Role of Wires in Dentistry: A Review

Ankur Kaushik[1]*, Nikita Gupta[2], Amit Sanghi[3], Anubhav Bansal[4], Adarsh Deep Kharel[5], Shilpa Pahal[6]

[1]Department of Orthodontics and Dentofacial Orthopedics, P.D.M Dental College Bahadurgarh, Haryana, India.
[2]Department of Orthodontics and Dentofacial Orthopedics, Jammu, Jammu and Kashmir.
[3]Department of Orthodontics and Dentofacial Orthopedics, Bhiwani, Haryana.
[4]Department of Orthodontics and Dentofacial Orthopedics, Najafgarh, Delhi.
[5]Department of Orthodontics and Dentofacial Orthopedics,Rangpo, Sikkim.
[6]Consultant Dental Surgeon Charkhi Dadri, Haryana.

Abstract

Orthodontic wires are used to carry out the necessary tooth movements as part of orthodontic treatment. A variety of materials is 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 available in the market.

Keywords: Nickel titanium, Orthodontic wires, Stainless steel, Tooth colored wires.

Introduction

During orthodontic treatment, forces are applied to the teeth through the interaction of orthodontic wires with brackets and molar tubes. The criteria that determine the properties of an ideal archwire are (1) high formability, (2) low stiffness, (3) high range, and (4) high strength. Weldability and solderability are also required properties. In addition to these the material should be cost effective. All these requirements are not achieved by any one orthodontic archwire material. Using specific archwires for specific purposes give best results.[1]

Definitions and Some Relevant Descriptions[2-4]

Stress

Stress is the internal distribution of the load measured as force per unit area.

Strain

Strain is the internal distortion produced by load.

Proportional limit or elastic limit

The point at which first plastic deformation occurs.

Access this article online

Website: www.jrad.co.in

DOI: https://doi.org/10.53064/jrad.2022.13.4.339

Load deflection rate

For a given load, the deflection observed within the elastic limit is known as load deflection rate.

Modulus of elasticity

The mechanical property that determines the load deflection rate of an orthodontic member is the modulus of elasticity. Load deflection rate varies directly and linearly with modulus of elasticity.

Tensile strength

Tensil strength is the maximum strength or load carrying capacity of the wire before it fractures. Fracture of the wire occurs when the internal stresses in the wire increase because of applied forces. It reaches a degree which can no longer be resisted by the inherent strength of the wire.

Address for correspondence: Dr. Ankur Kaushik, Department of Orthodontics and Dentofacial Orthopedics, P.D.M Dental College Bahadurgarh, Haryana, India.
Email: kaushik.ankur@yahoo.com

Received: Apr. 02, 2022; **Accepted:** May. 08, 2022; **Published:** Jul. 07, 2022

How to cite this article: Kaushik A, Gupta N, Sanghi A, Bansal A, Kharel AD, Pahal S. Role of Wires in Dentistry: A Review. J Res Adv Dent 2022;13(4):280-283.

Yield strength

It is the practical indicator at which a deformation of 0.1% is measured. It is measured as stress units (gm/cm).

rRange

Range is defined as the distance that the wire will bend elastically for permanent deformation occurs. It is measured in millimeters or other length units.

Springiness or spring back

Spring back is a measure of how far a wire can be deflected without causing permanent deformation or exceeding the limits of the material. Clinically, useful spring back occurs of the wire is deflected beyond the yield point but no longer returns to its original shape. It can also be described as the elastic property exhibited by the wire between yield strength and the ultimate tensile strength of the wire.

Stiffness

Stiffness is a measure of the amount of force required to produce a specific deformation in bending or torsion. Stiffness is proportional to the fourth power of the diameter of the wire.

Strength: Stiffness X range

A combination of stiffness and range is the strength of the wire.

Resilience

Resilience represents energy storage capacity of the wire, which is a combination of strength and springiness.

Formability

It represents the amount of permanent bending of the wire which will tolerate deformation that a wire can withstand before failing.

Flexibility

Is a measure the amount which a wire can be strained without undergoing plastic deformation.

Zero stress relaxation

This is the ability of the wire to deliver constant light elastic force when subjected to external forces or forces of occlusion.

