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Review Article

Wires In Orthodontics: A Review

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ABSTRACT:

Orthodontics is a branch of dentistry, dealing with the growth, guidance, correction, and maintenance of the dento–facial complex.Orthodontic wires are defined as devices consisting of a wire conforming to the alveolar or dental arch, used as an anchorage in correcting irregularities in the position of the teeth.The criteria that determine the properties of an ideal archwire arehigh formability, low stiffness,high range andhigh tensile strength. Weldability and solderability are also required properties.The most common wires are stainless steel, nickel-titanium (NiTi), beta-titanium, and cobalt-chromium. The recent development of esthetic composite and coated wires has enhanced the esthetics, particularly in adult patients.Other frequently used wires are Organic polymer retainer wire, SEP orthodontic wires, Filaflex, Orthocosmeticelastinol, Titanium tooth-toned archwire: NiTi. Imagination wire, Nanocoatedarchwire, Orthodontic archwire bending robot system, Motoman UP6, Drift Free Archwire, Medical-grade titanium wires, TiMolium™, Speed Super Cable, SPEED finishing archwires, SmartArch Multi-force, Hills Dual Geometry Archwire, Nitanium tooth toned archwires, Hills Dual-Geometry archwire, BioForce wires, New bactericide orthodontic archwires, Fiber Reinforced Composites as Archwire, TiMolium wire and Tri-Force wires.Recent advances in orthodontic wire alloys have resulted in a wide array of wires that exhibit an amazing spectrum of properties.NiTi wires are the best choice when it comes to producing light and continuous forces, even in the face of extensive deflections. NiTi wires can save professionals chair time since they do not require leveling and alignment loops or bends and can remain active in the oral cavity for a long period of time. Appropriate use of all the available wire types may enhance patient comfort and reduce chairside time as well as the duration of treatment.Most importantly, however, a comprehensive knowledge of wires allows the orthodontist to make an informed - and therefore safer - choice of arch wires free from media manipulation.

Keywords: Orthodontics, Malocclusion, Brackets, NiTi wires, Tensile strength.

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INTRODUCTION

Orthodontics is a branch of dentistry, dealing with the growth, guidance, correction, and maintenance of the dento–facial complex.

Malocclusions—usually referred to as "*crooked*" or "*misaligned teeth*"—are a worldwide dental problem.

Still, malocclusions can cause susceptibility to trauma and periodontal diseases.[2] The orthodontic practice involves the application of corrective appliances, commonly called braces, to move teeth. [1]

Standard treatments for dental malocclusions involve removable or fixed orthodontic appliances. Fixed appliances are, in general, more effective than removable ones—especially for more complex situations and/or for adult patients—and incorporate brackets, archwires, tubes, and/or bands, tightened by metallic or polymeric ligatures. [2]

Wires have important role in active phase of orthodontic treatment 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.[3]

Orthodontic wires are defined as devices consisting of a wire conforming to the alveolar or dental arch, used as an anchorage in correcting irregularities in the position of the teeth.[4]

During treatment, a constant load is transferred from the brackets to the teeth, by using orthodontic archwires (attached to the brackets), obtaining tooth movement while adjacent bone and tissue are remodeled.[2]
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.[5]
Tooth movements and changes in orthodontic appliances result from force systems and tissue responses to them. An ideal force produces tooth movement without damaging teeth or tissues.[6]
Factors including tooth size and type of movement need to be considered when applying force during orthodontic treatment. However, it is difficult to determine an ideal force. Hence, a sound knowledge of the mechanical behavior of orthodontic archwires is required to select the most suitable size and material to achieve optimal and predictable treatment results.[6]
A successful orthodontic therapy depends not only on manual skills and knowledge of treatment steps but also on knowledge and choice of materials used. One of the major components of fixed orthodontic therapy is the choice of wires.Orthodontic wires are defined as devices comprising a wire conforming to the alveolar or dental arch, which is used as an anchorage for correcting irregularities in the position of teeth. [4]
Arch wires made of different materials are used for tooth movement, and every material reacts differently intraorally. Arch wires should provide an ideal force delivery, and it may depend on frictional property, biocompatibility, fracture, and corrosion resistance. Wire dimension, material types, and various intraoral conditions affect their physical and mechanical properties. [7]

The most common wires are stainless steel, nickel-titanium (NiTi), beta-titanium, and cobalt-chromium. The recent development of esthetic composite and coated wires has enhanced the esthetics, particularly in adult patients.[7]

