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Orthodontic Wires- A Contemporary Overview with Clinical Perspectives

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Abstract

Orthodontic wires are components of fixed appliances that are used as part of orthodontic treatment to perform the required tooth movements. To manufacture orthodontic wires a range of materials such as metals, alloys, polymers, and composites are used. Various laboratory tests, such as tensile, torsional, and bending tests measure the properties of orthodontic wires. Oral conditions can, however, affect their behaviour, and it is necessary for the clinician to understand the properties of orthodontic wires and their clinical consequences in order to achieve optimal results. This article reviews, along with clinical implications, various materials used to make orthodontic wires and their properties.

Keywords

Orthodontic wires, properties, stainless steel, nickel-titanium, beta-titanium, cobalt-chromium, esthetic wires.

Introduction

In the last few years material science has made substantial progress. Up until the 1930s gold was the only usable orthodontic wire. But these gold wires were expensive. In 1929, orthodontists were introduced to austenitic stainless steel, with its greater strength, higher elasticity modulus, strong corrosion resistance, and moderate cost, and gained prominence over the gold alloy within a short period. And orthodontics has come a long way since then. Several alloys such as Cobalt – Chromium, Nickel – Titanium, Beta – Titanium, stainless steel wires, multi-stranded wires and aesthetic wires with desirable properties were adopted in Orthodontics. In this vast ocean of various available orthodontic alloys, the selection of a suitable wire with the necessary properties becomes very difficult for an orthodontist. For the appropriate use of orthodontic wires, one must have a detailed knowledge of the materials from which they are made. The mechanical and physical properties of such materials significantly alter in different situations. Therefore, the clinician must have an adequate knowledge of the various biomechanical properties of the wires and their clinical applications and also the recent advancements that have occurred in order to put it to the best use.

Desirable Properties of Orthodontic Wires

For optimal efficiency during treatment, many characteristics of orthodontic wires are deemed desirable.

1) Spring back-This is also known as maximum elastic deflection, maximum flexibility, range and so on. The ratio of yield strength to the elasticity modulus of the materials (Ys/E) is related to Springback. Higher springback values have the potential to apply large activations with a consequent improvement in the appliance's working time. This in turn ensures that less changes or modifications to the arch wire would be required. Springback is also a measure of how, without causing permanent deformation, a wire can be deflected.

2) Stiffness or load deflection rate- This is the magnitude of force provided by an appliance and is proportional to the elasticity modulus E. Low stiffness or load deflection rate offers:

a. The potential for lower forces to be applied.

b. As the appliance experiences deactivation, a more constant force over time.

c. Greater ease and precision in the application of a given force,

3) Formability- High formability allows the ability to bend a wire without breaking the wire, into desired configurations such as loops, coils or stops.

4) Resilience module-This property indicates the work that is available to move teeth. It is defined by the region under the line that determines the wire's elastic deformation.

5) Biocompatibility-The corrosion resistance and tissue tolerance to elements in the wire. It ensures the preservation of the wire's desirable characteristics for an extended period of time after manufacturing.

6) Joinability – It denotes the ability to attach auxillaries to orthodontic wires by welding or soldering which provides an additional advantage when incorporating modifications to the appliance.

7) Friction – Space closure and canine retraction in continuous arch wire mechanics involve extensive amount of bracket-wire friction which may result in anchorage loss or binding accompanied by little or no tooth movement. So least friction between wire and bracket is most desirable.

There are several other factors which play an important role in the design of an orthodontic appliance that are enumerated below:

a) Wire cross section

Small variations in cross-section can significantly affect both the overall elastic load and the rate of load deflection, becoming a very critical factor. The overall elastic load varies directly as the third power of the round wire diameter, and the load deflection rate varies directly as the fourth power of the diameter. It can be shown that decreasing the wire size is the most obvious way of reducing the load deflection rate, but this also decreases the overall elastic load at an alarmingly high rate.

In the design of an active member, consistent with a safety factor, it is also necessary to use a cross-section as small as possible in such a way that excessive permanent deformation would not occur. Any attempt to reduce the size of the cross-section to improve the springiness of the cross-section could lead to permanent undesirable deformation.

Load deflection rate rather than maximum elastic load is the primary factor in selecting the correct cross section for the rigid reactive members of an appliance, so it is important to pick a broad enough wire cross section to have sufficient rigidity.

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

b) Wire length

Depending on the configuration and loading of the spring, the length of a member can affect the maximum elastic load and load deflection in a variety of ways.

Increasing the wire length is a better way of reducing the rate of load deflection than reducing the cross-section. The load deflection rate is substantially decreased by raising the length of the cantilever, but the overall elastic load is not drastically altered.

One of the more efficient means of minimising load deflection rates for flexible members is to increase the length of the wire with vertical loops, while at the same time minimally altering their overall elastic load. There are restrictions, however, as to how much the length can be increased. The distance between the bracket in the continuous arch is predetermined by the width of the tooth and bracket. The occlusion and the interference of the mucobuccal fold restrict the vertical section of the wire.

c) Amount of wire

In the form of chains, helices or some other arrangement, additional quantities of wire may be added. This helps to reduce the rate of load deflection and raises the versatile member's range of activation.

The optimum location of additional wire is at the cross section, where the bending moment is the highest, to accomplish this goal with a minimal amount of wire. Activating a configuration and seeing where much of the bending or torsion happens is a realistic way of determining where these sections of a wire may be. The parts where wire has the greatest stress are these.

d) Direction of loading

Not only is the manner of loading significant but the direction in which a member is loaded will markedly affect its elastic properties. If a straight piece of wire is bent such that there is permanent deformation and an attempt is made to increase the bending magnitude, bending in the same direction as originally done, the wire is more resistant to permanent deformation than an attempt to bend in the opposite direction was made.

The overall elastic load would not be the same in both directions if a bend is made in an orthodontic apparatus. It will be strongest in the direction similar to the initial bending direction. This phenomenon is referred to as the Bauschinger effect.

e) Stress raisers

Theoretically, the force or stress required to permanently deform a given wire can be calculated, however, in some instances the wire will deform at values much lower than the predicted ones because of the presence of certain local factors or stress raisers.

