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Orthodontic Wires and Their Recent Advances - A Compilation

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Abstract: ***Orthodontic wires are used to carry out the necessary tooth movements as part of orthodontic treatment. A variety of materials are used to produce orthodontic wires. The archwire has been an integral part of the orthodontic appliance, and the high esthetic demand by the patient, along with the introduction of composite and ceramic brackets initiated research for esthetic archwires to go with these brackets. Esthetic archwires available are composite, optiflex and coated archwires. Appropriate use of all the available wire types may enhance patient comfort and reduce chairside time as well as the duration of treatment. The individual clinician must always know and understand the needs and options at every stage of therapy. This article reviews different materials used for manufacturing orthodontic wires and their recent advances available in the market.***

1. Introduction

Orthodontic treatment aims to move the teeth to a targeted position by the application of forces to them. An ideal force is the one that produces rapid tooth movement without damage to the teeth or periodontal tissues. Different biological and other factors like the type of movement and tooth size are the important factors to be considered during application of the force. Application of lower forces produces the optimal results and application of excessive force exceeding vascular blood pressure reduces cellular activity in periodontal tissues and slows down or stops tooth movement at least for a period of time. During orthodontic treatment, orthodontic wires are used as fixed appliances to apply forces to the teeth. They release the energy stored upon its placement by applying forces and torque to the teeth through the appliances placed on them . Therefore, an orthodontist should have adequate knowledge of the biomechanical behaviour and clinical applications of orthodontic wires to design the treatment plan. Earlier gold was most commonly used as orthodontic wire. These gold wires were expensive. After gold wires, stainless steel wires were commonly used since they are inexpensive and had improved mechanical properties. Cobalt-chromium, nickel-titanium, betatitanium and multi stranded stainless steel wires have been developed with extensive range of properties due to the advancements in the recent technology. The archwire has been an integral part of the orthodontic appliance and the high esthetic demand by the patient, along with the introduction of composite and ceramic brackets initiated research for esthetic archwires to go with these brackets. A promising approach toward achieving an esthetic archwire with excellent overall properties involves the use of composites, which can be composed of ceramic fibers that are embedded in a linear or cross-linked polymeric matrix. When compared with nickel titanium alloy, the resilience and spring back are comparable. Moreover, when failure finally does occur, the wire loses its stiffness, but it remains intact. The introduction of newer archwire materials has necessitated alterations in appliance design, construction and clinical manipulation. Hence, it is imperative on the part of the clinician, to make an informed decision in wire selection & manipulation based on the wire characteristics. In view of the aforesaid, the following endeavor is to compile information on orthodontic archwires of the present era of fiber reinforced composites.

Given below is a compilation of all the wires used in orthodontics followed by new recent advances in the same:-

1) Stainless Steel Wires

Stainless steel is the most commonly used wire in orthodontics also known as “18-8” Stainless steels, because of the percentages of chromium and nickel in the alloy. 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. 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. 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.

2) Nickel Titanium Wires

Nickel-Titanium alloy 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, Tititanium, 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. 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. Nickel-titanium archwires with Ion-implanted surfaces have been introduced to reduce the archwire bracket 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.

3) Cobalt Chromium Wires

Cobalt Chromium 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 Elgiloy 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.

4) Beta- Titanium Wires

A beta-titanium orthodontic alloy, also called as TMA, which represents Titanium-molybdenum alloy. The wire has a potential for delivering lower biomechanical forces compared to stainless steel and cobalt-chromium-nickel alloy to. Beta titanium alloy wires have excellent formability due to their 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 weldability. 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 weldability 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.

5) 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 and these wires are inexpensive than titanium alloys. They develop higher friction at bracket-wire interface compared to NiTi wires and single-stranded stainless steel wires.