HISTORY

The history of arch wire materials is as old as that of fixed orthodontic treatments and they present different features. In 1887, the father of orthodontics Edward Angle used nickel–silver alloy wires for his initial practice. Subsequently, as he kept experimenting with different materials such as copper, nickel, and zinc alloys, his favorite material became 14–18 karat gold.[4]
Noris Taylor and George Paffenbarger introduced steel as a substitute for gold in 1931.[5]
In 1993, Archie Brusse, founder of Rocky Mountain Orthodontics suggested for the first time the clinical application of stainless steel in orthodontics. [5]
In 1940, cobalt chromium alloy was developed by the Elgin Watch Company. However, it required heat treatment to fully function. The Rocky Mountain Orthodontics Company patented this alloy as *Elgiloy*.[4]
NiTi alloy was produced by Unitek Corporation in 1972 for clinical use under the trade name Nitinol. A new superelastic nickel-titanium alloy was reported to be used clinically and in laboratories in 1985 and it was known as “Chinese NiTi”. “Japanese NiTi” was introduced in 1986.[5]
Copper-nickel–titanium (CuNiTi) alloys were first became available in the mid 1990s and are another version of nickel–titanium alloys. By addition of copper to the former nickel–titanium alloy, thermal activation could be more easily controlled. They are marketed based on a variety of transition temperatures: 27 degrees, 35 degrees, and 40 degrees.[8]

Table 1: Development stages of orthodontic wires

PHASE	ALLOYS	CHRONOLOGY
PHASE I	gold	from the turn of the century to the early 1940s
	Stainless Steel	From the 1940s onward
PHASE II	stable NiTi	From the 1970s onward
	beta-titanium	Decade of the 1980s
PHASE III	Superelastic NiTi (active austenitic)	Mid-1980s
PHASE IV	Thermodynamic NiTi (active martensitic)	Decade of the 1990s
PHASE V	Gradually dynamic NiTi	Decade of the 1990s
PHASE VI	Metal wires with aesthetic coating	Decade of the 1990s
PHASE VII	Polymer composite wires lined with glass fiber	Researched in labs since 1994, launched on the market in 2008

PROPERTIES

Esthetics - Wires should be esthetic. No wire today meets this criterion, although manufacturers have tried. Although esthetics are important to the orthodontist, function is paramount. Anything less is unacceptable.[9]

Poor biohostability- Wires should have poor biohostability. This characteristic goes beyond biocompatibility— that is, the achievement of compatibility of non-living implant materials with the body—in that good biocompatibility is a prerequisite.[10]

Low coefficients of friction - Wires should possess low coefficients of fric-tion, independent of whether they are bathed in saliva" or whether the hydrodynamic boundary layer between archwire and bracket has been breached by the dry state.[10.]

Mechanical properties of arch wires - Mechanical properties of arch wires are generally assessed by tensile, bending, and torsional tests.The characteristics desirable in an orthodontic wire are a large springback, low stiffness, good formability, high stored energy, biocompatibility and environmental stability, low surface friction, and the capability to be welded or soldered to auxiliaries.[11]

Tensile strength - Yang PY et al investigated the mechanical properties of Ni-Ti coated orthodontic archwires after surface modification. There was no statistical difference between coated wires and conventional uncoated wires with regard to mechanical tensile strength.[12]

Modulus of elasticity (stiffness) - In orthodontics, it represents the force required to deflect or bend a wire. Low stiffness wires are preferable because they provide the ability to apply lighter and more constant forces during arch deactivation.[13]

Resilience and Formability- It is the energy that a wire is able to absorb in the elastic range and is able to give back during the alignment of teeth.[14]

Load deflection rate - Orthodontic archwires have an elastic behavior. When the wire is deflected, it gives back a force of response.[14]

