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Changing trends in orthodontic arch wire: A review

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***Abstract*---**Orthodontic wires are integral part of fixed mechanotherapy in orthodontics which are used to facilitate tooth movement. A wide range of materials available that are used to manufacture orthodontic archwires. Selection of suitable wire material increase patient comfort, efficiency of orthodontic mechanics and reduce chair side time. Nowadays esthetic wire materials are available that can be used in esthetically conscious patients. This article discusses the changing trend in wire materials.

***Keywords*---**orthodontic wires, fixed mechanotherapy.

Introduction

A successful orthodontic treatment affected by manual skills, treatment steps and also the knowledge of wire materials available which can be used for treatment mechanics.[1] Wires have important role in active phase of orthodontic treatment

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and also in retention phase after completion of treatment. Wires and auxiliaries manufactured from wire may be used for delivering orthodontic force to produce tooth displacements, they may prevent undesired displacement of teeth or they may transfer force from one area to other within the dentofacial complex.[2] Orthodontic wire is a device, conforming to the individual dental arch and is used as anchorage for aligning irregularly placed teeth.[1]

Orthodontic wires are manufactured from an ingot having suitable alloy composition. The ingot undergoes a sequence of mechanical reduction procedures to produce sufficiently small cross section for wire. Heat treatments are needed during manufacturing to remove the work hardening stresses which are induced during series of mechanical reduction of ingot. Manufacturing of titanium orthodontic wires needed special conditions as these alloys are more reactive in air[3]. Upto the 1920s, the only orthodontic wires available were made of gold. Austenitic steel, with its greater strength, higher Modulus of Elasticity, good resistance to corrosion, and moderate cost was introduced as an orthodontic wire in 1929 and shortly gained popularity over gold. After that there is continuous research on biomaterials resulting in introduction of variety of arch wires.

Stainless steel wire

In the mid nineteenth century, stainless steel was applied to dentistry and orthodontics, although it was between 1903 and 1921 that Harry Brearly of Sheffield, F.M. Beckett of the U.S., Benne Strauss, Edward Maurer of Germany shared the honour for the development of the material. Stainless steel has more resilience than gold and it breaks less under stress. Cost of stainless steel was less than gold. This alloy is more resistant to corrosion, rigid, can be welded and has less friction. Stainless steel wire generates higher loads even with small cross-sectioned wires. Multi stranded stainless steel wires are less rigid with same diameter. So it is possible to use them at initial phase of treatment. Ever since, almost all orthodontic practitioners have relied on it[4-6].

Chrome cobalt alloy wire

A chrome cobalt alloy was first used by a watch company. Chrome cobalt alloys were simultaneously developed in the midcentury and this had physical properties very similar to that of stainless steel. However, they had the advantage that they could be supplied in the softer and more formable state and then, could be hardened by heat treatment, a procedure that increased its strength significantly. The Rocky Mountain orthodontics company patented chromium cobalt alloy as Elgiloy.[7]

Titanium alloy wire

After few years, alloy made by using titanium was introduced. It showed changes when subjected to heat treatment. Structural changes in the atoms took place pertaining to their arrangements. This alloy is also called as beta phase titanium alloy. Beta phase was stabilized at room temperature in 1977 and in 1979, alloy was emerged in Orthodontics, known as titanium-molybdenum alloy (TMA).[6,8] TMA wires deliver lower forces as compared to stainless steel wires and cobalt-chromium-nickel alloy wires. This alloy has elastic force delivery in the range of 62-69GPa. It can also be welded. Beta titanium alloy wires are most expensive orthodontic wire but because of their advantages such as: formability, weldability and intermediate force delivery, these are widely used in orthodontics.[9]

Nickel Titanium alloy wire

Then was introduced the much talked about Nitinol wire, which was invented in 1960s by William F. Buehler, a research metallurgist at the Naval Ordinance Laboratory in Silver Spring Maryland (now called the Naval Surface Weapons Center). Mr. Buehler spent the next few years doing extensive research and publishing his finding on the properties and uses of his new alloy. The name Nitinol is an acronym derived from the elements which comprise the alloy, Ni for nickel and Ti for titanium and nol for naval ordinance laboratory[10]. In clinical orthodontics, Andreasen[10-12]and his associates were attracted by the unique properties inherent in NiTi alloy, such as the high elastic limits and low elastic modulus. In 1971, they reported the results of their investigation for clinical use. Subsequently, Unitek Corporation produced this wire for the orthodontic profession under the trade name of Nitinol. Nitinol has an excellent spring back property, but, it does not possess the shape memory of super elasticity as it is manufactured by a work hardening process[11].

