternary alloy of copper, nickel, titanium and chromium.

Multistranded and multibraded arch wires are also available.

Wire characteristics of clinical relevance

Several characteristics of orthodontic wires are considered desirable for optimum performance during treatment.

1) Spring back – This is also referred to as maximum elastic deflection, maximum flexibility, range etc. Springback is related to the ratio of yield strength to the modulus of elasticity of the materials (Ys/E). Higher springback values provide the ability to apply large activations with a resultant increase in working time of the appliance. This in turn implies that fewer arch wire changes or adjustment will be required. Springback is also a measure of how for a wire can be deflected without causing permanent deformation.
2) Stiffness or load deflection rate – This is the force magnitude delivered by an appliance and is proportional to the modulus of elasticity E. Low stiffness or load deflection rate provides:
    a. The ability to apply lower forces.
    b. A more constant force over time as the appliance experiences deactivation.
    c. Greater ease and accuracy in applying a given force.
3) Formability – High formability provides the ability to bend a wire into desired configurations such as loops, coils or stops without fracturing the wire.
4) Modulus of resilience – This property represents the work available to move teeth. It is represented by the area under the line describing elastic deformation of the wire.
5) Biocompatibility – It includes the resistance to corrosion and tissue tolerance to elements in the wire. It ensures the maintenance of desirable properties of the wire for extended period of time after manufactured.
6) Joinability – The ability to attach auxillaries to orthodontic wires by welding or soldering provides an additional advantage when incorporating modification to the appliance.
7) Friction – Space closure and canine retraction in continuous arch wire technique involve extensive amount of bracket / wire friction which may result in loss of anchorage or binding accompanied by little or no tooth movement. So least friction between wire and bracket is desirable.

Wire cross section

The most critical factor in the design of an orthodontic appliance is the cross-section of the wire to be used. Small changes in cross-section can dramatically influence both the maximal elastic load and load deflection rate.

The maximal elastic load varies directly as the third power of the diameter of round wire and load deflection rate varies directly as the fourth power of the diameter. It may be seen that the most obvious method of reducing load deflection rate is to cut down the size of the wire but this also reduces maximal elastic load at an alarmingly high rate (as d^3). So in the design of active member it is desirable to use as small a cross-section as possible consistent with a safety factor, so that undue permanent deformation will not occur. Any attempt to reduce the size of the cross-section to improve spring properties may well lead to undesirable permanent deformation.

In the selection of proper cross section for the rigid reactive members of an appliance, load deflection rate rather than maximal elastic load is the prime consideration hence it is necessary to select a large enough wire cross section to have sufficient rigidity.

The optimal cross-section for a flexible member is for multi directional activation in which the structural axis is bent in more than one plane, a ‘circular’ cross-section is the one of choice.

Many orthodontic wire configurations undergo unidirectional bending. An edgewise vertical loop used for anterior retraction has structural axis that bends in only one plane. For unidirectional bending, flat wire is the cross section of choice. More energy can be absorbed into spring made of flat wire than of any other cross section.

With respect to reactive members a square or rectangular wire would appear superior to a round one because of ease of orientation and greater multidirectional rigidity. This leads to a more definite control of anchor units.

Wire length

The length of a member may influence the maximum elastic load and the load deflection in a number of ways depending on the configuration and loading of the spring.

Increasing the length of the wire is better way to reduce load deflection rate than is reducing the cross-section. Increasing the length of cantilever markedly reduces the load deflection rate, yet the maximum elastic load is not radically altered.

Increasing the length of the wire with vertical loops is one of the more effective means of reducing load deflection rates for flexible members and at the same time only minimally altering their maximum elastic load. However there are limitations in how much the length can be increased. The distance between bracket in continuous arch predetermined by tooth and bracket width. Vertical segment in the wire are limited by occlusion and the intrusion of the mucobuccal fold.

Amount of wire

Additional amount of wire can be incorporated in the form of loops, helices or some other configuration. This tends to reduce the load deflection rate and increases the range of activation of the flexible member.

To achieve this objective with minimum amount of wire, the optimal placement of additional wire is at cross section, where the bending moment is the greatest. A practical way of deciding where these parts of a wire might be is to activate a configuration and see where most of the bending or torsion occurs. These are the sections where wire has the greatest stress.

In short, it is not the amount of wire used that is important in achieving a desirable flexible member but rather it is the placement of the additional wire and its form.

Stress raisers

From a theoretic point of view, the force or stress required to permanently deform a given wire can be calculated however in many instance the wire will deform at values much lower than the predicted ones because of presence of certain local factors or stress raisers.

Two common stress raisers are sudden change in cross-section and sharp bends. Any nick in wire will tend to raise the stress at that cross-section and hence may be responsible for permanent deformation or fracture at this point.

A sharp bend in wire may also result in higher stresses than those that might be predicted for a given cross section of wire. A sudden sharp bend will far more easily deform than a more rounded or gradual bend. Unfortunately in a continuous archwire, the orthodontist is somewhat limited in space between brackets and many times is require to make sharp bends because of this limitation.

Direction of loading

Not only is the manner of loading important but the direction in which a member is loaded can markedly influence its elastic properties. If a straight piece of wire is bend so that permanent deformation occurs and an attempt is made to increase the magnitude of bend, bending in the same direction as had originally been done, the wire is more resistant to permanent deformation than an attempt had been made to bend in the opposite direction.