Stress relaxation

When a specimen has been deformed and held in a fixed position, the stress may be diminish with time, even though the total strain remains constant. This phenomenon is known as stress relaxation.

Martenistic crystallographic lattice

Alloys containing lesser symmetric crystallographic network such as monoclinic, orthorhombic, tetragonal, and so forth.

Cubic crystallographic lattice

Alloys containing symmetric crystallographic network such as body centered cubic lattice and so forth.

Gold Alloys[5]

The composition of the alloys used in gold orthodontic wires is similar to the Type IV gold casting alloys, although there can be a wide variation between particular materials. These alloys may contain as little as 15% gold, although 55–65% gold is more typical. The wires are alloyed with 11–18% copper, 10–25% silver, and 5–10% nickel and acquire additional strengthening through cold working, incorporated during the wire drawing process. These wires are easily joined by soldering and the joints are very corrosion resistant. The gold wires have decreased usage in orthodontics because of their low yield strength and increasing cost.

Stainless Steel[3]

In the 1940s Austenitic stainless steel began to displace gold as the primary alloy orthodontic wires. The most commonly used types are 302 and 304 stainless steel, which contain approximately 18% chromium, 8% nickel, and <2–0% carbon. These alloys derive most of their strength from cold working and carbon interstitial hardening. In general, stainless steel has excellent formability, although the wires with higher yield strength may be somewhat brittle. Stainless steel can be soldered and has good corrosion resistance. The combined adequate springback, good formability, and moderate cost account for the popularity of stainless steel as an orthodontic arch wire.

Multistranded Stainless Steel Wire[6-9]

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.

Australian Orthodontic Archwires[4,10,11]

A. J. Wilcock produced orthodontic arch wire to meet Dr. Begg's needs for use in Begg technique. The wire produced has certain unique characteristics different from usual stainless steel wire.

1. It is an ultra-high tensile austenitic stainless steel arch wire.
2. The wire is resilient, certain bends when incorporated into the arch form and pinned to the teeth become activated. By which stresses are produced within the wire generating wires.
3. The wire has a unique property of zero stress relaxation. Zero relaxation allows the wire to maintain its force over a long period of time, yet resist permanent deformation from elastic load.
4. All these properties make the wire very hard and brittle. Depending on the resiliency, the wire has been graded and color coded for use.

Regular grade

White label lowest grade and easiest to bend. Used for practice bending or forming auxiliaries. It can be used as archwire when distortion and bite opening is not a problem.

Regular plus grade

Green label relatively easy to form yet more resilient than regular grade. Used for auxiliaries when more pressure and resistance to deformation are required.

Special grade

Black label highly resilient yet can be formed into intricate shapes with little danger of breakage.

Special plus grade

Orange label – hardness and resiliency of the wire are excellent for supporting anchorage and reducing deep overbite.

Extra special plus grade

Blue label – Highly resilient and hard and difficult to bend subjects to fracture.

To avoid breakage of Australian orthodontic archwire, the flat beak of the light wire plier should be used. This has the effect of introducing a moment about the thumb and wire gripping point that reduces the applied stress that might otherwise cause wire fracture.

Chorme Cobalt Alloy[12,13]

Chrome cobalt alloy is cobalt base alloy containing 40% cobalt, 20% chromium, 15% nickel, 7% molybdenum, 2% manganese, 0.15% carbon, 0.4% beryllium, and 15% iron.

Types of chrome cobalt alloy wires:

1. Blue Elgiloy – can be bent easily with fingers and pliers. Heat treatment of blue elgiloy increases its resistance to deformation.
2. Yellow Elgiloy – Relatively ductile and more resilient than blue elgiloy. Further increase in its resilience and spring performance can be achieved by heat treatment.
3. Green Elgiloy – More resilient than yellow elgiloy and can be shaped with pliers before heat treatment.
4. Red Elgiloy – Most resilient of elgiloy wires, with high spring qualities, withstands only minimal work hardening. Heat treatment makes it extremely resilent.

Nickel Titanium Alloys[14-17]

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, 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. 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. 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 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 is that permanent bends cannot readily be placed in the wires and that the wires cannot be soldered.