Sudden alteration in cross-section and sharp bends are two typical stress raisers. Any nick in the wire at that cross-section will appear to increase the stress and may therefore be responsible at this stage for permanent deformation or fracture.

A sharp wire bend can also lead to higher stresses than those that could be expected for a given wire cross section. A sudden sharp bend can deform much more quickly than a more gradual or rounded bend. Unfortunately, the orthodontist is somewhat limited in the space between brackets in a continuous archwire, and due to this restriction, sharp bends are needed several times.

Manufacturing of Orthodontic Wires

Every step in the manufacturing of the wire influences its physical properties beginning with the selection and melting of the alloying metals.

i) The ingot

As a matter of fact, wire is a modified casting. In wire making, one of the crucial operations is pouring the molten alloy into a mould to create an ingot. This ingot will have varying porosity and slag inclusions in various sections of the ingot. A magnified image of the inside of an ingot will reveal that the component metals are made up of crystals. They are called grains in metallurgical terms, and it is this granular structure that governs many of the mechanical properties. These grains are very dependent on the cooling rate and the size of the ingot in terms of size and distribution. The porosity in the ingot comes from gases that are produced by chemical reaction within the molten mass which form bubbles that get trapped in the metal.

ii) Rolling

In manufacturing, the first mechanical step is to roll the ingot into a long bar. This is accomplished by a set of rollers that progressively reduce the diameter of the ingot to a relatively small diameter. This is a form of work hardening. Every passage through the rollers increases this work hardening, until the structure is eventually so 'locked up' that it no longer changes to adapt to the roller squeezing. If rolling is continued past this stage the surface will start to display several small cracks and begin to crumble. The rolling process is stopped until this occurs, and metal is recovered by heating to a suitable high temperature. At this temperature, atoms become sufficiently mobile to move within the mass, breaking the tight crystalline structure apart. The annealed structure resembles that of the initial casting when the metal has cooled again, but it is much more uniform.

iii) Drawing

After the ingot has been reduced by rolling to a reasonably small diameter, it is reduced by drawing to its final size. This is a more detailed method in which a small hole in the die pulls the wire. This hole is slightly smaller than the initial wire diameter, so that as it passes through, the walls of the die compress the wire evenly from all sides. This reduces the wire to the die's diameter. Instead of squeezing from just two dimensions as in rolling, drawing exposes the entire wire surface to the same pressures.

A wire must be drawn through several series of dies and annealed many times along the way to alleviate the work hardening until it is reduced to orthodontic size. To resist breakage, this intermediate annealing is very important.

Types of Orthodontic Wires

GOLD ALLOY

The composition of the alloys used in gold orthodontic wires is identical to type IV gold casting alloys. With 55-18 percent copper, 10-25 percent silver, 5-10 percent nickel, these alloys can contain as little as 15 percent gold and acquire additional strengthening by cold working, incorporated during the process of wire drawing. With the correct heat treatment, these wires can theoretically be reinforced, but they are usually used in the drawn state. Depending on the alloy state, the yield strength of wrought gold wires can vary from 50,000 to 160,000 psi. Gold alloys have an elasticity modulus of approximately 15 x 166 psi. Gold is very formable and capable of producing lower forces than stainless steel because of this combination of properties. However, commercial goods usually have yield strengths at the lower end of the spectrum, which limits springback. These characteristics are very desirable. By soldering, these wires are easily joined, and the joints are very resistant to corrosion. Because of their low yield strength and increasing cost, gold wires have decreased use in orthodontics.

STAINLESS STEEL

As the main alloy for orthodontic wires, Austenitic stainless steel started to replace gold in the 1940s. 302 and 304 stainless steels, are the most widely used types which contain around 18% chromium, 85 nickel and carbon less than 02-0 percent. Most of their strength is derived from cold working and carbon interstitial hardening from these alloys. The microstructure shows the usual 'fibrous' appearance associated with extensively elongated strains. Short exposures to elevated temperatures will change this microstructure, which is why soldering procedures must be carefully performed. With this wire, the only heat treatment used is for stress relief that is usually done for less than few minutes at 8500F (4540C). These wires have 50,000-280,000 psi of very high yield power.

The elasticity modulus ranges from 23 x 106-24 x 106 psi for orthodontic stainless steel wires. For alignment procedures where lower forces are indicated, the high modulus allows the use of smaller diameter wires. The yield strength ratio of the modulus shows that the springback properties of stainless steel wire are significantly higher than gold. In general, stainless steel has excellent formability, although the wires can be somewhat brittle with greater yield strength. It is possible to weld stainless steel and it has strong corrosion resistance. As an orthodontic arch wire, the combined sufficient springback, reasonable formability and modest cost account for the success of stainless steel.

H.T. Gold from Ormco is a heat-treated stainless-steel wire that offers a higher degree of force and greater springback than standard stainless steel. In applications where resistance to deformation is a primary factor, it should be considered. This wire's higher force level and rigid design makes it an excellent choice for control of the transverse arch shape.

MULTISTRANDED STAINLESS STEEL WIRE:

By building up a strand of stainless steel wire around a core of 0.0065" wire along with 0.0055" wire used as wrap wires, stainless steel wire flexibility can be improved. This produces an average diameter of around 0.0165".

Owing to the contact slip between adjacent wrap wires and the core wire of the strand, the strand of stainless steel wire is more flexible. In general, the stiffness of the strand can be attributed to the normal forces between the wrap wires, and this is in turn related to the helix of the strandlay, which is the tightness of the strandlay, giving an impression of a material pseudo variable modulus material (false sense of change in material of wire with same cross section to produce the elasticity).

The wires that are both under stress and torsion will slip with respect to the core wire and each other as the strand is deflected. If there is no elastic deformation, each wire returns to its usual position, providing the wire strand with elasticity. Round, rectangular and square cross sections are available for multistranded wires.