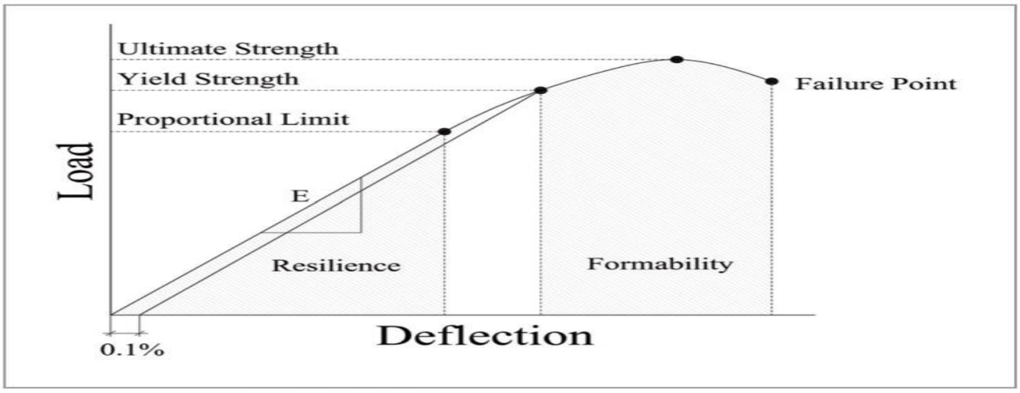

Figure 1: Load-deflection diagram.[14]

It has been shown that a low load/deflection ratio of an orthodontic wire provides desirable force and good control of force magnitude. The fact that NiTi wires possess those characteristics, among others, has made their use almost universal. NiTi alloys are used in the greater biomedical materials area and in dentistry are used in orthodontics.[12]

IDEAL REQUIREMENTS OF ORTHODONTIC WIRES

The forces delivered by the arch wires depend largely on the physical properties of the wire material and dimensions of the wire. The initial arch wires must be biocompatible.[10]

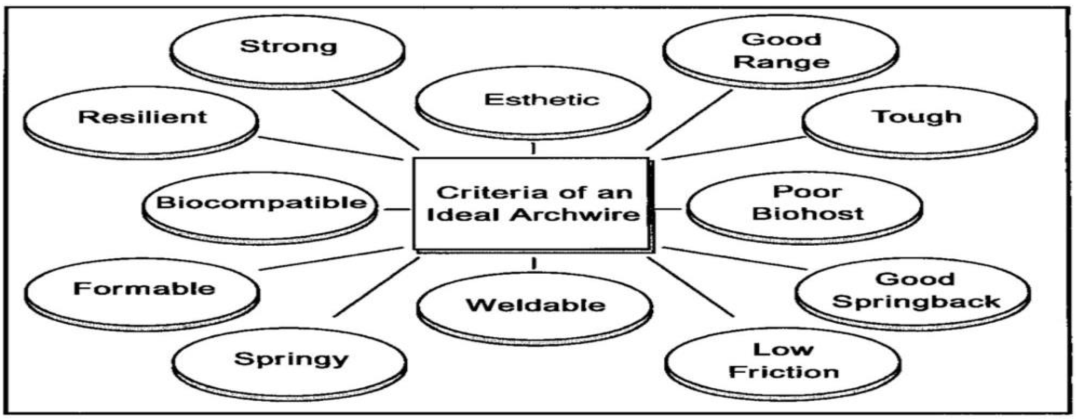

Figure 2: Requirements of ideal archwire

Table 2: Ideal requirements of orthodontic wires[15]

Property	Requirements
Biological	Should be nontoxic.
Chemical	Should be resistant to corrosion and tarnish.
Mechanical	Modulus of elasticity should be high.
Other	Should maintain the desirable properties for extended period of time after manufacture. Should be inexpensive. Should be easy to handle.

Selecting the proper wire

Three factors determine the selection of a proper wire for a clinical application: stiffness, maximum force or moment, and maximum elastic deflection.

CLASSIFICATION OF ORTHODONTIC WIRES

Classification of Orthodontic wires[16]

- Gold alloys
- Stainless Steel alloys. a) Multistranded /Braided wires b) Australian arch wires
- Cobalt Chromium alloy/Elgiloy
- Nickel Titanium alloys. a) Conventional NiTi/M-NiTib)Pseudo ElasticNiTi /A-NiTic) ThermoDynamic Ni-Ti d) GradedThermoDynamicNiTie) ChineseNiTi f) JapaneseNiTig) Copper NiTi
- Alpha Titanium
- Beta Titanium
- Combination wires
- Aesthetics wires a) Coated wires b) Composite wires
- Titanium Niobium and Timolium wires

TYPES OF ARCH WIRES

Gold and gold alloys

A gold alloy under similar conditions can do 70 per cent more work than stainless steel.