If a bend is made in an orthodontic appliance the maximum elastic load will not be the same in all directions. It will be greatest in the direction that is identical to the original direction of bending. The phenomenon responsible for this is referred as the Bauschinger effect.

Fatigue of metals

Fatigue is the result of repeated stress at a level below that which would normally cause failure. These stresses, usually in low plastic deformation range, gradually bring about additional work hardening until the metal finally fails in a fracture.

If there is a defect in the material such as a scratch or an internal flaw, the material remaining around the defect will have to carry an added load and may lead to fracture.

Prevention of fatigue failure

Broken wire can add time to treatment so it is imp0ortant that all possible preventive measures be taken, care should be taken in wire selection.

Metals that work harden rapidly may fatigue more easily. Hard wires are more brittle than soft wires of the same materials.

- During arch designing wire should never be marked or noted with a file or other sharp instrument.
- Smaller cross sectional wires have a broad working range and may not be so easily stressed to the proportional limit.
- Sharp bends should be avoided whenever possible, sharp bend causes much more work hardening than large radius bend.

- Repeated bending at the same point should be avoided.
- All adjustments should be done away from high stress areas such as soldered joints.

Manufacturing

The physical properties of metals are influenced at every step in production, beginning with selection and melting of alloying metals.

The ingot

Wire is actually a modified casting. One of the critical operations in wire making is pouring the molten alloy into a mold to produce an ingot. This ingot will have varying degree of porosity and inclusions of slag in different parts.

A magnified view of the inside of an ingot would show it to be made up of crystals of the component metals. In metallurgical terminology they are called grains and it is this granular structure which controls many of the mechanical properties. The size and distribution of these grains are very dependent on the rate of cooling and the size of the ingot.

The porosity in ingot comes from 2 sources – gases that are either dissolved in the metal or produced by chemical reaction within the molten mass from bubbles which are trapped in metal. As the ingot cools and shrinks, the late-cooling interior surface must shrink inside an already hardened shell. So additional voids of vaccum type result.

Rolling

1st mechanical step in processing is rolling the ingot into a long bar. This is done by a series of rollers which gradually reduce the ingot to a relatively small diameter. Through all this rolling and the later processing into the final wire, different parts of the original ingot never lose their identity. The metal that was on the outside of the ingot is of finest wire. Like wise the ends of the ingot will be at the ends of the wire. Wire is actually a grossly distorted ingot; thus it is easy to see that different pieces of wire from the same batch can differ depending on which part of ingot they came from.

Each grain is elongated in the same proportion as the ingot. The squeezing action of rolling the ingot increases the strength of the metal. The rolling action forces the grains into long, fingerlike shapes that are closely fitted together. This causes an increase in hardness or brittleness of the metal. This is a form of work hardening.

Each pass through rollers increases this work hardening, until finally the structure becomes so ‘locked up’ that it no longer adjust enough to adapt to the squeezing of the rollers. If rolling is continued beyond this point the surface will start to show many small cracks and begin to crumble. Before this happens, the rolling process is interrupted and metal is annealed by heating to a suitable high temperature. At this temperature atoms become mobile enough to move within the mass, breaking up the tight crystalline structure. When the metal has cooled again, the annealed structure resembles that of the original casting, but it is somewhat more uniform.

Drawing

After the ingot has been reduced to fairly small diameter by rolling, it is reduced to its final size by drawing. This is more precise process in which the wire is pulled through a small hold in a die. This hole is slightly smaller than the original diameter of the wire, so that the walls of the die squeeze the sire uniformly from all sides as it passes through. This reduces wire to the diameter of the die. Drawing subjects the entire surface of the wire to the same pressures instead of squeezing from only two sizes as in rolling.

Before it is reduced to orthodontic size, a wire must be drawn through many series of dies and annealed several times along the way to relieve work hardening. This intermediate annealing is very important to resist the breakage.

The actual number of drafts and frequency of annealing depends on the alloy being drawn. Gold is extremely ductile and can be reduced considerably with each draft. Ordinary carbon steel requires many more steps than gold and stainless steel requires many more than carbon steel. Gold work hardens slowly so that it also needs less frequent annealing than the more rapidly work hardening steel.

Rectangular wire

Rectangular wire can be made drawing the materials through a rectangular die or by rolling round wires to rectangular shapes. Drawing produces a sharper corner on rectangular wire; this can be an advantage in application of torque.

Gold wires

They come under precious metal alloys. Before 1950, precious metal alloys were used routinely for orthodontic purpose primarily because nothing else would tolerate intraoral conditions. Gold in its pure state is very soft, malleable and ductile.

Composition

Two types of gold wires recognized in ADA Spee No. 7.

Type I – High precious metal alloy must contain 75% of gold and platinum group metal.

Type II – Low precious metal alloy must contain at least 65% of the same metals.

The basic composition consists of

Gold – 11-15%
Copper – 11-15%
Silver – 10-25%
Palladium – 5-10%
Platinum – 5-10%
Nickel – 1-2%

General effect of constituents

Gold: Provides malleability and ductility

Platinum: Used for greater strength and toughness resistance to tarnish and corrosion

Palladium: Most effective element for raising melting point.