The stiffness of a triple stranded 0175" (3 x 008") stainless steel arch wire was close to that of 0.010" single stranded stainless steel arch wire, Kusy and Dilley noted. The multistranded archwire was also 25 percent stronger than the stainless steel wire of 010". A similar stiffness was then shown by 0175'" triple stranded wire and 015'" Nitinol. Nitinol, however, tolerated 50 percent greater activation compared to the multistranded wire. Even, the triple stranded wire was half as rigid as .016"-titanium multistranded wire, taking into account the price of titanium nickel wire.

Some of the available multistranded wires are:

1. Dentaflex - Dentaurum. (Dentaflex is available in triple strand, six strand co-axial and eight strand braided).
2. Flex twist - Unitex
3. Respond - Ormco
4. Force 9 - Ormco
5. Respond - Ormco

An 8 stranded, interwoven braided rectangular wire is D-rect. Its high versatility, together with 3-dimensional control and slot filling capabilities makes it ideally suitable for multiple applications including:

1. Regulation of initial torque
2. Picking up second molars later in therapy
3. A finishing arch wire to allow interarch occlusal settling, where torque is required but resilient.
4. Torque regulation with elastic vertical or anterior boxes.

A 9-strand, interworn, braided rectangular wire is Force 9. It delivers 50 percent more power than the D-rect 8-stranded. Its selection can be based on similar applications where it seems to suggest slightly more power.

React- is a spiral wrap of 6 strands with a central core wire. For greater power, React will deliver light, initial forces while filling the arch wire slot. Its resistance to permanent deformation makes react and excellent choice as an initial archwire in more serious dental malalignments.

There is also a stainless steel hybrid wire currently available. It consists of a rectangular anterior wire and a triangular posterior wire. The rectangular anterior wire provides better control of the torque and serves as brakes to burn out the anchorage. Often known as dual flex wires or wonder wires.

AUSTRALIAN ORTHODONTICS ARCHWIRES:

A.J. Wilcock developed orthodontic arch wire to fulfil the needs of Dr. Begg to be used for the Begg technique. There are some specific characteristics of the wire produced that vary from the normal stainless steel wire.

1. It is an arch wire of ultra-high tensile austenitic stainless steel.

2. The wire is resilient, and when shaped into the arch form and incorporated with bends, it becomes activated when pinned to the teeth, from which stresses are produced.

3. The wire has a special zero stress relaxation property. Zero relaxation makes it possible for the wire to sustain its strength over a long period of time, and to resist permanent elastic load deformation.

All these characteristics make the wire very tough and brittle. Depending on the resiliency the wire has been graded and colour coded for use.

REGULAR GRADE (white label):
Lowest grade, easiest to bend. Used for practicing bending or shaping auxiliaries. When distortion and bite opening are not a problem, it can be used as an archwire.

REGULAR PLUS GRADE (green label):
Relatively easy to form, but more resilient than regular grade, used for auxiliaries when more pressure and resistance to deformation are needed.

SPECIAL GRADE (black label):
Highly resilient and can be formed into complex shapes with little chance of breakage.

SPECIAL PLUS GRADE (orange label):
Wire hardness and resilience are excellent for anchorage support and deep overbite reduction.

EXTRA SPECIAL PLUS GRADE (blue label):
Highly resilient and hard, difficult to bend and subject to fracture.

The flat beak of the light wire plier should be used to prevent breakage of Australian orthodontic archwire. This has the effect of adding a moment about the gripping point of the thumb and wire that decreases the tension applied which may cause wire fracture in other ways.

Moreover, the tension on the crystalline structure is limited to a specific area that can cause the wire to crack when the wire is bent around the round beak of the plier. When the wire is bent around the flat beak, the offset stress points provide more space for crystalline adjustment and hence less risk of wire fracture.

The wire has a transition temperature that is ductile-brittle, and can be near or just above room temperature. To warm the wire, it is also advised to pull the wire with your fingertips, which decreases brittleness and prevents fracture.

With the orthodontist's demand for harder and harder wires, even higher grade wires were designed, premium and premium plus.

A.J. Wilcock created an even higher quality wire in the early 1980's that is commercially available as supreme. This wire is available in: .008", .009", 010" and .011". Such wires were originally used in lingual orthodontics for alignment where brackets are close together. Supreme wire flexibility is equivalent to that of Nickel Titanium wires and has the added benefit of good formability.

The supreme wire has the value of enhanced mobility, but it is very delicate. Some valuable tips on the management of the supreme wires have been given by Dr. Mollenhauer.

1. Use pliers where the beaks are flat.

2. The wire should be softly held in the beaks.

3. Gripping the wire more than 20 mm from the plier.

4. Very slowly bend the wire.

5. Pliers with two flat beaks are used.

Also, running the wire under hot water tap before bending, minimizes the chances of breakage.

Since 1970's preformed archwires, torquing auxiliaries and uprighting springs have been available commercially. Attempting to straighten the high tensile wire leads to repeated breakage for eventual shape into devices. As they are subjected to less work hardening and are thus more ductile, the low and medium grade wire show better formability. It was, however, the premium quality wire that had gained popularity that presented a challenge. Because of its increased risk of breakage, commercial businesses that created preformed arches were not prepared to use premium grades.

Up until then, by what is called the spinner straightening procedure, the wires were straightened. Spinner straightening is a mechanical straightening process, typically in the cold hard drawn state. The wire is pulled via high-speed rotating bronze rollers that twist the wire torsionally into a straightened state. Permanent deformation will result.

The premium and supreme wires are currently straightened by a method known as pulse straightening. While the exact technique probably remains a trade secret, it allows these high yield strength wires to be straightened without structural deformation and physical properties unchanged.

The supreme wires are routinely used to create torquing auxiliaries and uprighting springs due to their ability to generate continuous low forces. The more durable premium wires are used as base arch wires. In the 3rd stage of Begg Mechanotherapy, the combination of these two wires eliminates complications.