With the advent of NiTi wire, very high spring back and low stiffness have won wide clinical acceptance. NiTi, a new superelastic orthodontic wire, was originally developed by Dr. Hau – Cheng Tien and colleagues at the General Research Institute for Non-Ferrous metal in Beijing, China in 1978. Dr. Andreason also tested thermodynamic Nitinol wires (in 1980)[12], although they were introduced to clinical orthodontics only in the last few years. These wires can return to a previously set shape when heated to a transition temperature range (TTR). Dr. Andreason was the first person to suggest the use of shape changes in Nitinol wires to apply forces to the teeth in order to move them orthodontically. At the same time, Burstone, C.J. and Goldberg, A.J., in (1980)[13], introduced a new beta titanium alloy as TMA alloy in the clinical use of orthodontics. Beta Ti has a unique balance of low stiffness, high springback, formability and weldability which indicates its use in a wide range of clinical application.

Japanese NiTi

Furukawa electric company ltd. of Japan (in 1978)[14], produced a new type of Japanese NiTi alloy, possessing all the three properties of (excellent springback, shape memory, and superelasticity). The unique features of the stress value remaining fairly constant during deformation and rebound is a very important concept. A year later, in (1986)[14], Miura et al reported on Japanese NiTi alloy developed at Furukawa Electric Company Ltd., Japan in 1978. The two alloys, i.e., Chinese NiTi and Japanese NiTi have a basic austenitic grain structure and have the advantage of a transition in the internal structure without requiring a significant temperature change to accomplish this. This alloy has excellent spring back, shape memory, super elasticity and delivers constant force. It produces physiological tooth movement as it deliver constant force over a long time period during deactivation of wire. Super elasticity of this alloy is produced by stress not by temperature change.[9]

Chinese NiTi

Dr. Burstone (in 1985)[15], reported an alloy, the Chinese NiTi developed by Dr. Tion Hua Cheung and associates at the General Research Institute for non-ferrous metals in Beijing, China. It has high range of action and spring back so it is used when large deflections are required. Its spring back is 4.4 times higher than stainless steel and 1.6 times more than nitinol alloy wire. Its stiffness is 73% of stainless steel and 36% that of nitinol alloy wire.[9]

Copper NiTi

This wire was introduced by Rohit Sachdeva and it consists of 5-6% copper, 0.5-5% chromium along with nickel and titanium. Role of copper is to reduce energy loss during unloading phase of wire, but it increases phase transformation temperature of alloy above oral temperature. To bring the phase transformation temperature to 27 degrees, chromium is added to alloy. These wires showed unloading force value close to loading force value, therefore large sized wire can be used without any discomfort to the patient. Copper NiTi wire has four types:

- Type I: It has AF temperature of 15^0 C . It produces high level force and clinical use of this type is very less.
- Type2: It has AF temperature of 27^0C . Its force value is highest among all the types.
- Type3: AF temperature for this wire is 35^0C. Its force value is of medium rage. It is used in patients with low to normal pain threshold.
- Type4: AF temperature for this wire is 40^0C. These wires used in patients having low pain tolerance, compromised periodontal health of patient and poor patient compliance.[16]

Titanium Nobium wire

In 1995, Dr. Rohit Sachdeva introduced this wire and it is manufactured by Ormco. It has 20% less stiffness than TMA and 70% less than stainless steel. This wire has higher plastic range, same activation and deactivation curves and has low spring back that is 14% less than that of stainless steel alloy.[17]

Timolium titanium wire

These wires combine the properties of stainless steel and nickel titanium wires. These wires have flexibility, apply continuous force and spring back similar to nickel titanium wires and also have more stiffness and bendability like stainless steel wires. These wires are highly resistant to fracture, produce lower friction and esthetically pleasing as these are bright and polished. These wires can be used in all phases of treatment.[3]

Supercable arch wire

Hanson in 1993, created superelastic NiTi coaxial wire which combine mechanical advantage of multistranded cables and properties of superelastic wires. These wires consist of seven individual strands, woven together in a long, gentle spiral wire. This wire provides better treatment efficiency as it is flexible, eliminate need of archwire bending and can be easily ligated regardless of crowding. These wires generate light, continuous force, so there is no adverse effect on periodontal tissues and patient discomfort is also minimum. Uses of these wires reduce number of visits due to longer arch wire activation.[18]

Optiflex arch wire

This non metallic wire was introduced by Dr. Talass in 1992. It is made up of esthetic clear optical fibres with good mechanical properties and stain resistant. It delivers light continuous force and high flexibility producing wide range of action. It is used for reliving crowding without patient discomfort and root resorption. It is used in adult patients due to its esthetic appearance. Optiflex wire comprised of following three layers:

- Silicon dioxide core: This part of wire provides force for tooth movement.
- Silicon resin layer: This middle layer protects core of wire from moisture and provide strength.
- Nylon layer: Stain resistant nylon layer protects wire from damage and adds strength of wire.

