Orthodontic Arch Wires-A Review

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Abstract
INTRODUCTION:
Arch wires are the primary means of generating forces for orthodontic treatment.They are one of the active components of fixed appliances. They bring about various tooth movements through the medium of brackets and buccal tubes.Arch wires are fabricated from a myriad of alloys. Understanding the basic material characteristics is essential in selecting wires for use in treatment. The bottom line is that the wire act as springs in clinical orthodontics.Mechanical properties of a material are determined by several factorssuch as variation of intrinsic properties alters the nature of the alloy itself,extrinsic properties are macroscopic features (diameter, length) and can be determined by the clinician.Three major properties of archwires are critical in defining their clinical usefulness:strength,stiffness and range.[1]

Classification Of Archwires:
According to the Materials used arch wires can be classified as
1. Precious metal alloy
2. Stainless steel
3. Australian
4. Cobalt-Chromium alloys
5. Nickel Titanium alloy
6. Beta Titanium alloy
7. Composite
8. Esthetic

According to Cross- section :
1. Round
2. Rectangular
3. Square
4. Braided
5. Multi stranded
6. Co axial

Manufacturing Of Orthodontic Wires:
The starting point for the manufacturing of orthodontic wires is the casting of an ingot having the appropriate alloy composition.This ingot is then subjected to a series of mechanical reduction operations until the cross section is sufficiently small for wire drawing.Orthodontic wires with rectangular or square cross sections have some inevitable rounding at the corners.This can make an important contribution to the archwire bracket torque delivery, particularly when there is relatively tight engagement of the wires in the bracket slots.Heat treatments are necessary during maufacturing to eliminate the extensive work hardening that occurs during the various stages of mechanical reduction.Special atmospheric conditions are needed for manufacturing the titanium containing orthodontic wires because of the reactivity of these alloys with air

PHASES OF ARCH WIRES:[7]
Evans (BJO 1990) divided the phases of archwire development into five phases on the basis of :
- ✓ Method of force delivery,
- ✓ Force/Deflection characteristics and
- ✓ Material.

PHASE	Method of force delivery	Force/Deflection characteristics	Material
PHASE I	Variation in archwire dimension	Linear force/deflection ratio	Stainless steel, Gold
PHASE II	Variation in archwire material but same dimension	Linear force/deflection characteristics	Beta Titanium, Nickel titanium, Stainless steel, Cobalt chromium
PHASE III	Variation in archwire diameter	Non-linear force deflection characteristic due to stress induced structural change	Superelastic Nickel Titanium
PHASE IV	Variation in structural composition of archwire material	Non-linear force/deflection characteristic dictated by thermally induced structural change	Thermally activated Nickel titanium
PHASE V	Variation in archwire composition/structure	Non-linear force/deflectioncharacteristics dictated by different thermally induced structural changes in the sections of the archwire	Graded, thermally activated nickel titanium

EVOLUTION OF ARCH WIRES:

(A)**Gold:**

In 1887, Edward Angle used nickel silver alloys in his orthodontic accessories. In those days, 14 to 18-carat gold was routinely used.The advantage of using gold alloys :Since they can be heat treated, their stiffness can be altered by about 30%.Excellent resistance to corrosion.Many gold wires resembles type IV gold casting alloy in composition -Gold :55-65%, Silver :10-25%,Copper:11-18% ,Palladium 5-10%,Platinum 5-10% ,Nickel 1-2% Zinc - 0.6% .Properties of gold wires include Excellent biocompatibility,Strength- very low,Yield strength-less than stainless steel,Formability- very good,Soldering is easy and solder joints are resistant to corrosion,Excellent environmental stability.

(B)Stainless Stell:

In the 1931 AAO Conference, Norris Taylor and George Paffenbarger introduced steel as a substitute for gold. In 1933, the founder of Rocky Mountain Orthodontics, Archie Brusse, suggested for the first time the clinical application of stainless steel in orthodontics.In Brazil, stainless steel began to be utilized in the manufacture of orthodontic accessories in the late 1940.Typically fabricated from AISI (American Iron & Steel Institute) 302 & 304 alloys.304 alloys similar to 302 except that they have 0.8% carbon.

COMPOSITION:

- Chromium -17-25%
- Nickel - 8-25%
- Carbon - 0.2%
- Iron – balance

GRADATIONS OF STAINLESS STEEL:

- Regular grade – Those wires can be bent to almost any desired shape without breaking.
- Super grade – Yield strength is very high but is brittle thus it breaks when bent sharply.