A rectangular box style aligning auxiliary made of .010 supreme wire, known as M.A.A., which stands for maxillary or mandibular aligning auxiliary, Mollenhauer aligning auxiliary or Melbourne aligning auxiliary , was introduced by Dr. Mollenhauer. This auxiliary has the ability to simultaneously torque and align the teeth.

The supreme material remands the clinician of nickel titanium wire with additional formability advantages and dramatically reduced costs. This size enables it to be positioned with other arch wires in the same slot without having to use deep slotted, specially built brackets. This decreases treatment time by allowing the teeth to be aligned while other mechanisms are ongoing. These wires exert incredibly light pressure, minimising patient discomfort and the risk of damage to the tissue.

Wallaby is an Australian high-temper stainless steel wire made by Ormco. For a given deflection, its greater yield strength over the equivalent diameter of stainless steel offers higher forces. This wire is recommended for use in all light wire technique stages and for initial levelling and reduction of cases of deep bite.

Nickel Titanium

The first titanium alloy introduced in orthodontics in recent years is nickel titanium alloy branded as nitinol by Unitek corporations for the space programme, but due to its exceptional springiness, it has proven very useful in clinical orthodontics. The term Nitinol is an acronym derived from nickel titanium and NOL, its place of origin, which stands for NAVAL ORDINANCE LABORATORY. In dentistry, the Niti alloys have two remarkable properties that are unique, shape memory and superelasticity,

Shape memory is a phenomenon in which the alloy is soft and readily formable at a low temperature, but when heated to a suitable transition temperature, it can easily be restored to its original configuration.

Superelaticity is the characteristic exhibited by these wires when the value remains relatively constant up to a certain point of wire deformation and remains constant as the wire recovers.

Niti can exist in more than one type of crystal structure, just like stainless steel and many other metal alloys. The type of martensite occurs at lower temperatures and the form of austenite at higher temperatures. Both shape memory and super elasticity are correlated with phase transitions between the martensitic and austenitic type within the Niti alloy that occur at a relatively low transition temperature.

After significant research, in the late 1970s, Nitinol was marketed for orthodontic use in a stabilised form of martensite, with no face transition effects. Nitinol is extremely springy and very strong, but has poor formability, as defined for orthodontic use. That family of commercially available stabilised martensitic alloys is referred to as M-NITI.

New Niti cables with an active austenitic grain structure emerged in the late 1980s. The other remarkable properties of Niti alloys, namely superelasticity and shape memory, are exhibited by these wires. A- Niti wires are referred to as this category of Niti wires.

From a metallurgical study, the physical behaviour of Niti alloy wire has been interpreted and clarified. The fact that Niti alloy is an almost equiatomic intermetallic compound that contains a variety of properties that can be regulated by the production process. Between the high and low temperature scales, a given zone lies. The crystal structure of the Niti alloy is an austenite phase at a high temperature range, which is a body centred cubic lattice. At a low temperature range, the martensitic level, is a tightly packed hexagonal lattice.

A change in crystal structure called martensitic transformation can be created by regulating the low and high temperature ranges. It is said that this process induces a change in its physical properties. The metal is ductile in the martensitic phase, which has a low temperature range, and acts like a safety fuse to quickly cause a shape change. It is more difficult to cause deformation in the austenite phase in the elevated temperature range.

When the deformation of most metals is induced by a lattice slip when external force is applied, the deformation of Niti alloy is induced by martensitic transformation. By heating the alloy to return to its austenite level, the martensitic transformation can be reversed and it is eventually transformed by reversing back into the stable state of energy. This ensures that it will return to the previous shape of the alloy. This phenomenon is called shape memory.

A metal with a phenomenon of this kind may exhibit remarkable superlasticity. This can be created by stress, not by the difference in temperature, and is called the martensitic transformation caused by stress. When an external force is applied in such a way that the stress exceeds a given level, martensitic transformation begins. Even when strain is applied, due to the progressive deformation created by stress-induced martensitic transformation, the rate of stress increase levels off, indicating a motion similar to slip deformation. On the other hand, if the stress is reduced, the Niti alloy returns to the previous shape without preserving the permanent deformation due to the characteristics of returning to the austenite process within a given temperature range.

Nitinol, the industrial Niti alloy wire does not possess superelasticity, although it belongs to the same group as Niti alloy wire. The stress has been raised in Nitinol in relation to the rise in strain, which is similar to the pattern of stainless steel and chrome cobalt wires. This wire mainly follows the martensitic phase, which does not exhibit superelasticity because during the development process its shape memory has been reduced by work hardening.

Miura et al Japan produced a new Japanese Nickel Titanium alloy. Better superelastic and shape memory properties were demonstrated by this wire. Over an extended portion of the deactivation range, the wire produced a constant force. It showed less tendency towards permanent deformation during activation as compared to Nitinol. Heat treatment has allowed both temperature and time to influence and regulate the load magnitude at which superelasticity is reflected. Due to the relatively constant force delivered for a long period of time during the deactivation of the wire, this alloy produced a physiological tooth movement.

Another nickel titanium alloy introduced by Burstone and produced by Dr. Tien Hua as Chinese Niti alloy exhibits superior spring back property compared to Nitinol due to little work hardening. Furthermore, Chinese Niti wire has a much lower temperature range for transformation.

Part of a peculiar nature of a superelastic material like A-Niti is that its unloading curve varies from its loading curve (i.e., reversibility has an energy loss associated with it hysterisis. This means the force it delivers is not the same as the force applied to activate it). The separate loading of the unloading curves produces an even more remarkable effect, that is, the force supplied by an A-Niti that can be altered merely by releasing and retying it during clinical use.

Wire bending with A-Niti is almost impossible for orthodontists in the classic sense, since they do not undergo plastic deformation unless a remarkably high force is applied. However, if their temperature is increased, the wires may be shaped and their properties altered. This can be accomplished by bending the wire in a clinical environment as an electrical current is passing through it, using adapted orthodontic pliers as the electrodes.

The method of electrically heating the wire is known as DERHT or direct electrical resistance heat treatment. The presence of a bend does not affect the elastic properties of the wire. Through heat treatment of that part, the superelastic properties of a portion of an archwire can also be modified. This is done by passing an electrical current through electrodes that are connected to only one wire segment.