6) Teflon Coated Stainless Steel Wires

Teflon is coated on stainless steel wire by an atomic process that forms a layer of about 20-25ìm thickness on the wire that imparts to the wire a hue which is similar to that of natural teeth . Teflon coating protects the underlying wire from the corrosion process. However, corrosion of the underlying wire is likely to take place if it is used for longer period in the oral cavity since this coating is subject to flaws that may occur during clinical use.

7) Lee White Wires

Lee white wires were manufactured by LEE pharmaceuticals. It is a resistant stainless steel or Nickel titanium arch wire bonded to a tooth colored epoxy coating. The epoxy coating which is completely opaque does not chip, peel, scratch or discolour.

8) Bioforce Wires

BioForce is aesthetic and is part of the first and only family of biologically correct archwires. "Bioforcearchwires' were introduced by GAC. The Ni-Ti Bioforce wires apply low, gentle forces to the anterior teeth and increasingly stronger forces across the posterior teeth until plateauing at the molars. The level of force applied is graded throughout the arch length according to tooth size.

9) Marsenol

Marsenol is a tooth coloured elastomeric poly tetra fluroethyl emulsion (ETE) coated nickel titanium wire. The working characteristics of these wire are similar to an uncoated super elastic Nickel titanium wire.

10) Optiflex

Optiflex is a most aesthetic orthodontic arch wire designed by Dr. Talass and manufactured by ORMCO. It has highly aesthetic appearance as it is made of clear optical fiber, which comprises of 3 layers. Inner core is silicon dioxide core, middle layer is made with silicon resin and the outer layer is nylon layer. Core provides the force for moving tooth, middle layer protects the core from moisture and also provides strength and the outer layer prevents damage to the wire and also further increases the strength. Optiflex is very flexible and is effective in moving teeth using light continuous force.

It is made of clear optical fiber comprises of three layers:

a) Silicon Dioxide Core: Provides the force for moving teeth
b) Silicon Resin Cladding: Protects core from moisture and adds strength and
c) Nylon Coating: It is stain resistant and prevents damage to the wire and further increases strength.

11) Fibre Reinforced Composite Wires

Fiber-reinforced polymer composites have been used as arch wires for more than a decade. These materials have got many advantages over the conventional metallic alloys as they are highly esthetic, biocompatible. Other advantages include hydrolytic stability, less water sorption, stiffness is same as metallic wires, post processing formability and sliding mechanics are good. However, there is a chance of wearing of these arch wires at the interface, chances of leaching of glass fibers within the oral cavity.

Structure: Three configurations of FRC are available:

a) Rope type- 2 mm wide, round strips
b) Can be wrapped around corners of an arch and thus is useful in cuspid-to-cuspid retainers.
c) Unidirectional parallel configurations have best mechanical properties for bending

Advantages:

- Esthetic as the connecting bar is clear or translucent.
- Biocompatible and less hypersensitivity reported as compared to stainless steel and other metals.
- High modulus of elasticity in flexure (70% greater than highly filled dental composite), six times greater yield strength and 2 times greater resilience.
- Option to join pieces together with an adhesive to make a string structural unit.
- Attachments can be added for inter-maxillary tooth movement without bands or brackets, making it simple to position hooks with ideal direction and point of force application respective to maxillary and mandibular center of resistance.
- Vertical elastics can be applied directly to FRC bars, either on full arches or on segments for closure of an open-bite.
- Intra-arch movements such as space closure, with bonded tubes on FRC bars, which can be positioned to increase the inter-bracket distance.
- Correction of poorly erupted second molars after completion of orthodontic therapy can be done by uprighting the tooth using full-arch FRC as an anchorage unit. Active force applied by straight wire segment, T-loop or wire with differential bend.
- Ease of modification as more layers can be added if greater rigidity required. Attachments can be repositioned, repaired or replaced any time.
- Passive applications such as bonded tooth-to-tooth retainer can be made with ideal esthetics as compared to metal wire bonded retainers.

Limitations

- FRC bars are strong and rigid in tension but less in bending mode and are weakest in shear and torsion.
- Unlike metals, they are not homogenous materials so shear loads need to be minimized.
- Sound bonding technique is required.