Although gold wires were first used in orthodontic practice, although these noble metal wires have minimal use currently because of their much greater cost and low yield strength compared to the popular base metal wires.[16]

Gold Plated stainless steel wire

24 Karat Gold Plated Archwire The perfect archwire to compliment your patients golden brackets. These wires are coated with a super hard finish that will not come off during treatment. The super smooth finish enhances sliding mechanics. Available in both SS and nitanium pro-form archwire with midline marked black for upper and red for lowers.[17,18]

Stainless steel

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, 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. [3]

Stainless Steel Variants

A.J. Wilcok Wires - Mr. Arthur Wilcock of Whittlesea, Victoria, Australia originally developed this special orthodontic wire at the request of Dr. P.R. Begg nearly 40 years ago. Each grade is easily identified by a colored label (figure).[16]

Combination Arch Wires - The wire is combination of two diameters. In the posterior segment diameter is 0.018” ovoid whereas anterior segment 0.018” x 0.022”.

Respond Wires- Respond is a strand, spiral wrap with a central core wire (coaxial) (Figure 2). Respond can deliver light, initial forces while filling the archwire slot for greater control.[16]

Nickel Titanium alloys -The developments in nickel-titanium (NiTi) wire technology have resulted in a decline in the popularity of stainless steel wires for initial alignment. However, stainless steel arch wires are still used by a small proportion of orthodontists.[10]

NiTi wires can be classified according to the crystal structure and phase transformation as follows:[19]

- Stabilised e.g. Nitinol, Titanal and Orthonol.
- Superelastic active austenitic e.g. Sentalloy.
- Thermodynamic-active martensitic e.g. copper NiTi (CuNiTi).
- Graded thermodynamic e.g. Bioforce.

Table 3: Surface modification on NiTiarchwires[20]

Surface modification studies of NiTi alloys.

Technique used	Coating Material Used	Improvement
Electrodeposition	Co and inorganic fullerene-like tungsten disulfide (IF-WS_2) nanoparticle film	66 % of friction coefficient reduction
Electrodeposition	Bisphenol-A epoxy resin and rutile TiO_2	Increase in surface roughness and contact angle, inhibition of Ni ion release
Sandblasting	-	Increase in friction forces
Plasma oxidation with using direct current or radiofrequency	TiO_2	Improvement in superelastic elongation, corrosion resistance and biocompatibility
Physical Vapor Deposition	TiN/Ti	Protection against mechanical damage, inhibition of Ni ion release
Aerosol spray method and immersion method	Octadecylphosphonic acid covalently bonded on the oxide covered onto the Nitinol	Stability and corrosion resistance
Ion beam plating	Diamond-like carbon film	Improvement in wear performance and corrosion resistance
Plasma electrolytic oxidation	-	Aesthetic appearance and good cytocompatibility
Chemical deposition	ZnO	21% reduction in the frictional forces and antibacterial activity against *Streptococcus mutans*
Filtered arching ion plate	TiN	Increase in surface roughness, wettability and biocompatibility
Electrodeposition	Ag nanoparticles	Decrease in *Streptococcus sanguinis* and *Lactobacillus salivarius* colonies
High vacuum plasma ion sputtering	Ti	Reduction in surface roughness and friction coefficient Minimum variations in elasticity of modulus and hardness by nanoindentation in artificial saliva
Ceramic conversion	TiO_2	Improvement in fretting corrosion resistance and reduction in Ni release into the simulated body fluid

Copper Ni-Ti

There are 4 types of Copper Ni-Ti

- Type I: (AF =15°C) **-** It generates very high force and has few clinical indications.
- Type 2: (AF= 27°C) **-** It generates highest force among type 2, 3 and 4. It is best used in patients who have an average to higher pain threshold, patients with normal periodontal health and patients where rapid tooth movement is required and force system generated by the wire is constant.
- Type 3: (AF=35°C) **-**It generates force in mid-range, and best used in patients who have a low to normal pain threshold, periodontium normal to slightly compromised, and when low forces are desired.
- Type 4 :(40°C) **-**It generates intermittent forces, indicated in patient who are sensitive to pain, compromised periodontium. It gets activated only after having hot food and beverages. [21]