In 1990, Miura et al showed that the teeth can be repositioned to the ideal post-treatment occlusion on a dental cast, bond brackets to the setup, push an A-Niti wire into the brackets, and then heat treat the wire so that it memorises its form with the desired positions. The wire then integrates all of what the finishing bends would otherwise be. At least in principle, this enables certain forms of treatment to be done with a single wire, gradually sweeping the teeth towards their predetermined location. For treatment with such wires, the ordinary edge wise, brackets would be appropriate, one does not even need to use pre-adjusted bracket. Therefore, when we use only one or at most two wires to finish a case with little to no wire bending at all, the days are not far away.

Of all the orthodontic wires, the surface roughness of Niti is the greatest d ue to its complicated manufacturing process and patented surface treatment. The method of vaccum induction melting or vaccum arch melting process is most often used to manufacture the nickel titanium alloy. In order to improve the homogeneity of the nickel titanium alloy, many remelts are often required. Powders are then produced from the alloy. The manufacturer utilises the method of hot isostatic processing to form the powders into wires. In the regions where the powders are not completely pressed together, voids occur. By the method of drawing or rolling, the wires attain their final form. The drawing or rolling process can leave scratch marks on the surface.

Nickel titanium alloy wires' desirable mechanical properties and their comparatively high cost have led many clinicians to recycle these wires. Many of the clinicians who recycled these wires stated that their main concern was a degradation in the mechanical properties of the wires. Recycling involves repeated exposure of the wire to mechanical stresses and elements of the oral environment for several weeks or months, as well as sterilisation between uses.

The cumulative effects may be subject to prolonged clinical use and sterilisation, degradation and cold working of the wire, resulting in changes in its properties. Medical recycling increases the loading and unloading forces associated with these wires and thus decreases the superelasticity of these wires.

1) Niti is the perfect wire for initial levelling and aligning due to its superior spring back, superelasticity, shape memory and its ability to generate light force for a longer length. Rectangular Niti enables the bracket slot to be fully engaged and gives better torque control in the initial treatment process. Niti's reverse curve, also known as Niti's rocking chair, helps to open the bite and helps to close the bite with levelling and aligning when positioned upside down.

(2) Titanium alloys represent a major improvement over currently available tooth separation products, in particular for adult patients or teenagers with close contact and large contact amalgam filling. Distortion is not a concern as it can be with tempered stainless steel or elasomerics. The breakage problems associated with elastomeric modules are resolved. With Niti springs, reuse is also possible after autoclaving.

3) A Niti palatal expander that is used for transverse maxilla expansion has recently been developed. It is a palatal expander activated by temperature with the ability to create continuous light pressure on the mid palatal suture while uprighting, rotating and distalising the first maxillary molars at the same time. A result of Niti's shape memory and transition temperature effects is the mode of action of the appliance. The Niti expender has a temperature of 940F for transition. It becomes flexible when it is chilled before insertion and can easily be bent to allow positioning. As the mouth begins to warm the appliance, the metal stiffens, shape memory is restored and the expander starts to exert a light, continuous force on the teeth and the midpalatal suture.

4) Nickel - titanium, in the form of coil springs, is also available. Manufactured by ORMCO, these Niti coil springs significantly increase performance in both space closing and space opening. The Niti coil springs are also used for molar distalization.

NiTi alloy wires trade names produced by several firms.

1. Elastinol – Masal orthodontics
2. Bioforce sentalloy – GAC International
3. Nitanium – Ortho organizers
4. Neosentalloy – GAC International
5. BMA arch wire – maseal orthodontics
6. Titanal XR – Lancer orthodontics
7. Rematitan – Dentaurum
8. Nitinol SE – Unitek
9. Nitinol XL – Unitek
10. Turbo – Ormco
11. Orthonol – Rocky Mountain
12. Marsenol – Glenroe Technologies
13. Reflex – T.P. Orthodontics
14. Senstinol – Gac international
15. Align – A company
16. Force I – American orthodontics.

Titanal XR is a titanium nickel wire that can be bent or contoured and won't creep back.

The BMA or Bendible masel alloy is designed to prevent straightening of cinched ends and to accommodate elastic hooks, teardrops, bayonet bends and stops, thus removing the need for auxiliaries.

The first braided Niti wire developed by ORMCO is TURBO wire. In even the most severely malposed situations, it enables the complete engagement of the bracket slot and at the same time provides low continuous forces that reduce patient discomfort. Turbo wire becomes the wire of choice when, during the initial stages of levelling and aligning, immediate torque control is necessary.

Nitinol XL Nickel titanium arch wires also have much lighter continuous forces than those usually associated with super elastic wires with the same cross-section. This body temperature triggered wire provides easier engagement than other round wires, in addition to improved versatility.

The copper Niti wire introduced by Ormco is the newest of all Niti wires which is the next generation of both super elastic and form memory wires. This groundbreaking new alloy, set at four transformation temperatures for four different levels of force, allows the clinician to reliably have the optimum forces for tooth movement than ever before. It is possible to create correct transformation temperature characteristics during the development process with the alloy copper element matter.

This built-in precision, like no other force delivery system currently available, is designed to put the clinician in charge, especially during the early stages of treatment.

Stress induced martensite is responsible for Niti alloys' super elastic properties. Martensite conversion is also temperature-dependent, however. One of the most significant indicators is the austenitic finish temperature. The working temperature of the orthodontic appliances should be greater than the austenitic finish temperature to leverage super elasticity to its fullest potential.

It is the difference between the temperature of the austenitic finish and the temperature of the mouth that determines the force produced by Niti alloys. By influencing the alloy's structure, thermomechanical treatment and manufacturing processes, this temperature can be regulated over a wide range. The development of this new quaternary alloy consisting of nickel, titanium, copper and chromium has led to the understanding of the factors that can affect the thermomechanical characteristics of Niti alloys.