Sharp bends should not be given in these wires and also avoid use of metal ligatures with these wires as they can break the wire. Specially designed mini distal end cutters are used to cut the wire as these cutters cut all the three layers of wire. Cost of wire is also high. These wires should not be cinched back as the wire can fracture with sharp bends.[19]

Organic polymer wire

It is esthetic retainer wire and made up of 1.6mm diameter round polyethylene terephthalate. It is elastic in nature. It return to its original shape after bending if it is not heat treated for a few seconds at temperature lower than 230 degree centigrade. It is used in esthetically concerned patients after completion of treatment as esthetic retainer.[20]

Nitanium tooth tone plastic coated wire

These wires are stain and crack resistant having plastic and tooth colored coatings. These are marketed by Ortho Organizer and available sizes of these wires are: round 0.014", 0.016" 0.018" and rectangular 0.016 × 0.022"and 0.018 × 0.025."The wire delivers force of value 29 to 150 grams. Their colours blend in with color of tooth, esthetic brackets such as ceramics, plastic and composite brackets, thus enhancing esthetics of brackets.[20,21]These wires deliver gentle, constant force over a long period of activation and also resistant to fracture.[22]

Split-it wire

These are fiber reinforced wires, incorporating S2 glass fibres in a bis GMA matrix. These are flexible, adaptable and very easy to contour over the teeth due to their partial polymerization during manufacturing process. Modulus of elasticity of these wires is 70 % higher than highly filled dental composite and have six times greater yield strength than that of filled dental composites.[20] These wires have 24 times more resilience than that of composites. These are available in variety of forms such as rope, woven strip and unidirectional strip.[22]

Turbo wire

These are nine strand rectangular braided NiTi wires having low stiffness and high flexibility. These wires are used for torque control and full bracket engagement. These are also efficient for finishing, retaining torque and allow use of vertical elastics.[23]

Bioforce wire

These wires were introduced by GAC and have special property of variable transition temperature. These wires can deliver differential forces as per need of individual dental arch segment. These wires deliver force of 80 grams for anterior teeth and 320 grams force for molars. These esthetic wires are white in appearance due to reflective rhodium coating.[24,25] Use of these wires reduces number of wire changes and provide greater comfort to the patients.

Bio Twist NiTi wire

It is a 0.021 × 0.025 pre formed rectangular arch wire having multiple strands of titanium super elastic wire. This multistranded structure generates low force, low stiffness and high flexibility. It is used for initial leveling and alignment and also controls the torque. It can be used for retention of torque and allow movement of teeth with use of elastics.[26]

Silver plated wire

Alloys that can be used for coating of wires for esthetics include gold, silver, rhodium, platinum. By adjusting silver alloy composition, its colour closely matches to the tooth colour. Coating of silver is done by electroplating process and 0.5mm thickness is used. These wires available in same dimensions as of uncoated stainless steel wires. Silver get easily discolored by chloridation and sulfidation. In oral cavity discoloration is seen limited to bracket slot area. Because proper cleaning in bracket slot is not done, so plaque persists in that area, increasing silver sulfidation over time. Hydrogen sulfide, methyl mercaptan and dimethyl sulfide can be present in oral cavity and enhancing silver sulfidation.[22]

Silver –Rhodium coating on wire gives longest life with best performance. Use of these wires with ceramic brackets gives ideal combination. This type of coating has less thickness than that of Teflon coated wires. Friction in case of these wires decreased and these are more esthetics in appearance. Gold plated NiTi wire is available with super hard gold 24 carat. Stainless steel wire with gold plating are also available with midline marked black for maxillary and red for mandibular arch wire. This gold plating provides smooth sliding mechanics and gives a beautiful rich look.[22]

Teflon coated wire

Teflon coating on wire gives it appearance of tooth colored wire. Another function of this coating is to protect wire from corrosion. Teflon coating enhances esthetics of wire and reduces friction related to wire. Teflon coating is applied in two ways:

- By conventional air spray or
- By electronic technique.

Thickness of coating on the wire is 0.002”. These wires are available in following colours

- Natural tooth color
- Blue
- Green
- Purple colors.[21,24]

It was observed that microbial plaque accumulation on coated nickel-titanium wires is less than that of uncoated nickel-titanium wires. Teflon coating on intra oral instruments also, reduces bacterial plaque accumulation and it is easy to remove from instruments.[27,28]

Epoxy coated wire

Epoxy resin is the frequently used material for coating of orthodontic arch wires because of following properties:

- Its excellent adhesion
- Chemical resistance
- Electrical insulation.
- Dimensional stability.