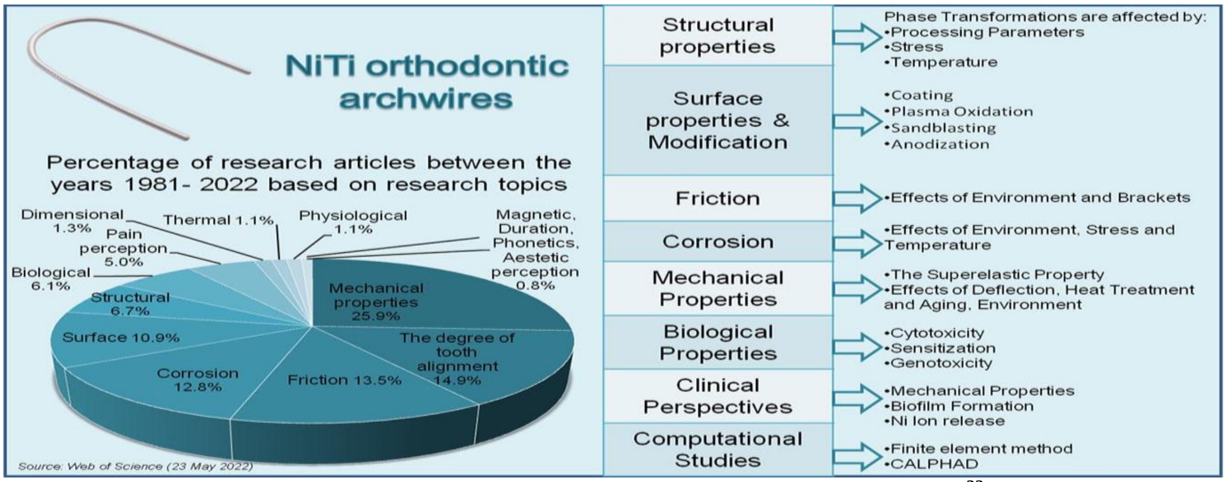

Figure 3: Perspectives of Nickel Titanium Orthodontic archwires[22]

Beta Titanium

Nowadays, β-Ti are used in many applications such as intrusion arches, uprighting molar spring, and cantilevers for intrusion or extrusion of teeth.[13]

Cobalt-chromium nickel alloy (Elgiloy)

Cobalt-chromium nickel alloy has been developed since 1950 and called (Elgiloy) that was initially manufactured by the Company (Elgin, USA). The blue type is the most commonly used by orthodontists because of its formability and the possibility to increase its durability by heat treatment.[23]

Newer Advances in Orthodontic Archwires

Aesthetic archwires

Aesthetics has been an integral part of dentistry these days. Every orthodontic treatment aims to provide the utmost aesthetics to the work. Also, with the evolution of aesthetic brackets and clear aligners, this advancement in archwires has been made. These wires can be of three types: **composite, Optiflex, and coated.**[24]