Depending on Af temperature, copper NiTi can be classified as

Type I – Af -15 deg C: - not used for clinical applications due to its high force level.

Type II – Af – 27 deg C: -This generates heavy force than type III, IV wires and is best used in

(1) Patients with average or high pain threshold.

(2) Patients with normal periodontal health

(3) Patients in whom rapid tooth movement is required.

Type III- Af – 35 deg C: -This generates mid-range of forces and best used in
1) Periodontally compromised patients
2) Patients with low to normal pain threshold
3) When relatively low forces are requested.

Type IV- Af – 40 deg C: -This generates tooth-moving forces when mouth temperature exceeds 40 deg C. These wires are best used in
(1) Patients who are sensitive to pain
(2) Periodontally compromised patients.

TITANIUM – TITANIUM MOLYBDENUM ALLOY OR T.M.A

•- Titanium is among one of the new alloys to be introduced to the orthodontic profession. Titanium has been used a structural metal since 1952, and its possible use in orthodontics has been suggested periodically. The lack of success of such an application until now can be explained by the springback characteristics and chronologic development of titanium metallurgy. To compete with stainless steel, a wire must possess at least comparable formability and springback, which is proportional to the ratio of yield strength to modulus of elasticity (YE/E). This ratio for typical stainless steel orthodontic wire is approximately 1.1 x 10-2 as it is for some of the gold based and cobalt – chromium – nickel alloys. The early industrial applications of titanium employed commercially pure material i.e., 99.2% Titanium.

At temperatures below 16250F, this metal has a hexagonal close packed (HCP) crystal form, with room temperature modulus and yield strength values of 15.5 x 106 psi, and 55 x 103 psi respectively. The ratio of these values is 0.35 x 10-2 which would imply that one third the maximum elastic deflection of a comparable stainless steel appliance. The second phase of titanium, chronology saw the development of titanium alloys, but still based on hexagonal close packed structure. This commercial alloy has a yield strength to modulus of elasticity ratio of 0.87 x 10-2, still below stainless steel. In the 1960's an entirely different "high temperature" form of titanium alloy became available. At temperature above 16250F pure titanium rearranges into a body centered cubic lattice (B.C.C.), referred to as 'Beta' phase. A titanium-based alloy can retain its beta structure even when cooled to room temperature with the addition of elements such as molybdenum or columbium. Titaniums are referred to as beta stabilised alloys. A special set of properties are imparted by the alloying and body-centered cubic structure.

Goldberg and Burstone demonstrated that an orthodontic wire with an elasticity modulus of 9.4 x 106 psi and a yield strength of 17 x 104 psi can be produced with the proper processing of 11 percent molybdenum, 6 percent zirconium and 4 percent tin beta titanium alloy. For stainless steel, the corresponding YS/E ratio of 1.8 x 10 is superior to 1.1 x 10-2.

Beta-titanium is a modern orthodontic alloy with unique properties and an exceptional combination of properties that can be deflected approximately twice as far as stainless steel wire without permanent deformation. The force value is less than half that of stainless steel. These properties make it possible to use larger rectangular wires, while preserving or decreasing the load/deflection rate, for earlier or more full torque control. Its excellent elastic range and resilience are tantamount to increased activation efficiency. The expanded plastic range from T.M.A. makes it highly formable, easily bent for loops or bends that compensate. Wires may be directly welded to simplify the positioning of stops, intermaxillary hooks, and finger spring active auxiliaries.

Beta-titaniums balance of physical properties also makes it an excellent choice for utility arches. Its excellent formability makes it reasonably easy to produce utility arches.

For three key factors, T.M.A tends to be well-suited as a utility arch.

1. It is highly formable and is easy to make utility arches.

2. With its enhanced resilience, all that is needed to achieve vertical corrections is a single activation.

3. The incisor torque control can be obtained by its reduced load/deflection rate while remaining within accepted force ranges.

The preformed tear drop looped T.M.A. arch wire offers double the working range and needs less retraction activations than stainless steel. The moderate forces of T.M.A. generate less patient discomfort and improve patient satisfaction. With decreased chair time, retraction can be done more effectively. For 1 mm activation, a stainless steel teat drop loop creates a force of 728 gm and a T.M.A. tear drop loop generates a force of 367 gms for 1 mm activation.

A low friction T.M.A. with a significantly reduced friction coefficient for superior sliding mechanics has been introduced by Ormco. The T.M.A. surface friction is decreased by an average of 54 percent through a special ion beam implantation. Minimum wire to bracket friction are your targets in sliding mechanics, and if you understand the advantages of T.M.A., your wire of choice should be low friction T.M.A.

Ormco has also introduced a low rectangular T.M.A. friction with a reverse speed curve that is suitable for opening bites, arch levelling, closure of space and early manipulation of three dimensions and torque control

Beta-titanium, with its increased springback, decreased force magnitudes, good ductility and weldability, not only provides an improvement in the properties of currently designed orthodontic appliances, but its excellent balance of properties should allow the design of future appliances that produce superior force systems with simplified configuration.

Cobalt Chromium

Chrome cobalt alloy is a cobalt base alloy containing 40% cobalt, 20% chromium, 15% Nickel, 7% Molybdenum, 2% manganese, 0.15% Carbon, 0.4% Berryllium and 15% Iron.

Initially it was manufactured for watch springs by Elgin watch company, hence the name Elgiloy. It is marketed as Eligiloy, azurloy, Multiphase, Ramaloy etc.
Types of chrome cobalt alloy wires:

1. **Blue Elgiloy** - With fingers and pliers, it can be easily bent. The thermal treatment of blue elgiloy increases its deformation resistance.
2. **Yellow Elgiloy** - It is relatively ductile and more elastic than blue Elgiloy. By heat treatment, further improvements in its resilience and spring performance can be achieved.
3. **Green Elgiloy** - more durable than yellow elgiloy, and can be moulded with pliers before heat treatment.
4. **Red Elgiloy** - The most robust of elgiloy wires with high spring characteristics, withstands only slight work hardening. Heat treatment renders it highly resilient.

