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Review Article

Orthodontic wires and their properties along with clinical implications: A review study

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ABSTRACT:

Orthodontic wires are parts of fixed appliances that are used to move teeth as part of orthodontic therapy. Orthodontic wires are made from a range of materials including as metals, alloys, polymers, and composites. Various laboratory tests, like as tensile, torsional, and bending tests, are used to assess the qualities of orthodontic wires. However, oral circumstances may alter their behaviour, therefore it is essential for clinicians to understand the qualities of orthodontic wires as well as their clinical implications in order to get the best outcomes. This article examines the many materials used to make orthodontic wires, as well as their qualities and therapeutic consequences.

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INTRODUCTION

In orthodontics, an archwire is a wire that conforms to the alveolar or dental arch and may be used with dental braces as a source of force to address anomalies in tooth position. An archwire may also be utilised to keep current dental placements in place; in this instance, it serves a retentive function.[1] Orthodontic archwires may be made from a variety of alloys, the most popular of which are stainless steel, nickel-titanium alloy (NiTi), and beta-titanium alloy (composed primarily of titanium and molybdenum).[2] The goal of orthodontic therapy is to apply pressures to the teeth in order to shift them to a certain position. An optimal force is one that causes fast tooth movement while causing little harm to the teeth or periodontal tissues. Different biological and other elements, such as the kind of movement and tooth size, must be considered when applying the force; nonetheless, it is impossible to exactly identify the value of the optimal force; orthodontic/orthopedic forces typically vary between 01.5-5 N. [3] Lower forces offer the best outcomes, whereas high force that exceeds vascular blood pressure inhibits cellular activity in periodontal tissues and slows or prevents tooth movement for a period of time. [4]

Lowering pressures and achieving a broader range of motions between sessions may enhance treatment quality and performance. Orthodontic wires are used as permanent items to apply forces to the teeth during orthodontic treatment. They release the stored energy by delivering pressures and torque to the teeth through the appliances put on them. To construct the treatment plan, an orthodontist should be well-versed in the biomechanical behaviour and clinical uses of orthodontic wires. Previously, gold was mostly employed as orthodontic wire. These gold wires were pricey. Following gold wires, stainless steel wires were widely utilised because they were less costly and had better mechanical qualities. Because of recent technological breakthroughs, cobalt-chromium, nickel-titanium, beta-titanium, and multistranded stainless steel wires with a wide variety of characteristics have been produced. To analyse the attributes of orthodontic wires, tension, bending, and torsional tests are employed, and each of these tests is a totally separate stress state that investigates various factors connected to wire performance.[5]

TYPES OF ORTHODONTIC WIRE

WIRES MADE OF STAINLESS STEEL (SS)

The most prevalent stainless steel type is austenitic 18-8. It has a chromium and nickel concentration of roughly 18% and 8%, respectively. The most essential characteristic of 18-8 stainless steel is its strong corrosion resistance due to the creation of a passivated oxide layer, which prevents further oxygen migration to the underlying mass. Commercially available stainless steel wires exhibit a variety of elasticity and yield strength values due to changes in several factors throughout the manufacturing process, such as freezing and incandescence during cold working. Because stainless steel wires have a lesser spring back ability and retain less energy than beta-titanium or nickel-titanium wires, they create stronger pressures applied over shorter time periods. [6]

Using a fastening agent, stainless steel wires may be welded with various biomechanical attachments. To achieve good results, new welding methods such as LASER or tungsten inert gas (TIG) are advised for use in orthodontics without a fastening agent. However, they are prohibitively costly and need the use of specialised laboratory equipment. Stainless steel has high corrosion resistance in general, although it releases less nickel and chromium and may cause hypersensitivity responses. Stainless steel wires have lower bracket-wire friction than other wire types, and this friction may be decreased even more by applying nanotechnology techniques.[7]

Australian wires are stainless steel wires that come in a variety of grades with steadily increasing stored energy values (resiliency). These wires have up to ten times the carbon content of a conventional stainless steel orthodontic wire (up to 0.20 percent), resulting in increased surface roughness, hardness, porosity, and susceptibility to breakage during clinical bending, especially for higher grades. [8] As a result, its use is limited to biomechanical attachments. Recently, super stainless steels with reduced nickel content, stronger corrosion resistance, and superior mechanical characteristics have been created. Because of these qualities, these wires have been selected over titanium wires, which are more costly.

