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Wires in Orthodontics - A Short Review

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Abstract
Aim- The aim of this review is to discuss about the orthodontic wires and to discuss in detail about their mechanical and physical properties.
Objective- To list out the different types of orthodontic wires and their mechanical properties and clinical implications.
Background- Orthodontic wires are components of fixed appliances used to carry out the necessary tooth movements as part of orthodontic treatment. A variety of materials like metals, alloys, polymers and composites are used to produce orthodontic wires. The properties of orthodontic wires are evaluated by various laboratory tests like tensile, torsional, and bending tests. However, oral conditions may influence their behaviour and it is important for the clinician to understand the properties of orthodontic wires as well as their clinical implications to turn out optimal results. This article reviews different materials used for manufacturing orthodontic wires and their properties along with clinical implications.
Reason- This review is mainly done for better assessment and benefits of various orthodontic wires.

INTRODUCTION-

Material sciences have made a rapid progress in the recent years. Up till the 1930s, gold was the only orthodontic wire available. Austetenitic stainless steel, with its greater strength, higher modulus of elasticity, good resistance to corrosion, and moderate cost was introduced to the orthodontists in 1929 and within a short span gained popularity over the gold alloy. Since then orthodontics is come a long way. Several alloys like Cobalt – Chromium, Nickel –Titanium, Beta – Titanium, stainless steel wires and multistranded wire with desirable properties have been adopted in orthodontics. In this vast ocean of different orthodontic alloys available, it becomes very difficult for an orthodontist to select a proper wire with the required properties.

For the correct use of orthodontic appliance one must have a thorough knowledge of the materials from which these appliances are made. The mechanical and physical properties of these materials change greatly under varying conditions of manipulation.

Therefore the clinician must be thoroughly conversant with the various mechanical properties of the wires and their clinical applications. The objective of the article is to review the related literature available in order to describe the mechanical properties and their clinical applications of Stainless steel, Cobalt-Chromium, Nickel-Titanium, Beta-Titanium and multistranded wires.

STAINLESS STEEL WIRES:

Stainless steel is the most popular wire alloy used in orthodontics because of an outstanding combination of mechanical properties, corrosion resistance, and cost. The wires used in orthodontics are generally American Iron and Steel Institute types 302 and 304 austenitic stainless steels.These alloys are known as “18-8” Stainless steels, so designated because of the percentages of chromium and nickel in the alloy (1,2,3). The chromium in the stainless steel forms a thin, adherent passivating oxide layer that provides corrosion resistance by blocking the diffusion of oxygen to the underlying bulk of the alloy. The chromium, carbon, and nickel atoms are incorporated into the solid solution formed by the iron atoms. The nickel atoms are not strongly bonded to form some intermetallic compound, so nickel alloy releases from the alloy surface, which may interfere with the biocompatibility of the alloy.

Research has shown that the modulus of elasticity for stainless steel orthodontic wires ranges from about 160 to 180 GPa. This value depends on the manufacturer and temper, and is indicative of difference in alloy compositions, wire drawing procedures and heat treatment conditions(4,5,6). The yield strength of the wire ranges from about 1100 to 15000 MPa. The yield strength can be increased to about 1700 MPa after heat treatment.

The yield strength to modulus of elasticity ratio indicates a lower spring back of stainless steel as compared to the newer titanium based alloys. This suggests that stainless steel produces higher forces that dissipate over shorter periods therefore requires frequent activations (7). Heat treatment of the wire causes decrease in residual stress and increase in resilience.

Heat treatment of stainless steel wires at above 650 0 C must be avoided because rapid recrystalization of the wrought structure takes place, with deleterious effects on the wire properties. Heating stainless steel to a temperature between 400 to 900 0 C causes reaction of the Chromium and carbon to form chromium carbide precipitate at the grain boundaries. Loss of chromium from the iron solid solution matrix results in depletion of chromium content which in turn causes the stainless steel alloy to become susceptible to inter-granular Corrosion.

COBALT- CHROMIUM WIRES:

These wires are very similar to stainless steel wires in appearance, mechanical properties, and joining characteristics, but have a much different composition and considerably greater heat response. They are also known as Elgiloy which was developed during 1950's by the Elgiloy Corporation. The Elgioly wires are available in four tempers depending on there resilience and are colour coded by the manufacturer; Soft { blue}, Ductile { yellow }, Semi-resilient { green } , Resilient { red }.

The advantage of these wires over stainless steel wires includes the greater resistance to fatigue and distortion. In most respect the mechanical properties are similar to that of stainless steel so the stainless steel wires can be used instead of cobalt chromium wires. They have a high modulus of elasticity suggesting that they deliver twice the force of Beta Titanium and four times the force of Nickel Titanium archwires.