All changes should be made before precipitation hardening process because elgiloy wire fractures easily after heat treatment.

For all non-heat treated cobalt chromium wires, smaller springback is required with the exception of red elgiloy.

Heat treatment:

In a dental furnace, the ideal temperature for heat treatment is 9000F or 4820C for 7.12 min. This contributes to alloy precipitation hardening that increases the wire's resistance to deformation.

With a temperature indication paste, electrical heat treatment using a heat treatment unit may also be used.

In localised areas where stresses can be concentrated, heat treatment increases the flexural yield strength, elasticity modulus, and decreases corrosion failure.

Pre-heat treated wires will be soft and easy to manipulate, making it easier for the clinician to conveniently position precise bends, the same wire will obtain improved spring back properties after heat treatment, and will be beneficial in clinical applications.

Compared to stainless steel, the downside of this wire is the propensity to harden at the point where two segments are welded or soldered, and the greater degree of work hardening. As high temperatures (above 12000F) cause annealing with the resulting loss in yield and tensile strengths, soldering should be performed carefully. Low solder fusion is recommended.

Elgiloy's advantages over stainless steel wires include greater fatigue and distortion resistance and longer function as a resilient spring. The high modulus of elasticity of elgiloy wire means that for equal amount of activations, these wires produce twice the forces of Beta Titanium wires and four times the force or nitinol wires.

Azurloy is a heat treatable alloy with excellent formability in its non-heat treated form. Applications that take advantage of this formability followed by heat treatment in order to increase the spring rate may include:

1. Multiloop systems.
2. Utility arches
3. Overlay intrusion or base arches.

Tooth Coloured Orthodontic Wires:

New orthodontic materials have been adapted from those used in aerospace technology in recent years. The high-performance aircraft of the 1970s and 1980s were built on titanium, but composite plastics are used for the purpose in the current century, and there is every reason to expect that orthodontic wires of this kind will shift into potential clinical use. The fact that one non-metallic wire has already been offered for clinical use is interesting. OPTIFLEX is a modern orthodontic arch wire designed by Dr. Talass and manufactured by ORMCO. With a highly aesthetic look, it has unique mechanical properties.

It consists of three layers made of transparent optical fibre.

1. A core of silicon dioxide which provides the force for moving teeth.
2. A middle layer of silicon resin protects the core from moisture and adds strength.
3. A stain resistant outer layer of nylon that prevents wire damage and improves its strength further.

Optiflex has five benefits that make it a special archwire in terms of both aesthetics and mechanics.

1. Optiflex is probably the most aesthetic orthodontic arch wire.
2. Optiflex is totally resistant to stains. Even after many weeks in your mouth, the arch wire will not smear or lose its clear look. In elastomeric ligatures and chains, the yellowish stain usually seen will never be present in optiflex.
3. Beyond aesthetics, optiflex is very effective in shifting teeth using light continuous forces. The force applied with the optiflex is around half of the force applied with a similar size archwire.
4. Optiflex is very flexible. It has an incredibly broad spectrum of action. If indicated, it can be tied to severely malaligned teeth with elastomeric ligatures without the fear of breaking the archwire.
5. Optiflex can be used with any bracket device owing to its superior mechanical properties.

Some care should be taken when using Optiflex.

1) Optiflex archwires must be tied to the braces with elastomeric ligatures. Since they fracture the glass core, metal ligation can never be used.
2) Sharp bends, similar to those you put with in metal archwire, should never be tried. The core would be instantly broken by these bends.
3) To push the wire into the bracket slot, avoid using instruments with sharp points, such as scalers, etc. Instead, use gentle force to insert the archwire into the slot with your finger.
4) Use of the (501) mini distal end cutter is recommended to cut the end of the arch wire distal to the molar. This cutter is specially built to cut all three optiflex layers in the correct way.
5) Report the nature of optiflex and its structure to your patients. Make sure they realise that the archwire can be impaired by a harsh diet and inturn prolong the progress of treatment.
6) Do not cinch back optiflex. Since friction between elastomeric ligatures and the outer surface of the arch wire will prevent unnecessary slipping of the arch wire, you really don't need a cinch back.

The following clinical applications are available at Optiflex:

1) It is used in adult patients who, for reasons linked to personal concerns or professional considerations, prefer their braces not to be very visible.
2) In cases with moderate levels of crowding in one or both arches, it may be used as an initial wire.
3) It should be used in cases where no bicuspid extraction is needed to be handled. The perfect arch wire for major cuspid retraction is not Optiflex. Due to its limited ability to regulate the distal tipping and labio lingual rotation of the retracted cuspids, retracting cuspids in the extraction cases with optiflex has been disappointing.
4) In cases involving orthognathic intervention as part of treatment, Optiflex may be used in the presurgical stage.

Optiflex archwires combine to create the pinnacle in labial appliance aesthetics with transparent braces. Optiflex is available in ten 6 inch straight lengths of 0.017" and 0.021".

Marsenol is a nickel titanium -tooth colored wire manufactured by Glenroe Technologies. It is nickel titanium coated by E.T.E. (Elastomeric Poly Tetra Flourethylene emulsion). All the same working characteristics of an uncoated superelastic nickel titanium wire are demonstrated by Marsenol. The coating adheres and remains flexible to the wire. The coating adheres and remains flexible to the wire. Over long periods of activation, the wire provides continuous force and is fracture resistant.

Lee White wire, manufactured by Lee Pharmaceutical, is a resilient stainless steel or titanium nickel arch wire, coated with a tooth-colored epoxy coating suitable for use with ceramic and plastic brackets. It is completely opaque and does not chip, peel, dye or decolor.

Clinical Selection of Orthodontic Wires

When stainless steel was the predominant material used for fabrication of orthodontic wires, control of forces generated by the wires was limited to the use of either varying cross – sections of complicated loop configuration to affect the stiffness characteristics of the appliances. This treatment strategy has been aptly termed "Variable cross sectional" approach to orthodontic treatment.