12) Epoxy Coated Wires

Epoxy coated archwire is tooth colored and has superior wear resistance and color stability of 6-8 weeks. It is available in nickel titanium and stainless steel in preformed arches of different sizes such as round 0.016" to 0.022" Niti, rectangular 0.018" x 0.024" to 0.021" x 0.027" NiTi and round 0.014" to 0.018, rectangular – 0.18" x 0.024" to 0.021" x 0.027" stainless steel. Epoxy coated archwires are available under the trade name of Filaflex (American Orthodontics), have high tensile stainless steel core and durable tooth coloured plastic coating. This is available in preformed round 0.018" arches. They are available under another brand name of Orthocosmetic Elastinol (Masel Orthodontics) which is esthetically coated high performance NiTi super elastic archwires and blends exceptionally well with ceramic or plastic brackets and doesn't stain or discolor plus they resist cracking or chipping.

13) Nitanium Tooth Toned Wire

It is a superelastic Ni-Ti wire with special plastic and friction reducing tooth colored coatings which blends with natural dentition, ceramic, plastic and composite brackets and maintains its original color. However, the coated white colored wires have routinely succumbed to forces of mastication and enzyme activity of oral cavity. On the other hand, the uncoated transparent wires have poor mechanical properties that they function merely as placebo. Esthetics is important to the orthodontist but function is paramount and anything less is unacceptable. It is marketed by Ortho Organizers and is available in round 0.014", 0.016", 0.018" and rectangular 0.016" x 0.022"sizes. These wires deliver gentle force.

14) Titanium Nobium Wires

It was introduced in early 1995 by Dr Rohit Sachdeva & Manufactured by Ormco.Ti- nb is soft and easy to form, yet it has the same working range of stainless steel. Its stiffness is 20% lower than TMA and 70% lower than stainless steel. Ti-nb wire have a larger plastic range, similar activation and deactivation curves and relatively low spring back. Its bending stiffness corresponding to 48% lower than that of stainless steel and a spring back 14% lower than that of stainless steel. We can easily make creative bends and avoid excessive force levels of a steel wire. The stiffness of ti-nb in torsion is only 36% of steel, yet the spring back of ti-nb in torsional mode is Slightly higher than stainless steel. This property makes it possible to utilize the ti-nb wire for even the major third order corrections.

15) Timolium Titanium Wires

Timolium Titanium Wire is manufactured by TP ORTHODONTICS. Timolium archwires combine the flexibility, continuous force and spring back of nickel titanium with the high stiffness and bendability of stainless steel wire. When compared to nickel titanium or beta titanium wire, Timolium outperforms in the following: More resistant to breakage, Smoother for reduced friction, Brightly polished and aesthetically pleasing. Timolium wire is excellent for all phases of treatment. During initial treatment it is excellent for space closure, tooth alignment, levelling and bite opening. During intermediate treatment, early torque control can begin because of the moderate forces that are delivered. In final treatment phase total control during detailing makes Timolium the wire of choice.

16) Supercable

In 1993, Hanson combined the mechanical advantages of multistranded cables with the material properties of superelastic wires to create a superelastic nickel titanium coaxial wire. This wire, called super cable, comprises seven individual strands that are Woven together in a long, gentle spiral to maximize flexibility and minimize force delivery. It has improved treatment efficiency, Simplified mechanotherapy, Elimination of archwire bending, Flexibility and ease of engagement regardless of crowding. It has no evidence of anchorage loss. It delivers a light, continuous level of force, preventing any adverse response of the supporting periodontium. There is minimal patient discomfort after initial archwire placement. Also, Supercables require less patient visits, due to longer archwire activation. Disadvantages include tendency of wire ends to fray if not cut with sharp instruments, tendency of archwires to break and unravel in extraction spaces, Inability to accommodate bends, steps, or helices, tendency of wire ends to migrate distally and occasionally irritate soft tissues as severely crowded or displaced teeth begin to align.