Material used is synthetic fluorine containing resin or epoxy resin consisting mainly polytetrafluoroethylene. Epoxy coating is applied on wire by a depository process called as Electrostatic coating or E – coating in which atomized liquid epoxy particles are air sprayed over the wire surface along with application of high voltage on archwire. Coating thickness on the wire is 0.002-inches. If thickness of coating on wire is increased, it results in alteration of the mechanical properties of the wire because of reduction nickel titanium thickness[29]. Elayyan et al[30] reported that epoxy coated ultraesthetic wires produce lower loading and unloading forces as compared to uncoated nickel titanium wires of same dimension. Kaphoor et al[31] compared load deflection properties of epoxy coated wires from 4 different manufacturers and observed similar results as explained above for Ultraesthetic, Spectra and plastic coated NiTi wire But no difference was seen for Reflex esthetic wires. Alavi et al[32] also found same results.

Medical Grade titanium wire

Metal allergy is common problem in dentistry. This may results in gingival inflammation, puffy face and breathing problem. To prevent these problems, pure titanium containing no copper, molybdenum or chromium, can used. It is as strong as stainless steel. Therefore these wires are best suited for sensitive patients.[20]

Menzamium wire

It is stainless steel wire which is manufactured in patented high pressure melting procedure by replacing allergic Nickel with manganese and nitrogen. The wire is corrosion resistant and durable. It is best suitable for patients allergic to nickel.[20]

Retranol wire

It is 'The Bite Opener' reverse curve arch wire manufactured by work hardening of NiTi. Working range of this wire is greater than that of stainless steel wire and also has ideal dimensional stability, so prevent dumping of anterior teeth during retraction phase. It opens the bite in less than half time as compared to stainless steel wire. This wire remains active throughout the treatment and needs fewer archwire changes and adjustments during treatment. These wires are available in round and rectangular dimension for both maxillary and mandibular arch.[22]

Triangular wire

This wire was introduced in 2001 by Broussard and Graham. It is stainless steel triangular wire with equilateral triangle cross section of 0.030" to a side with rounded edges. Their bending is done with special pliers. These wires are used for making retainers and removable appliances. Adaptability of wire interproximally is better that round wire. Flat surface of wire decreases jiggling so there is less tooth abrasion as compared to round wire in Hawley's appliance. Clasp fabricated with triangular wire enhances patient comfort, periodontal health and appliance stability.[22]

Speed finishing arch wire

These wires have labial –gingival beveled shape. These finishing wires promote full expression of interaction between superelastic spring clip and archwire. Deviation in bracket position relative to archwire leads to deflection of spring clip, which stores energy for recovery. The stored energy is released gently through three dimensional tooth positioning. The quarter round shape of wire facilitate insertion of wire and closure of spring clip. The rounded edge of wire is always directed in occlusion direction in either arch. The available sizes of these wires are: 0.017x0.022 inch for the 0.018 slot or 0.020x 0.025 inch for the 0.022 slot.[33]

CV NiTi wire

These wires provide predictable force level like copper NiTi wire. These wires eliminate the problems related to copper NiTi wires such as copper allergy, colour change of wire and chemical taste. In these wires, transition temperature range has been changed and set to a specific temperature through pressure variation and heat treatment. These wires are of three types.

- Type 1: Maximum force activation (27^0C)
  This wire works immediately after placement in the mouth. So the wire is first cooled down for bending and engagement. It is best suitable and effective for impacted canine alignment.
- Type 2: Moderate force activation (35^0C)
  This wire gets activated with warm liquids. It is perfect for leveling, aligning and also popular for settling phase.
- Type 3: Minimum force activation (40^0)
  This wire generates light force, used as initial arch wire and eliminates patient discomfort.[33]

Bactericide orthodontic arch wire: NiTi with silver nanoparticles

These wires are fabricated by electrodeposition of silver nanoparticles, without effecting mechanical properties of wire. This electrodeposition of silver nanoparticles controls the plaque accumulation. It was observed that there is reduction of bacteria due to these silver nanoparticles. As oral hygiene in orthodontic patients get compromised due to brackets. So there are chances of enamel decay, gingivitis and periodontal diseases. To all these problems, these wires give a good solution.[34]

Conclusion

Variety of wire materials is introduced till date. With appropriate knowledge, orthodontist can select the proper wire material for each individual patient according to needs of treatment to increase quality of treatment, patient comfort and satisfaction. Introduction of esthetic wires is very useful especially in adult patients along with esthetic brackets. These wires increase patient's self esteem, self confidence and appearance of patient even when fixed orthodontic appliances are worn. Nowadays, wire materials are available for allergic and sensitive patients also. Therefore, to be a good orthodontist, one should have appropriate knowledge about orthodontic wires and their properties to take best result by using them and enhancing treatment efficiency.

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