WIRES OF COBALT-CHROMIUM

Elgiloy, a cobalt-chromium-nickel alloy, is available in wire and band forms for different dental equipment. ELGIU national firm first produced these alloys for use as watch springs. These wires are available in a variety of tempers based on the amount of cold work done and are often color-coded. There are three kinds of tempers available: high spring temper (red), semispring temper (green), and soft or ductile temper (yellow). They are simple to bend. After manipulation, they may be heat hardened at 482° C for roughly 7 minutes to achieve hardness (strength) comparable to stainless steel. The spring-back of non-heated cobalt-chromium wires is less than that of stainless steel wires.[9] These wires are tarnish and corrosion resistant, cheap, and may be soldered (fluoride fluxes are required) and welded. Blue Elgiloy, a cobalt-chromium wire type, has been popular in clinical practise because to its high formability along with enhanced elasticity and yield strength after heat treatment by 10% and 20- 30%, respectively.

WIRES MADE OF BETA-TITANIUM

These wires, also known as titanium-molybdenum alloy (TMA) (ORMCO, Orange, CA, USA) or Titanium-Niobium (ORMCO, Orange, CA, USA), were launched as orthodontic wires in 1979. The modulus of elasticity of these wires is half that of stainless steel wires and almost double that of Nitinol wires. [10] These wires have excellent formability but should not be bent too tightly or they may break. Electrical welding of biomechanical attachments is conceivable, however overheating the wire causes it to become brittle. According to a recent research, beta-titanium wires are superior than stainless steel wires in terms of joinability because they have stronger resilience and better surface and structural qualities, indicating only a slight change in wire properties after welding. Because it lacks nickel, its corrosion resistance is comparable to that of cobalt-chromium and stainless steel wires. It is also an excellent biocompatible material. Their corrosion resistance is owing to the creation of a surface passivation oxide layer; nevertheless, exposure to fluoride chemicals causes deterioration, subsequent corrosion, and qualitative changes to the wire's surface. The length of wire exposure to fluoride chemicals seems to be important. These wires are very costly and have the highest bracket-wire friction of any alloy. [11] Recently, an alpha-beta titanium alloy was introduced. The stiffness and other properties (such as elasticity and yield strength) of alpha-beta titanium alloy, commonly known as TiMolium, are between the values specified for stainless steel and beta-titanium wires.

NI-TI (NICKEL-TITANIUM) WIRES

In 1972, Nitinol (Nickel-Titanium naval ordinance laboratory) was developed as a wrought Ni-Ti alloy. Its strong resilience, restricted formability, shape memory or heat memory, and pseudoelastic or superelasticity distinguish it. At various temperatures, Ni-Ti alloys include two primary phases and one intermediate phase. The major phases are austenitic at higher temperatures and have a body centred cubic structure (BCC), and martensitic at lower temperatures and have a hexagonal tightly packed structure (HCP). The intermediate phase postpones the transition from austenite to martensite during cooling until temperatures are lower. [12] A volumetric change is connected with the phase changeover (from BCC austenitic to HCP martensitic) and may be detected by reducing the temperature from a high temperature. This transformation produces two distinct properties: shape memory and pseudoelasticity or superelasticity.

Shape memory is obtained by initially forming a shape at temperatures close to 482° C. If the appliance wire is chilled and shaped into a second shape before being heated through a lower transition temperature range (TTR), it will revert to its original shape. The cobalt concentration regulates the transition temperature range, which might be close to oral temperature. Stress may cause the austenitic to martensitic transition, resulting in superelasticity, which is used with Ni - Ti wires. This concept was based on structural changes in the wire (phase transformation) caused by temperature fluctuations or the loading process. [13]

Burstone et al. advocated Chinese NiTi (Ormco, Orange, CA, USA) wires in 1985. If a steady force was applied in the centre of its deactivation range, they demonstrated 4.4 times the spring-back of stainless steel wires and 1.6 times the spring-back of the original Nitinol wires. [14]

Miura et al. introduced the Japanese NiTi (Sentalloy, DENTSPLY GAC International, Bohemia, NY) wire in 1986. [15]

Their characteristics were virtually identical to those of Chinese NiTi wires. [16] In the early 1990s, NeoSent alloy wires and Copper-Nickel-Titanium alloy (Cu-Ni-Ti) wires were produced. In oral cavity temperature, the NeoSent alloy wires exhibit 100% shape memory. Because such alloys achieve the whole austenitic structure below the oral temperature, [12] NeoSent alloys always have the austenitic structure at oral temperature. Nitinol wires achieve austenitic structure at temperatures significantly greater than oral temperature. At various temperatures, copper-nickel-titanium wires (Cu-Ni-Ti) develop an austenitic structure (270 C, 350 C and 400 C). Superplastic Nitinol SE (Nitinol Super Elastic) wires They exhibit pure form memory and are very sensitive to temperature changes, which impact their mechanical characteristics, but they do not have thermoelastic shape memory in vivo. When triggered with the same amount of bending, nickel-titanium wires have a larger energy storage capacity than beta-titanium or stainless steel wires. [6] The primary benefit of these wires is their greater elasticity, which enables a broad deflection and activation range while providing minimal forces, as well as their corrosion resistance. The downsides include limited formability, high cost, and inability to be welded or fused. The friction at the bracket-wire contact is greatest with Nitinol wires, then beta-titanium, stainless steel, and chromium-cobalt wires. If nitinol wires are left in the mouth cavity for many days, they are more prone to fail due to regular wear. This kind of wear occurs more often with bigger or rectangular section wires than with smaller section wires. [17]