The increased palladium, platinum content ensures that wire will not melt or recrystallize during soldering procedure. Also they ensure fine grain structure.

3) Copper – Contributes to age hardening
4) Nickel – Small amount as strengthener.
5) Silver – To balance the colour
6) Zinc – As a scavenger to obtain oxide free ingot.

Fusion temperature

Minimum fusion temperatures are established to ensure that wire do not melt or lose their wrought structure during normal soldering procedure. According to ADA Spe. No. 7 for Type 1 – 955^0 (1751^0F) and for Type II minimum fusion temperature is 871^0C (1600^0C).

Mechanical properties

The wire of a given composition is generally superior in mechanical properties to a casting of the same composition. The casting contains unavoidable porosity which has a weakening effect. When cast ingot is drawn into a wire, small pores and blebs may be collapsed and welding may occur so that such defects disappear.

Modulus of elasticity – 96,500 to 1,17,200 MPA which is slightly higher than that for gold casting. It increases approximately 5% after hardening heat treatment.

Heat treatment of gold alloys

Heating the wrought metal at an elevated temperature for a certain period of time to alter its mechanical properties is called heat treatment. Depending on temperature and duration the alloy may become harder or softer.

Hardening heat treatment (Age hardening)

Gold alloy can be hardened by heating it to 250 – 450^0C for 15-20 minute and quenching it. This changes the crystal structure from FCC to FCT thus improving strength and hardness.

Solution heat treatment (Softening heat treatment)

This consists of heating the alloy just below the solidus temperature i.e. approximately 700^0C for 10 minute. This changes alloy composition to random solution. Thus alloy becomes softer and ductile. This is often done after cold working to reduce stresses induced by cold working.

Work hardening

Gold alloy work harden much more slowly and to lesser degree than steel. This can be a great advantage. To the manufactures, this low work hardening means that drawing is much easier, with fewer intermediate annealing required. To the orthodontists, it means that these materials are less brittle and will take much more manipulation before they have hardened excessively.

Microstructure

The microstructural appearance of cold worked or wrought alloys is fibrous with very elongated crystals. It results from drawing operation to form the wire; such structure exhibits enhanced physical properties than a corresponding cast structure. Specifically wrought material possesses increased tensile strength and hardness.

Now a days use of Gold is greatly reduced because it is too soft to use as an ortho appliance high cost and also because of recent advances in wire materials and mechanical properties of the same.

Cobalt chrome nickel alloys

These alloys were originally developed for use as match springs (Elgiloy) but their properties are also excellent for orthodontic purpose.

The wires are furnished to the orthodontist in different gauges and cross sectional shapes with differing physical properties as well. Their resistance to tarnish and corrosion is excellent. Furthermore they can be subjected to soldering and welding procedures.

Composition

Cobalt – 40%
Chrominum – 20%
Nickel – 15%
Molybdenum – 7%
Manganese – 2%
Carbon – 0.5%
Berylium – 0.4%
Iron – 1.5%

Heat treatment with cobalt chromium

- Cobalt – Chrominum nickel alloy can be softened by heat soaking at 1100^0 to 1200^{0}C, followed by quenching.
- The age hardening temperature range is 260-650^{0}C e.g. holding at 480^{0}C for 5 hours as recommended by the manufacturer of elgiloy.

Ordinarily the wire is heat treated before being supplied to the user. The heat treatment increases yield strength and decrease ductility.

Wires made from this alloy should not be annealed. The resultant softening can not be reversed by subsequent heat treatment.

Physical properties

Tarnish, corrosion resistance excellent. Hardness, yield strength and tensile strength are much the same as those of 18-8 S.S. Ductility in softened condition is greater than that of 18-8 S.S. and less in hardened condition.

Recovery heat treatment

An increase in the measured elastic properties of wire can be affected by heating it to comparatively low temperature (370-480^{0}C) after it has cold-worked. This stress-relief heat treatment removes residual stress during recovery without pronounced alteration in mechanical properties. Such a treatment also stabilizes the shape of the appliance.

Co-Cr-Ni wires are more responsive than S.S. to low temperature heat treatment. A reduction in ductility accompanies increase in yield strength.

Mechanical properties and clinical implication

Co-Cr-Ni alloys are available commercially as Eligiloy, Rockmountain orthodontics, Azyra and multiphase.

With the exception of red temperature elgiloy, non heat treated Co-Cr wire have a smaller spring back than S.S. wires of comparable size but this property can be improved by adequate heat treatment.

The advantage of Co-Cr wire over S.S. includes greater resistance to fatigue and distortion and longer function as a resilient spring. In most other respects, mechanical properties of Co-Cr are very similar to those of S.S.wire.

The high modulus of elasticity of Co-Cr and S.S. wires suggest that they deliver twice the force of β-titanium and 4 times the force of Nitinol wires for equal amount of activation.

Co-Cr wires have good formability and can be bent into many configurations relatively easily. Caution should be exercised when soldering attachments to these wires, since high temperature cause annealing with resultant loss in yield and tensile strength, low fusing solder is recommended.

Functional for between brackets and Co-Cr wire is greater compared to S.S.