Beta-titanium Wires[18]

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.

Tooth Colored Orthodontic Wires[19-21]

Fiber-reinforced composite arch wires

Fiber-reinforced polymer composites have been used as arch wires for more than a decade.

An overview of orthodontic wires

These materials have got many advantages over the conventional metallic alloys as they are esthetic biocompatible, hydrolytically stable, less water sorption, and 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.

Teflon coated stainless steel arch wires

Teflon is coated on stainless steel wire by an atomic process that forms a layer of about 20–25 ìm 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.

Bioforce wires

BioForce is esthetic and is part of the first and only family of biologically correct archwires. “Bioforce archwires” 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.

Optiflex

Optiflex is a most esthetic 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 three 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.

Marsenol

Marsenol is a tooth colored 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.

Lee white wire

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 discolor.

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 behavior 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.

References

1. Proffit WR. Contemporary orthodontics, 5th edition. Br Dent J Off J Br Dent Assoc 2013;213:258.
2. US Naval Academy. EN380 Naval Materials Science and Engineering Course Notes. Ch. 10. US Naval Academy.
3. Gaonkar P. Orthodontic archwires: Past, present and future (review part 1). Int J Curr Adv Res 2020;9:4387.
4. Egg PR. Light arch wire technique: Employing the principle of differential force. Am J Orthod Dentofac Orthop 1961;47:30.
5. Ritter AV, Walter R. Sturdevant's Art and Science of Operative Dentistry. 7th ed. Amsterdam, Netherlands: Elsevier; 2019. p. 453-510.
6. Wilkinson PD, Dysart PS, Hood JA, Herbison GP. Load-deflection characteristics of superelastic nickel-titanium orthodontic wires. Am J Orthod Dentofacial Orthop 2002;121:483-95.
7. Rucker BK, Kusy RP. Elastic flexural properties of multistranded stainless steel versus conventional nickel titanium archwires. Angle Orthod 2002a;72:302-9.
8. Kusy RP, Stevens LE. Triple-stranded stainless steel wires. Evaluation of mechanical properties and comparison with titanium alloy alternatives. Angle Orthod 1987;57:18-32.
9. Rucker BK, Kusy RP. Resistance to sliding of stainless steel multistranded archwires and comparison with single-stranded levelling wires. Am J Orthod Dentofacial Orthop 2002c;122:73-83.
10. Begg PR, Kesling PC. Begg Orthodontic Theory and Technique. Philadelphia, PA: WB Saunders Company; 1977.
11. Pelsue BM, Zinelis S, Bradley TG, Berzins DW, Eliades T, Eliades G. Structure, composition, and mechanical properties of Australian orthodontic wires. Angle Orthod 2009;79:97-101.
12. Brantley WA, Eliades T. Orthodontic materials: Scientific and clinical aspects. Am J Orthod Dentofac Orthop 2001;119:672-3.
13. Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires. Am J Orthod Dentofac Orthop 1989;96:100-9.
14. Kusy RP, Greenberg AR. Comparison of the elastic properties of nickel-titanium and beta-titanium archwires. Am J Orthod 1982;82:199-205.
15. Andressen GF, Morrow RE. Laboratory and clinical analyses of ninitol wire. Am J Orthod 1978;73:142-51.
16. Burstone CJ, Qin B, Morton JY. Chinese NiTi wire--a new orthodontic alloy. Am J Orthod 1985;87:445-52.
17. Burrstone CJ. Variable-modulus orthodontics. Am J Orthod 1981;80:1-16.
18. Burstone CJ, Goldberg AJ. Beta titanium: A new orthodontic alloy. Am J Orthod 1980;77:121-32.
19. Zufall SW, Kusy RP, Sliding Mechanics of coated composite wires and the development of engineering model for binding. Angle Orthod 2000;70:34-47.
20. Krishnan V, Kumar JK. Weld characteristics of orthodontic archwire materials. Angle Orthod 2004;74:533-8.
21. Elayyan F, Silikas N, Bearn D. *Ex vivo* surface and mechanical properties of coated orthodontic archwires. Eur J Orthod 2008;30:661-7.