17) Combined Wires

Combined wires are the key to success in a multi attachment straight wire system .It has the ability to use light tipping movements in combination with rigid translation. It uses three specific combined wires for the technique

a) Dual Flex-l
b) Dual Flex-2
c) Dual Flex-3 (Lancer Orthodontics).

Dual Flex-1consists of a anterior section made of 0.016-inch round Titanal and a posterior section made of 0.016-inch round steel. The flexible front part easily aligns the anterior teeth and the rigid posterior part maintains the anchorage and molar control by means of the "V" bend, mesial to the molars. It is used at the beginning of treatment.

Dual Flex-2 consists of a flexible anterior segment composed of an 0.016 ´ 0.022-inch rectangular Titanal and a rigid posterior segment of round 0.018-inch steel.

Dual Flex-3consists of a flexible anterior part of an 0.017 ´ 0.025-inch Titanal rectangular wire and a posterior part of 0.018 square steel wire. The Dual Flex-2 and 3 wires establish anterior anchorage and control molar rotation during the closure of posterior spaces. They also initiate the anterior torque.

18) Australian Archwire

Claude Arthur j wilcock produced this wire for Dr. P.R.Begg. The unique characteristics of this wire are it is high tensile austenitic stainless steel. The wire is resistant to permanent deformation, maintaining its activation for maximum control of anchorage. All these properties make this wire very hard and brittle.

Properties of Wire- 1. The tensile strength of the P.S wire is 8-12% higher than of S.S so greater resistance to fracture. 2. The LDR was high by 10%for 0.016 ps wire and by 235% to 0.020premium wires indicates that when used for intrusion they deliver significant higher loads .3. High working range and good recovery patterns. 4. Frictional resistence of ps wires was lesser by 50% than S.S wires.

Grading and Colour Coding - Older Wires

a) **Regular Grade**- White Label
b) **Regular Plus**- Green Label
c) **Special Grade**- Black Label
d) **Special Plus**- Orange Label
e) **Extra Special Plus**- Blue Label

Newer Wilcock Wires-Newer grade of wires came to market with superior properties with advent in manufacturing process they are

- Premium – Purple
- Premium Plus – Gold
- Supreme - Beige

Premium Grade-They are more difficult to bend, occasional breakage to be expected. They are efficient to open the bite.

Premium Plus-The 0.014 premium plus wire is used in high angle cases to prevent undue molar extrusion and due to less diameter they donot produce much.

Supreme Grade- They are used to unravel crowding of anterior teeth. They have resistance and yeild diameter near to NI-TI wires and cost wise they are more economic. When used as MAA the lighter forces produced do not tax the anchorage.

a) Chinese NITI

In1985 Dr. Burstone C.J. reported of an alloy named the Chinese ni-ti developed by Dr. Tien Hua Chang. This alloy has unique characteristics and offers significant potential in the design of orthodontic appliances. It has a history of little work hardening in a parent phase .Because of this high range of action and spring back chineseni-ti is applied when large deflections are required. It has sprinback that is 4.4 times more compared to stainless steel and 1.6 times that of nitinol. Stiffness of this wire is 73%that of s.s and 36% that of nitinol. These wires are highly suitable if low stiffness is required and large deflections are needed.

b) Japanese NITI

In 1986 miuraf.etal reported Japanese NITI, developed by furukowa electric comp.ltd. japan.in 1978 It posses excellent spring back, shape memory, super elasticity. They delivered a constant force over an extended portion of deactivation range and less likely to undergo permanent deformation. It generates a physiological tooth movement because of relatively constant force delivered for a long period of time during the deactivation of the wire .This super elasticity can be produced by stress and not by temperature difference.

c) Organic Polymer Retainer Wire

Organic polymer retainer wire made from 1.6mm diameter round polytheline terephthalate. This material can be bent with a plier, but will return to its original shape if it is not heat–treated for a few seconds at temperature less than 230°C (melting point).

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