Stainless steel

It is the most widely used and accepted material in orthodontics. It was between 1903 and 1921 that Harry Brealy of shiffield, F.M. Becket of U.S. Benno strauss Edward Maurs of Germany shared to how our of the development of the material.

Steels are iron bases alloys that contain less than 1.2% carbon. Different classes of steel evolve from three possible lattice arrangement of iron. Pure iron at root temperature has body centered cubic (BCC) structure and is referred to as ‘ferrite’. This phase is stable upto 912^0C. The spaces between atoms in BCC structure are small and oblate, hence carbon has very low solubility in ferrite (0.02 wt%).

At temperature between 912^0C and 1394^0C the stable form of iron in face centered cubic structure called austenite. The interstices in (FCC) are larger than BCC structure. Maximum carbon solubility is 2.11 wt %.

When austenite is cooled slowly from high temperature, the excess carbon is not soluble in ferrite forms iron carbide. Fe_3C, This hard, brittle phase adds strength to relatively soft and ductile ferrite and austenitic forms. However is austenite is cooled very rapidly (quenched) it will undergo a spontaneous, diffusion less transformation to body centered tentragonal (BCT) structure called ‘Martensite’. This lattice is highly distorted and strained, resulting in very strong hard and brittle alloy.

The formation of martensite is an important strengthening mechanism for carbon steel. The cutting edges of carbon steel instrument are ordinary martensitic steel. The extreme hardness allows for grinding a sharp edge that will be retained in use.

- When 12-30% chrominum is added to steel it is called stainless steel.
- It resists tarnish and corrosion because of passivating effect of chromium.

Composition

18% Chromium

8% Nickel

71% Iron

0.2% Carbon

Other metals like Titanium, Manganese, Silicon.

Effect of alloy constituents

Chromium: Passivating effect by forming strongly adherent layer of chromium oxide (Cr_2O_3) on surface.

Nickel: Stabilizes homogenous mass and corrosion resistant austenitic phase at low temperature.

Carbon: Provides strength and hardness

Silicon: Resistance to oxidation at high temperature and to corrosion

Sulfur: Easy machining of alloy particles.

Phosphorous: Lower temperature for sintering

3 types of S.S.

Type	Cr.	Ni	C
Ferritic	11.5-27	0	0.2 max
Austenitic	16-26	7.22	0.25 max
Martensitic	11.5-17	0.25	0.15-1.20

1) Ferritic S.S. (AISI 400)
    a. Good corrosion resistance at low cost
    b. Strength not much high
    c. Not heat hardenable
2) Martensitic S.S. (AISI 400)
    a. Can be heat treated

   b. Because of high strength and hardness used for surgical and cutting instruments.
   c. Corrosion resistance less than other types.

3) Austenitic S.S. (AISI 302) (AISI 304)
   a. Most corrosion resistant

   Basic composition (AISI 302)

   Chromium – 18%
   Nickel – 8%
   Carbon – 0.15%

   Type 304 similar component except carbon content which is limited to 0.08%.
   Cold working during fabrication of a wire contributes to increase in strength
   This is partly because of

- Strain hardening
- A change from face centered to a body centered lattice.
- Hardening of S.S.
  - Only way – cold working
- Annealing stainless steel
  - All effects of cold working are eliminated metal returns to softest, most workable form. Cooling must be by quenching.
- Stress relief of S.S.
  - Most important heat treatment process for S.S.
  - Used both in manufacturing and orthodontic office
  - Hardening by cold working – inter locking of grains. These parts are under pressure or tension.
  - Stress relief eliminates such areas of stress, puts it into a condition to work most effectively.
  - 2nd reason for stress relieving – When wire is bent to form an arch, it is full of residual stress and tends to return to original form, stress relieving heat treatment prevents this change.
- Intergranular corrosion
  - Carbon is an undesirable impurity in austenitic S.S. It is difficult to remove completely

- At temperature between 800^0F to 1200^0F – C reacts with Cr to form chromium carbide CCr_4. this reaction is called 'sensitization'. At temperature above 1200^0F CCr_4 breaks of in component elements.
- CCr_4 is harmless by itself but Cr tied up to carbon can not contribute to corrosion resistance.

Prevention

1) Keeping out of sensitizing temperature range.
2) Controlling the carbon.

1) CCr_4 reaction taken time, speed in handling metals in sensitizing temperature range such as soldering is very effective.

   S.S. should always be quenched immediately after soldering.
2) Stabilization to prevent intergranular corrosion
   a. Not making carbon available for sensitization reaction.
   b. By keeping carbon content low
   c. Addition of titanium, columbium which preferentially react with carbon.

Properties:

A wide range of values – possible from many different S.S. available and from the alloy in work-hardened or heat softened condition. Cold working by swaging or drawing operation rapidly increases the strength of austenitic S.S. They are malleable and ductile when annealed 8 in such a condition can be contoured and adapted.

Typical values for aust. 18-8 S.S. and a gold alloy wire are given in following table.

Wire	**Stainless steel**		**Gold alloy**	
	S	**H**	**S**	**H**
Yield Str.	275	690	550	930
Tensile Str.	585	965	860	1200
Elongation (%)	55	25	20	8
BHN	165	275	175	275
Modulus of E	20		10	

- Percentage elongation or ductility is greater for steel than for gold alloys.
- Hardness is quite similar
- Modulus of elasticity of steel is almost twice that of gold
- Tensile strength and yield strength of gold alloy is greater than S.S.