The elastic modulus of Elgioly blue ranges from about 160-190 GPa when under tension, while after heat treatment it increases to range from about 180-210 GPa.Similarly the yield strength ranges from 830-1,000 MPa under tension, and 1.100-1,400 MPa after heat treatment.

The clinical use of Elgioly blue is fabrication of fixed lingual quad-helix appliance, which produces slow maxillary expansion in the treatment of maxillary constriction.

NICKEL-TITANIUM WIRES:

Nickel-Titanium alloy marketed as Ninitol by the Unitek Corporation is useful in clinical orthodontics because of its exceptional springiness. The generic name Ninitol which is applicable to this group of nickel titanium alloy originates from Ni-nickel, Ti-titanium, NOL-Naval Ordnance Laboratory. The pioneer for the development of these wires for orthodontics was Andreasen. Two new super-elastic nickel titanium wires were also introduced namely; Chinese NiTi and Japanese NiTi(8,9).

Shape memory is one of the remarkable properties of the NiTi alloys. There are two major NiTi phases in the nickel-titanium wires. The austenitic phase has the ordered body centered cubic structure that occurs at high temperatures and low stresses. The martensitic phase has a distorted monoclinic, triclinic or hexagonal structure that forms at low temperatures and high stresses. The shape memory characteristics of the nickel titanium alloys are associated with a reversible transformation between the austenitic and martensitic phases. The martensitic phase forms from the austenitic phase over a certain transformation temperature range or when the stress is increased above some appropriate levels. The difference in the temperature ranges for the forward transformation from the martensitic phase to the austenitic phase, and for the reverse transformation, is termed Hysteresis. In order for a nickel titanium archwire to possess shape memory, the transformation of the phases must be completed at the temperature of the oral environment (10).

Nickel-titanium archwires with Ion-implanted surfaces have been introduced to reduce the archwirebracket friction. As provided for orthodontic use, Ninitol is exceptionally springy and quite strong but have poor formability. The advantages of these wires can be enumerated as fewer archwires are required to achieve the desired changes, less chair side time, and less patient discomfort. Their poor formability makes them best suited for the pre-adjusted appliance. Placing bends in the wire adversely affects the spring back property of the wire. Clinical disadvantage of these alloys are that permanent bends cannot readily be placed in the wires and that the wires cannot be soldered (11).

BETA-TITANIUM WIRES:

A beta-titanium orthodontic alloy, also called as TMA, which represents" Titanium-molybdenum alloy" is marketed by the Ormco Corporation. The wire has a potential for delivering lower biomechanical forces compared to stainless steel and cobalt-chromium-nickel alloy to (12).

Beta titanium alloy wires have excellent formability due to there body centered cubic structure. The TMA alloy has the elastic force delivery ranging from about 62-69 GPa, which is less than that of stainless steel wires. Another clinical advantage of the alloy is that it possesses true weldablity. Welded joints that are fabricated from stainless steel and cobalt-chromium-nickel alloys must be built up with the use of solders to maintain adequate strength. The excellent corrosion resistance of the wire is due to the presence of a thin, adherent, passivating surface layer of Titanium oxide.

Following are some properties which should be considered by the orthodontists before the clinical use of the wires; Heat treatment by the clinician is not recommended. Solution heat treatment between 700-730 degree C, followed by water quenching, and then aging at 480 degree C results in the precipitation of alpha titanium phase. The beta titanium wires are generally the most expensive of the orthodontic wire alloys, but there advantages like excellent formability, intermediate force delivery, and weldeblity when fabrication of more complex appliances makes them to be used widely in orthodontics. It has been shown that TMA wires have high surface roughness. This surface roughness contributes to the high values of arch wire-bracket sliding friction, along with localized sites of cold welding or adherence of the wire to the bracket slots. However recently developed N+ Ion-implanted TMA wires that have substantially reduced arch wire-bracket friction are available from Ormco or Sybron.

MULTISTRANDED WIRES:

Multistranded wires are made of a varying number of stainless steel wire strands coaxially placed or coiled around each other in different configurations. The important characteristics of these wires are development of low forces, low stiffness and a resilience (13,14) and these wires are inexpensive than titanium alloys (15). They develop higher friction at bracket-wire interface compared to NiTi wires and single-stranded stainless steel wires (16).

CONCLUSION:

Metals, alloys, polymers and composites are the materials used for producing orthodontic wires. Each type of material has its advantages over the other. However, the practitioner should have a thorough knowledge of the mechanical and physical properties of wires to determine their clinical behaviour and to achieve a satisfactory and predictable outcome. Fiber reinforced composites are regarded as the cutting edge of orthodontic materials due to their excellent esthetics, strength and the ability to customize their properties to the needs of the practitioners.

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