ACCORDING TO AMERICAN ORTHODONTICS:

- Standard
- Gold Tone
- Super Gold Tone
- General properties of stailess stell wires include:Great ductility,formability,ease of welding ,ability to unergo cold work without fracture,ability to overcome sensitization.Advantages of stainless steel are low cost,biocompatibility ,excellent formability and it can be soldered and welded. Disadvantages of stainless steel includes High force delivery,relatively low spring back in bending compared to beta-titanium and Nickel titanium alloys,can be susceptible to intergranular corrosion after heating to temperatures required for joining.[3]

(C) COBALT CHROMIUM ALLOYS:

In the 1940s the Elgin Watch Company developed cobalt-chromium alloy.Composed of – Cobalt (40%), Chromium (20%), Silver (16%) and Nickel (14%).In the 1960s, cobalt-chromium alloys found their way into Orthodontic practice as Elgiloy® by Rocky Mountain Orthodontics.

A cobalt-chromium-nickel orthodontic wire alloy (Elgiloy) was developed during the 1950s by the Elgiloy Corporation.Available in four tempers: soft, ductile, semi resilient and resilient.

As with the stainless steel alloys, the corrosion resistance of Elgiloy arises from a thin passivating chromium oxide layer on the wire surface. Can be subjected to same welding and soldering procedures as for stainless steel orthodontic wires.

Blue Elgiloy:

This is very popular with many orthodontists as it can be manipulated into desired shapes.Can be heat treated to achieve considerable increase in strength and resilience.The other three tempers of Elgiloy have mechanical properties that are similar to tempers that are available with less expensive stainless steel wire alloys. These tempers, which are also responsive to heat treatment, are not as popular for orthodontics as the Elgiloy Blue wires.Orthodontists can mistakenly believe that Elgiloy Blue wires have substantially lower elastic force delivery than stainless steel wires. In reality, the values of modulus of elasticity for the Elgiloy Blue and stainless steel orthodontic wires are very similar. Other than the major differences in composition, the stainless steel and Elgiloy Blue wire alloys have similar force delivery and joining characteristics.The Elgiloy Blue wires contain a comparable amount of nickel to that found in the stainless steel wires.

(D)Beta Titanium Alloy:
The pioneer for the development of nickel-titanium wires for orthodontics was Dr. George Andreasen, in the early 1970s. The first nickel-titanium orthodontic wire alloy (Nitinol) was marketed by the Unitek Corporation (now 3M Unitek, Monrovia, CA, USA).
Beta-titanium alloys have been used as structural material since 1952.The first clinical applications of this alloy in orthodontics occurred in the 1980's when a different form of titanium called "high temperature" was introduced. Since then, this titanium gained wide clinical acceptance and popularity.
Beta titanium(TMA) is the newest alloy to be introduced to orthodontic profession.With the addition of molybdenum , a titanium based alloy can maintain its beta structure even when cooled to room temperature.At temperature >885ºC,pure Ti is rearranged in to BCC lattice called BETA-phase. Such alloys are referred to as beta stabilized titanium or TMA.[4]

(E)Nickel Titanium Alloys:
In 1972, Unitek Corporation produced the NiTi alloy for clinical use under the trade name Nitinol®.
In 1985 the clinical and laboratory use of a new superelastic nickel-titanium alloy was reported. It was called "Chinese NiTi".In 1986 "Japanese NiTi" was introduced. These alloys were produced by the GAC Company (GAC Int., NY, USA) under the trade name Sentalloy.The generic name "nitinol" that is applicable to this group of nickel-titanium alloys originates from *ni* ckel, *ti*tanium and the *N*aval *O*rdnance *L*aboratory where the alloys were developed by Buehler and associates.[5]
The wire has 2 forms- At low temperature and high stresses MARTENSITIC form is more stable and at high temperatures and low stresses AUSTENITIC form is more stable.The uniqueness of NiTi is that the transition between the two structures is fully reversible and occurs at a relatively low temperature.

Stabilised Niti Alloy :
These are martensitic stabilised alloys do not possess shape memory or superelasticity, because the processing of wire creates a stable martensitic structure i,e.. Do not undergo any changes in its crystal structure.

Active Niti Alloy :
It has fixed composition but capable of undergoing changes in its crystal structure when stress or transition temperature is applied.

Active Austenitic Alloy :
Transformation temperature is below the room temperature.On stress application, it demonstrates a change in the crystal structure from austenite to martensite.