Comparison of contemporary arch wires

	Strength		**Stiffness**		**Range**	
	0.016	**0.018**	**0.016**	**0.018**	**0.016**	**0.018**
Stainless steel	1		1		1	
TMA	0.6	0.6	0.3	0.3	1.8	1.8
M-NiTi	0.6	0.6	0.2	0.2	3.9	3.9

- Strength of M-NiTi and TMA are same almost 60% as strong as steel
- Stiffness of NiTi and TMA are almost same 1/3rd that of S.S.

Clinical implications

- Carbon interstitial hardening and cold-working brings high yield strength and modulus of elasticity
- Residual stress can affect elastic properties markedly therefore heat treatment for stress relieving after bending wire into arches, loops or coils.
- Recommended time schedule – 750^0F for 11 minute
- Large modulus of elasticity and stiffness – use of smaller wire for alignment of moderate to severely displaced teeth therefore poor fit in bracket loss of control during tooth movement.

  High stiffness □ advantageous □ resisting deformation caused by extraoral and intraoral tractional forces.
- Yield strength to elastic modulus ratio □ indicate lower spring back. Stored energy of activated S.S. less than β-Titanium and Nitinol □ High forces, which dissipate over short period.
- Low levels of bracket / wire friction therefore lower resistance to tooth movement.
- S.S. wires can be used in fixed orthodontic treatment with edgewise appliance.

In the 1st stage of alignment and leveling as an option to NiTi wires; S.S. can be used. If S.S. is used, multistranded wires or loops to increase springiness can be used.

- For alignment smallest diameter wire with adequate strength is preferred. When multiple strands of same diameter wire are used, strength increases, springiness relatively unaffected.
- Wires with loop primarily indicated when arch is well aligned except at one spot, where tooth is malpositioned. If highly flexible wire is used □ chances of distorting arch form increase hence need of a wire that is reasonably stiff except at one spot, loops produce the same effect.
- S.S. wire also finds application in 2nd stage i.e. closing extraction spaces.
  A closing loop made of S.S. wire generate closing force as well as appropriate moments to bring root apices together at extraction site.
- Finally the typical finishing archwire is either 17 × 22 or 17 × 25 steel. These wires are flexible enough to engage narrow brackets even if moderate degree of tipping has occurred and it will generate the necessary root paralleling forces.

Triple stranded stainless steel archwires

Besides single stranded round and rectangular wires there are now multistranded wires of varying size, shape and number.

Theory for the general multistranded arch wires

Classic mechanical theory shows that as the diameter of wire strand is reduced, the stiffness decreases as a function of fourth power, and the range increases proportionately. In terms of performance, the wire is delivering higher forces per unit of activation over a greater distance. These trends will be acceptable if there is not strength reduction which is usually to the third power; this permits distortion and even failure of light single stranded arch wire. To improve the strength and at the same time to maintain the desirable stiffness and range properties many small wires are twisted together and even swaged or spot welded. The result is an inherently high elastic modulus material having low stiffness because of its co-axial spring like nature.

Australian heat treated arch wires

- In collaboration with Australian metallurgist A.J. Willcock, Begg sought to develop a wire material.
- After several years of experimentation they produced a wire which is
    - Tough enough to distribute forces at an optimal level for tooth movement over a considerable distance for a long period of time and with minimum loss of force intensity while doing so
    - Thick enough to resist weakening and distortion due to wear and tearing forces.
- Outstanding properties of Australian wire
    - Its resilience or ability to spring back after having been deflected.

Wires are available in following forms

Regular	white
Regular plus	Green
Special	Black
Special plus	Orange
Premium	
Premium plus	
Supreme	

Regular grade:

- Lowest grade
- Easiest to bend
- Used for practice or forming auxiliaries
- Can be used for archwires when distortion and bite opening is not a problem.
- Available in sizes 0.012”, 0.014”, 0.016”, 0.018”, 0.020”.

Regular plus grade

- Relatively easy to form, more resilient than regular grade
- Used for auxillaries and arch wires when more pressure and resistance to deformation is desired.
- Available in sizes 0.014”, 0.016”, 0.018”, 0.020”.

Special grade

- Highly resilient yet can be formed into intricate shaped with little danger of breakage.
- The 0.016” is often used for starting arches in many techniques.
- Available in sizes 0.014”, 0.016”, 0.018”, 0.020.

Special plus grade

- Routinely used by experienced operators
- Hardness and resilience of 0.016” are excellent for supporting anchorage and reducing deep overbite.
- Available in sizes 0.014”, 0.016”, 0.018”, 0.020”, 0.022”.

During last 2 decades 3 more grades have been introduced namely. Premium, premium plus and supreme in an order of increasing yield strength.

Because of increased yield strength there is

1) In creased springback or elastic strain
2) Increased resiliency
3) Zero stress relaxation – ability of the wire to deliver over long periods, a constant force when subjected to external load
4) Formability however decreases.

If the wire is straightened by the process of reverse straining, meaning flexing in a direction opposite to that of original bend, yield point of wire reduces. This phenomenon is known as ‘work softening’ due to reverse straining or the ‘Bauschinger effect’.