Further development of materials in orthodontics was influenced by the orthodontist demands to have appliance systems that were relatively resistant to permanent deformation, thus providing a large range of activation. This blend of characteristics required the use of materials that had high yield strength to elastic modulus ratio, as exemplified by Niti and T.M.A. with the introduction of those materials to orthodontics, a new clinical strategy evolved, namely, the "variable modulus" concept (Burstone). This treatment approach essentially effects the orthodontists ability to control stresses imposed upon the dentition from the onset of treatment by simply using rectangular wires fabricated from materials with a gradation of moduli running from low to high. Hence during the initial stages of tooth movement, a low modulus rectangular cross section wire, rather than round may be used, thus offering three-dimensional control of tooth movement and the opportunity to apply low stresses to the dentition.

Now the "variable transformation temperature, orthodontics" represents another major advance from "variable modulus mechanics". Copper Niti from Ormco is a good example of this concept.

Orthodontic arch wire fabrication from this alloy have been developed for specific clinical situations and are classified as type I, II, III and IV with an austenitic finish temperature of 150C, 350C and 400C respectively. These four alloys form the basis for "variable transformation temperature orthodontics".

Clinical indications for these different transformation temperature wires are:

Type I: (150C)
It has not been used frequently in clinical situations because it generates very heavy forces and clinical indications are few.

Type II: (270C)
This wire generates higher forces when compared to type III and IV. It is best used:

1. In Patients who have an average or higher pain threshold
2. In patients who have normal periodontal health.
3. In patients who have normal periodontal health
4. In patients where rapid tooth movement is required and the force system generated by the orthodontic arch wire is constant.

Type III:
This wire generates forces in mid-range, and is useful:

1. In patients who have low to normal pain threshold.
2. In patients where periodontium is normal to slightly compromised.
3. When relatively low forces are desired.

Type IV: (400C)
These wires generated tooth driving forces only when the mouth temperature exceed 400C. These forces are intermittent in nature. The indication for use of this alloy include:

1. Patients who are sensitive to pain.
2. Patients who have compromised periodontal conditions.
3. Where tooth movement is deliberately slowed down, that is, when the patient may not be able to visit the orthodontist regularly, or the co-operation is very poor.

Given the recent proliferation of wire alloy choices and sizes, the diverse treatment philosophies, and the empirical nature of orthodontics, it is most difficult to selects the optimum wire for a particular clinical situation:

You should ask some questions to yourself.

1) How much control is required? Is it an important treatment consideration to fill the arch slot, at this point in treatment, to gain or maintain torque control? A decision on control can limit wire selection to round or rectangular wires and to a narrow range of sizes.
2) What are the load / deflection requirements? Do the prevailing conditions call for a wire with high deflection or one which resists deformation? A decision on the load / deflection rate requirement can further narrow the wire choices.
3) Elastic or plastic working range? Do you wish to place bends in the wire? If the decision is to make a bend in the wire or to place loops etc. you will automatically limit the choices to those which exhibit a good plastic range like stainless steel T.M.A.

4) Wire cost vs value "If the three previous decisions have indicated a possible wire choice that includes one of the more expensive alloys will that wire return a value commensurate with its cost? Some additional question must then be asked.

a. Will the wire remain in place long enough to bring about the desired change?

b. Is the desired correction localized or to be accomplished for several teeth, or will adding wire length with an adjustment loop in a stainless steel wire or using a multistranded stainless steel wire accomplish the same result as with a more expensive alloy with a high deflection.

`Niti wire with its superior spring back and super elastic properties is the ideal arch wire for initial aligning and leveling. If simultaneous torque control is required a rectangular braided Niti wire can be used. A less expensive alternative for this wire is the multistranded stainless steel wires. Optiflex can be used with ceramic brackets for initial leveling and aligning.

Space closure using sliding mechanics, requires a wire which produces less friction between the bracket. Arch wire and bracket friction slows the movement of teeth along the wire, also rectangular wire produces more friction can smaller wires. Cobalt chromium, •-Titanium and Nickel titanium produce more friction than stainless steel wires due to the surface topography of the wires. An 016″ stainless steel wire lowest friction can be distorted by elastic force, causing excessive tipping A .016″ x .0022″ stainless steel wire in .018" slot and .017" x .025" stainless steel wire in 22 slot is ideal for sliding mechanics.

Stainless steel looped arch wire for space closure with frictionless arch wire has a limited activation range. The moment of force ratio is influenced by amount of preactivation. Higher preactivation is possible if a material with lower modulus of elasticity and relatively high yield strength can be substituted for stainless steel. The use of T.M.A with a modulus of elasticity of approximately 2/5th of stainless steel allows the use of large preactivation angles. The T.M.A generates low forces and has greater range of action when compared to stainless steel.

Because of its rigidity stainless steel is the ideal archwire for finishing and detailing. If some inter arch settling is required a braided stainless steel wire can be used.

As you can see there is no easy way to recommend an ideal arch wire sequence without clear understanding of all the variables. Yet one thing is clear, with a good understanding of the relationships of arch wires to the appliance along with an understanding of the working ranges and the material values of the available wires, you will be better able to choose the right wire for any phase of treatment.

Conclusion

A plethora of modern wire alloys have been incorporated into orthodontics in the last few decades. These wires exhibit a wide variety of mechanical properties and have contributed to the versatility of orthodontic therapy. Appropriate use of all the available wire types can enhance patient comfort, reduce chair side time and the length of treatment. It helps the clinician to recover the smiles of millions quicker.

Using the desirable qualities of a particular form of wire that is specifically selected to meet the requirements of the present clinical situation can be advantageous. The orthodontist has been benefited by superelasticity and shape memory wires to bring in more efficient tooth movement. Esthetic wires and coloured wires are being used in today's advertisements to bring about greater patient acceptance. With a logical series of arch wires, treatment has become easier and is carried out.

At each point in time, the clinician must weigh the requirements of the particular case and make the choice of the arch wire based on practice, experience and intuition. Hopefully, in that decision process, the information given in this chapter will support and provide you with a better understanding of meeting your wire selection needs.

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