Active Martensitic Alloy :
Transformation temperature is between room and oral temperature.On heat application it demonstrates a change in crystal structure from martenisite to austenite

PHYSICAL PROPERTIES OF Niti:
Shape memory:The ability of the material to remember its original shape after being physically deformed while in martensitic form.In a typical application, a certain shape is set while the alloy is maintained at an elevated temperature.When the alloy is cooled below the transition temperature, it can be plastically deformed.But the original shape is restored when it is heated enough to regain austenitic structure. Subsequent heating through a lower transition temperature

causes the wire to return to its original shape.The cobalt content is used to control the lower transition temperature which can be near mouth temperature 37°C (98.4° F).
Clinical application of NiTi:Cases that benefit most from the use of nitinol wires, depend on the criteria of the amount of malalignment of the teeth from the ideal arch form.The more the wire has to be deflected from the ideal arch form when ligated into the bracket, the greater benefit nitinol wire has over stainless steel.A clinical comparison of the effectiveness of two types of orthodontic aligning archwire materials, both HANT and SENT archwires were equally effective in the aligning stage of orthodontic treatment.

(F) Australian Arch Wire:
A.J. Wilcock Australian wires were of 18/8 stainless steel type. Carbon content is 10 times higher than standard value.This increased carbon content→ rough , irregular and excessively porous surface. Outstanding property of Australian wire is its resilience or ability to spring back after having been deflected. Australian wires are available in the following forms:Regular-White Label ,Regular Plus-Green Label,Special-Black Label ,Special plus-Orange Label , Extra Special Plus-Blue Label , Premium-Purple Label , Premium Plus-Orange Label ,Supreme-Yellow Label and Supreme Plus-Cream Label

(G) **Titanium Nobium Wires:**[8]
It was introduced in early 1995 by Dr Rohit Sachdev 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. Can easily make creative bends and avoid excessive force levels of a steel wire.

(H) Timolium Titanium Wires:
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

(I) 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.[9]

(J) Combined Wires:
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(K) Esthetic Archwires:[10]

Ideal features of esthetic wire includes mechanical properties ,correct dimensions, biocompatible,pleasantly aesthetic and consistent with the translucency of aesthetic brackets.Esthetic wires includes coated wires,imagination wires,composite wires,ceramic wires etc. Composite wire can be Round or Rectangular and its properties of composite wire includes wide range of action ,light continuous force but sharp bend must be avoided and wires are highly resilient .

SPLIT-IT WIRES:

Burstone and Kuhlberg have described the clinical application of a new fiber reinforced composite called "Splint-It" which incorporates S2 glass fibers in a bis GMA matrix.These materials are only partly polymerized during manufacture (pre-pregs), which makes them flexible, adaptable and easily contourable over the teeth.Modulus of elasticity in flexure of splint IT is 70 percent greater than that of a highly filled dental composite. Yield strength is six times greater than that of a highly filled dental composite. [11]

CERAMIC WIRES:[12]

Optiflex Wires :

A composite ceramic fiber-plastic-nylon (ORMCO) Dr. Talass 1992 .
Silicon dioxide core : Provides the force for moving teeth
Silicon resin cladding: Protects core from moisture and add strength
Nylon coating: It is stain resistant and prevents damage to the wire and further increase strength

Bioforce High Esthetic Wires:[13]

BioForce archwires' are introduced by GAC.These are graded thermodynamic arch wires and aesthetic.The NiTi BioForce wires apply low, gentle forces to the anteriors and increasingly stronger forces across the posteriors.BioForce High Esthetic archwires are available in .018 x .018 and .020 x 020 in medium. BioForce provides the right force to each tooth, reducing the number of wire changes and providing greater patient comfort
Orthodontic wires covered with a polyether ether ketone tube (PEEK):[14]
A PEEK tube was developed as an auxiliary device to help make orthodontic treatment more efficient and to satisfy consumer esthetic demands.An orthodontic wire passed through a newly designed tube made of a polyether ether ketone (PEEK) resin.The PEEK tube showed a color difference that was almost identical to that of coated wires indicating a sufficient esthetic property. Friction test showed that the frictional force was greatly reduced by passing the archwire through the PEEK tube in almost all of the archwires tested.It is a good combination of estheticand functional properties for use in orthodontic appliances.

CONCLUSION:

Acquiring scientific knowledge of orthodontic wires enables professionals to choose the best possible treatment protocol for the patient.We see that there is no archwire that meets all the requirements of the orthodontist. We still have a long way to go, in terms of finding the 'ideal' archwire. But, with such rapid progress being made in science and technology, It is sure that we will see significant improvements in archwires in the near future.

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