A special process of straightening the wires called pulse straightening has been developed with avoids reverse straining. It permits even the highest tensile wire to be straightened without reducing yield point of the wire.

Due to extreme hardness of A.J. Willcock Australian wire special attention must be given to bend it successfully.

1) Prewarm the wire by sliding between thumb and forefinger. Do not attempt to straighten the wire by stripping between plier beaks.
2) Hold the wires lightly when bending the wire. Do not squeeze or pull the wire.
3) Never pinch the wire with plier before or during bending.

4) Bend the wire very slowly pressing with thumb and forefinger, do not rotate plier while bending loops.

Australian wires become hard from bending (work hardening) hence there is no need for heat treatment and there is no margin to permit back bending to correct mistakes.

Uses of newer Willcock wires

1) Unravelling of crowded anterior teeth
2) MAA – Mollenhauer's aligning auxillary
3) Mini Uprighting springs

They produce very light forces there by decreasing anchor strain.

Clinical implications

They are difficult to bend but interestingly when they are removed from patient's mouth several months later they are still stiffer than S.S. wires which tend to soften in mouth.

Nickel-Titanium archwires

Nitinol was invented in early 1960's by William F. Buchler, at Naval Ordinance laboratory.

Mechanical properties

- Modulus of elasticity of Nitinol is 41.4 × 10^3 Mpa
- Yield strength – 423 Mpa
- Ultimate tensile strength 1489 Mpa.

These properties result in very low orthodontic forces when compared with wire's large elastic deflection or working range. The alloy has limited formability.

Composition and physical properties

Nickel – 54%
Titanium – 44%
Cobalt – 2%

Composition results in one to one atomic ratio of major components. As with other systems, this alloy can exist in different crystallographic forms. At high temperature – BCC lattice referred to as austenite phase is stable, appropriate cooling can induce transformation to closed packed hexagonal martensitic lattice. This transition can also be induced by application of stress.

This characteristic of austenitic to martensitic transition result in two unique features of potential.

Clinical relevance

Shape memory and superelasticity

Shape memory wire

- Most orthodontists are aware of nitinol because of unique property of 'Shape memory'.
- It has characteristic of being able to return to a previously manufactured shape when it is heated through a transition temperature range (TTR).
- To use this property the wire must 1^{st} be set into the desired shape and held while undergoing a high temperature heat treatment. After the wire has cooled to room temperature it may be deformed within certain strain limits.

  The 'Memory' effect is achieved by 1^{st} establishing shape at temperature near 482^0C. the appliance such as orthodontic archwire is then cooled and formed into a second shape. Subsequent heating through a lower transition causes the wire to return to its original shape.
- The cobalt content is used to control the lower transition temperature with can be near mouth temperature 37^0C.

Although shape memory principle theoretically could be used to impart orthodontic forces, it has not yet been reduced to clinical practice.

Superelasticity

Inducing the austenitic to martensitic transition by stress can produce superelasticity a phenomenon, which is employed with some nickel-orthodontic wires.

- If alloy is stressed, it initially results in the standard proportional stress-strain behaviour. However at stress sufficient to cause phase transformation, there is significant increase in strain, referred to as superelasticity.
- This additional strain is due to the volume change that results from change in crystal structure.
- At the completion of phase transformation, the behavior returns to conventional elastic and plastic strain with increasing stress.

NiTi alloy, therefore can be produced with either the austenitic or martensitic structure, may have varying degrees of cold work and variation in transition temperature.

- In general Nickel-Titanium wires have relatively low modulus values and large working range, the wires are difficult to form, can neither be soldered nor welded.
- Since hooks can not be bent or attached to nitionol, crimpable hooks and stops are recommended for use.
- Cinchback distal to molar buccal tube can be obtained by flame annealing the end of the wire. A dark blue colour indicates the desired annealing temperature.

  Findings on resistance to corrosion of nitinol wires have been inconsistent.
- The most important benefit from Nitinol wire is realized when a rectangular wire is inserted early in treatment. Simultaneous rotation, leveling, tipping and torquing can be accomplished early with a resilient rectangular wire like Nitinol.
- When the case is nearing completion with a nitinol arch wire, there is very little to be done in the way of placing compensating bends to upright roots once the spaces have been closed.

Clinical implications

High springback, flexibility, low constant force, shape memory and superelasticity are the important and advantageous properties for clinical application.

- Wire / bracket frictional forces with Nitinol wire are higher than S.S. but lower than β-Titanium NiTi can be successfully used in treatment of
    - Crossbite correction
    - Uprighting impacted canines
    - Opening the bite
- Nitinol wires can be used in Class I, II, III malocclusion in both extraction and non-extraction cases.
- In selecting cases that benefit most from the use of nitinol wire, the primary criteria are the amount of malalignment of teeth from ideal arch form.

Use of thermal nitinol with TTR between 31-45^{0}C.

It has a unique property of returning to a previously manufactured shape when it is heated to a transition temperature range (TTR). If we are to take advantage of this property.

- Set wire in desired shape
- Heat treatment
- After cooling to room temperature can be deformed with in certain limits.

When heated to its unique TTR it will remember its shaped and return to the original configuration.

Nitinol after being deformed will spring back to its original shape by either of two methods.