WIRES WITH MANY STRANDS

Multistranded wires are made up of a variable number of stainless steel wire strands that are coaxially arranged or wrapped around each other in various configurations. These wires have key properties such as low force development, low stiffness, and durability, and they are less costly than titanium alloys. When compared to NiTi wires and single-stranded stainless steel wires, they create more friction at the bracket-wire contact. [18]

COMPOSITE ARCH WIRES WITH FIBRE REINFORCEMENT

For more than a decade, fiber-reinforced polymer composites have been employed as arch wires. Because they are very aesthetic and biocompatible, these materials offer several benefits over traditional metallic alloys. Other benefits include hydrolytic stability, low water sorption, stiffness comparable to metallic wires, post-processing formability, and superior sliding mechanics.[19] However, there is a risk of arch wire wear at the interface, as well as glass fibre leaking into the oral cavity.

ARCH WIRES MADE OF STAINLESS STEEL WITH A TEFLON COATING

Teflon is coated on stainless steel wire using an atomic technique that creates a coating of around 20-25m thickness on the wire that gives the wire a colour comparable to real teeth. The Teflon covering protects the underlying wire from corrosion. However, corrosion of the underlying wire is probable if it is used for an extended amount of time in the oral cavity since this coating is susceptible to faults that may emerge during clinical usage. [20]

BIOFORCE CABLES

BioForce is an aesthetically pleasing archwire that is part of the first and only family of physiologically accurate archwires. GAC pioneered the use of "Bioforce archwires." The Ni-Ti Bioforce wires deliver modest, mild stresses to the front teeth and gradually increase the force over the posterior teeth until it reaches a plateau at the molars. The amount of force used is graded throughout the length of the arch based on tooth size.

OPTIFLEX

Dr. Talass created the Optiflex orthodontic arch wire, which is produced by ORMCO. Because it is constructed of transparent optical fibre, it has a very appealing look, which is made up of three layers The inner core is silicon dioxide, the intermediate layer is silicon resin, and the outside layer is nylon. The core provides the force for moving the tooth, the intermediate layer protects the core from moisture while also providing strength, and the outer layer protects the wire while also increasing its strength. Optiflex is an extremely flexible material that effectively moves teeth with little continuous force.

MARSENOL

Marsenol is a tooth-colored nickel titanium wire coated with elastomeric poly tetrafluroethyl emulsion (ETE). These wires have the same operating properties as an uncoated extremely elastic Nickel titanium wire.

MANUFACTURING OF ORTHODONTIC WIRE

The casting of an ingot with the suitable alloy composition is the starting point for the production of orthodontic wires. After that, the ingot is subjected to a succession of mechanical reduction processes until the cross section is small enough for wire drawing. Orthodontic wires with rectangular or square cross sections will always have some corner rounding. This may make a significant contribution to archwire bracket torque delivery, especially when the wires are quite tightly engaged in the bracket slots. Heat treatments are required throughout the manufacturing process to remove the significant work hardening that happens during the different phases of mechanical reduction. Because of the reactivity of these alloys with air, certain atmospheric conditions are required for the production of titanium-containing orthodontic wires.

PHASES OF ARCH WIRES[21]

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 1	Variation in arch wire dimension	Linear force/deflection ratio	Stainless steel, Gold
PHASE 2	Variation in arch wire material but same dimension	Linear force/deflection characteristics	Beta Titanium, Nickel titanium, Stainless steel, Cobalt chromium
PHASE 3	Variation in arch wire diameter	Non-linear force deflection characteristic due to stress induced structural change	Superelastic Nickel Titanium
PHASE 4	Variation in structural composition of archwire material	Non-linear force/deflection characteristic dictated by thermally induced structural change	Thermally activated Nickel titanium
PHASE 5	Variation in arch wire composition/structure	Non-linear force/deflection characteristics dictated by different thermally induced structural changes in the sections of the arch wire	Graded, thermally activated nickel titanium

CONCLUSION

Learning about orthodontic wires scientifically allows specialists to choose the optimal treatment regimen for the patient. We can see that there is no arch wire that fits all of the orthodontist's standards. In terms of identifying the 'perfect' arch wire, we still have a long way to go. However, with such quick advances in science and technology, it is certain that we will witness considerable advancements in arch wires in the near future.

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