1) Nearly complete spring back because of its modulus of elasticity.
2) Will experience complete springback from the deformed shape by being placed in transition temperature range between 31-40^{0}C.

At present two types of NiTi alloy wires are commercially available

The 1st is work hardened alloy manufacture a as nitinol (unitek corp) developed in early 1960's and introduced into orthodontic in 1971. More recently a new nickel-titanium alloy has been introduced for orthodontic application and is available as NiTi cormaco, sentalloy.

Two types of wires demonstrate several different in properties.

Original nitinol wires are primarily in martensitic phase at room temperature, newer NiTi wires have austenitic grain structure and 1.6 times greater spring back. When compared with nitinol, NiTi wires are 36% stiff at 80% activation and are not time dependent with regard to stress relaxation.

Problems encountered with nickel-titanium wires

1) Difficulty of placing bends, steps
2) Brittleness and breakage
3) Tendency of archwire to slide from one side to other
4) Non self-limiting
5) High cost.

β-Titanium alloy archwires

Titanium has been used as structural metal since 1952.

In 1960, an entirely different ‘high temperature’ form of titanium alloy become available. At temperature above 1625^0 F pure titanium rearranges into a BCC lattice referred to as β-phase. With addition of elements like molybdenum, columbium, a titanium based alloy is referred to as β-stabilized titanium. The alloying and BCC structure provide unique properties.

Composition

Titanium 77.8%	Zirconium 6.6%
Molybdenum 11.3%	Tin 4.3%

The alloy is marketed in the form of straight wire lengths or preformed arches under trade name of TMA.

Mechanical properties

Wrought β-titanium has modulus of elasticity of 71.7×10^3 Mpa and yield strength between 860-1170 Mpa.

These properties produce several clinical desirable characteristics

- The low modulus allows low forces ever for large deflection.
- The high ratio of yield structure to elastic modulus produces high springback
- Mechanical properties of many titanium alloys can be altered by heat treatment that utilize the β-transition. However heat treatment of current orthodontic β-titanium is not recommended.
- The β-titanium in structure wire application can be deflected 105% more than S.S. without perm deformation.
- Modulus of elasticity of β-titanium is twice that of nitinol and less than one half that of S.S. Its stiffness makes it ideal in application where less for than steel is required but where lower modulus material would be inadequate to develop required force magnitude.
- Formability of β-titanium wire is similar to S.S. however titanium can not be bent over as sharp a radius as S.S.
- β-titanium can be joined by welding and has good corrosion resistance.

Clinical application

- Because of unique and balance properties, β-titanium can be used in a number of clinical application.

- Ideal edgewise arches fabricated of titanium have sufficient superiority over S.S. They can be deflected approximately twice as far without perm deformation thus greater range of action for initial tooth alignment or finishing arches.
- Forces produced are approx 0.4 that of steel producing move gentle delivery of forces with edgewise wire.
- β-titanium is ductile, which allows for placement of tie-back loops or complicated bends
- Springback properties are not lost during bending applications.
- With β-titanium, larger activation is possible as low forces are produced without loss of orientation of the wire with bracket.
- Specialized springs or auxiliaries fabricated from β-titanium allows for simplification of design for achieving ideal force delivery.
- The high formability of titanium allows the fabrication of closing loops with or without helices.

Production of low friction

A low coefficient of friction is desirable in an orthodontic archwire. However studies have shown that NiTi and TMA have higher coefficient of friction than S.S.

In case of TMA friction is due to softness surface treatment – increased hardness – coefficient of friction of TMA wire while maintaining its desirable mechanical properties.

Ion implantation

A process in which various elements are ionized and then accelerated towards a target, in this case the arch wire.

It takes place in vaccum chamber where a vapour flux of ion is generated with an electron beam evaporator and deposited on the substrate. Gas ions (N_2 and O_2 in this case) are simultaneously extracted from a plasma and accelerated in the growing physical vapour deposited film at energies of several hundred to several thousands electron volts.

The ions penetrate the surface of the wire on impact building up a structure that consists of both the original wire and a layer of tin compounds on the surface and immediate subsurface. This layer is extremely hard and creates considerable amount of compressive forces in the material at the atomic level. The compression forces and increased hardness improve the fatigue resistance and ductility and reduce coefficient of friction of wire.

Chinese Ni-Ti wire

A new Nickel-titanium alloy has been developed especially for orthodontic application by Dr. Tien Hua Cheng at General Research Institute, China.

Alloys has unique characteristics

Its history of little work hardening and a parent phase which is austenitic yield mechanics properties that differ significantly from Nitinol wire.

Mechanical properties

1) It has 1.4 times the springback of nitinol wire and 4.6 times to S.S. for 80% activation at 40% activation Chinese NiTi has 1.6 times the springback.
2) At 80% activation, average stiffness of Chinese NiTi wire is 73% of S.S. wire and 36% of nitinol wire.
3) Temperature dependent effects

   Chinese NiTi wire exhibits some small differences at varying temperature because material components have lower transition temperature.

   The stiffness is approx the same between room temperature of 22^0C and mouth temperature at 37^0C.

   At temperature above 60^0C, wire loses springback property.

Clinical significance

- Because of high range of action and springback
- Application in situation where large deflection is required
- Application includes structure wire procedures when teeth are badly malaligned and in appliances designed to deliver constant forces during major stages of tooth movement.

Japanese NiTi wire

In 1978 Furukawa Ele. Ltd. of Japan produced a new type of Japanese NiTi alloy possessing all 3 properties-

- Excellent springback

  - Shape memory
  - Superelasticity
- The unique feature of the stress value remaining fairly constant during deformation and rebound is very important concept of this entire investigation.
- It has high degree of resistance to corrosion.

Mechanical properties

The Japanese NiTi has higher values of elastic modulus than nitinol wire when the stretch exceeds 2%. The stress value does not change appreciably when strain is induced upto 8%, it produces stresses of 55-58kg/mm^2 when wire specimen is stretched 8% or more, the stress increases further. This property is called 'superelasticity'.

When strain is reduced Co-Cr, S.S. or nitinol wires exhibit almost straight stress-strain curve. In comparison when strain is reduced Japanese NiTi does not change proportionally to the stress decrease from 8% to 2%.

α - Titanium arch wires

It is recent alloy in the family of titanium alloy.

Composition

Titanium – 90%
Aluminium – 6%
Vanadium – 4%

The alloy is different in that its molecular structure resembles a closely packed hexagonal lattice as against BCC lattice of TMA.s

The hexagonal lattice possess fewer slip planes. Slip are planes of atom in a crystal that glides past one another during deformation.

More the slip planes-easier it is to deform the material.

BCC has two planes of easiest slip where as HCP has only one active slip plane thus the near Alpha phase titanium is less ductile than TMA.

It is not pure α-phase titanium as some β-phase is retained in it at room temp.

Copper Ni-Ti alloy

- Most recent introduction in family of NiTi alloy wires
- Introduced by Rohit Sachdeva and Sychio Miyasaki in 1994.

Cu- NiTi is a new quaternary (Nickel, Titanium, Copper, Chromium) alloy with distinct advantage over the formerly available nickel-titanium alloys.

These improvements are

1) Cu-NiTi generates a more constant force over long activation span than other nickel-titanium alloys.
2) For very small activation, Cu-NiTi generates near constant force.
3) More resistant to permanent deformation compared to other NiTi alloys.
4) It exhibits better springback properties.
5) The addition of Cu combined with more sophisticated manufacturing and thermal processes make possible the fabrication of 4 different Cu-NiTi archwires with precise and consistent transformation temp 15^0C, 27^0C, 35^0C, 40^0C.

   This enables clinician to select archwire on a case specific basis.

Composition

Titanium 42.99%

Nickel 49.87%

Chromium 0.50%

Copper 5.64%

Load – deflection characteristics

Studies indicate that loading factor reduction in Cu-NiTi is less than superelastic NiTi by 20%. Clinically it implies that it delivers more constant forces especially for small activations compared to superelastic NiTi. It makes possible the insertion of larger size wires and better bracket slot engagement early in treatment without causing pain and patient discomfort.

Surface roughness

SEM studies indicate that surface of Cu-NiTi is quite porous and rough. It resembles the surface of untreated TMA wire, the implications of surface finish on friction and corrosion needs to be investigated.

Classification

Depending on austenitic finish temp they are classified into

Type I Af 15^0C

Type II Af 27^0C

Type III Af 35^0C

Type IV Af 40^0C

Variation (TR) thermo-mechanics

Stress induced martensite is responsible for the superelastic characteristic of NiTi alloys however; martensite transformation is also temperature dependent. In other words stability of martensite and/or austenite phase at a given temperature is based on the transformation temperature. One of the most important markers is the materials austenitic finish temperature (Af). To exploit super elasticity to its fullest potential, the working temperature of orthodontic appliance should be greater than the Af temperature.

It is the differential between Af temperature and mouth temperature that determines the force generated by nickel titanium alloys. Understanding the factors that can influence the thermomechanical characteristics of nickel titanium has enabled to develop this new quaternary alloy.

Type I is not used for clinical application due to high force levels.

Type II produces highest force and in indicated in normal patients.

Type III is indicated in patients with low to normal threshold of pain and also in periodontically compromised patients.

Type IV produces lowest level of force and are good in patients highly sensitive to pain.

Ceramic / optiflex archwires

Optiflex is a recent archwire designed by Tallas. It combines unique mechanical properties along with highly esthetic appearance. It is made up of clear optical fiber. It comprises of 3 layers.

1) A silicon dioxide core that provide force for moving teeth
2) A silicon resin middle layer that protects care from moisture and adds strength
3) A strain resistant nylon outer layer that prevents damage to the wire and further increases its strength.

Wire can be round or rectangular and is manufactured in various sizes. Its mechanical properties include wide range of action, ability to apply light continuous forces.

Sharp bends should be avoided since they could fracture care. It is highly resilient archwire that is especially effective in alignment of crowded teeth.

Conclusion

Recent advances in orthodontic wire alloy have resulted in varied array of wire that exhibit a wide spectrum of properties. Presently the orthodontist may select, from all the available wire types, one that best meets the demands of a particular clinical situation. The selection of an appropriate wire size and alloy type in turn would provide the benefit of optimum and predictable treatment results. The clinician must therefore be conversant with the mechanical properties and the clinical application of these wires.

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