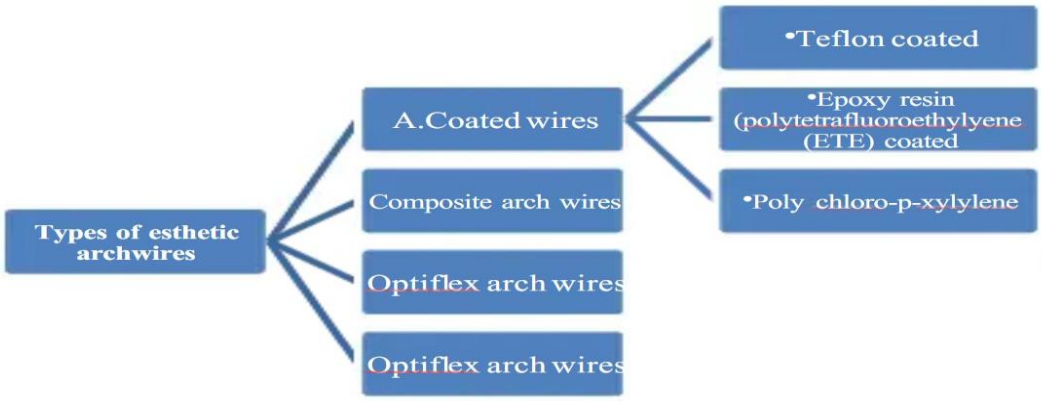

Figure 4: Flowchart showing types of Aesthetic archwires

Other frequently used wires are
Organic polymer retainer wire, SEP orthodontic wires, Filaflex,Orthocosmeticelastinol, Titanium tooth-toned archwire: NiTi. **Imagination wire**, **Nanocoatedarchwire, Orthodontic archwire bending robot system, Motoman UP6, Drift Free Archwire,Medical-grade titanium wires, TiMolium™, Speed Super Cable, SPEED finishing archwires, SmartArch Multi-force , Hills Dual Geometry Archwire, Nitanium tooth toned archwires, Hills Dual-Geometry archwire, BioForce wires, New bactericide orthodontic archwires, Fiber Reinforced Composites as Archwire, TiMolium wire.**[24]**Tri-Force wires**
These are special types of wires that are considered to exert varied and desirable amounts of force on a specific tooth region in the oral cavity, that is, firm pressure on the molars, moderate pressure on the premolars, and very gentle pressure on the incisors. Added advantages of this type of archwires are that it prevents the undesirable tilting of the molars and rotation of the premolars and it has a mild impact on the anterior teeth that will not cause pain to patients. Aside from that, the 3D control over these wires is available since the start of treatment.[24]

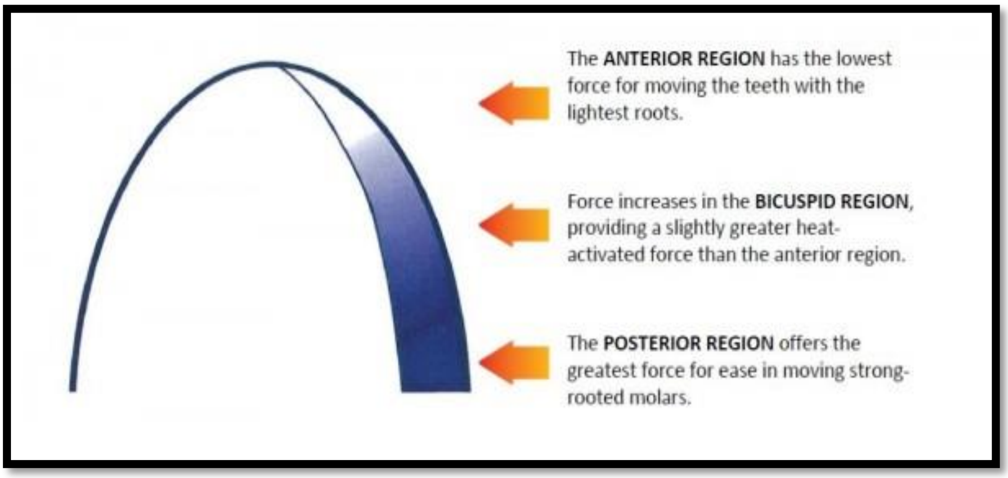

Figure 5: Force distribution by the Tri-Force wire[25]

EFFECT OF ARCH WIRES ON PAIN LEVEL
A randomized controlled clinical trial was performed to compare the nature, prevalence, intensity, and duration of pain related to the use of a relatively recently developed superelastic arch wire and a more traditional multistranded steel arch wire. Other factors likely to influence the pain experience were also investigated.
The results suggested that the thicker 0.016-inch wires were more comfortable, and the analgesic used with them was less. No significant differences were found in terms of gender, in the perception period of initial pain as regards the areas affected within the mouth or the effect of pain on daily living when the 0.014 and 0.016 inch wire groups were compared at 6 hours, 1, 2, 3, 4, 5, 6 and 7 days. At 24 hours, which was found to be statistically significant, more pain relief was used in the 0.014 incharchwire group. The results show that in both groups, initial pain was perceived at 2 hours, peaked at 24 hours and decreased by day 3.[26]

APPLIED TO CLINICAL PRACTICE

KNOWLEDGE OF ORTHODONTIC WIRES APPLIED TO CLINICAL PRACTICE

When to use stainless steel alloys

The advantage of using stainless steel arch wires at the start of treatment, even with loops, lies in the fact that they allow greater control over the arch wire shape while preventing undesirable tooth expansions and projections. Besides, SS wires are extremely affordable.[22]

When to use multi-stranded stainless steel arch wires

Although less formable than conventional steel wires multi-stranded wires are responsive to contours and bends, such as omega loops for posterior tying, thus preventing tooth projection. By resorting to this option the wire properties are optimized.[22]

When to use beta-titanium alloys

These wires have proven an ideal solution for patients with hypersensitivity to chromium and nickel, which are components of all other orthodontic alloys.[22]

When to use nickel-titanium alloys

Thermally activated NiTi wires feature thermally induced shape memory effect in addition to being pliable at lower temperatures and returning to their initial configuration - with increased rigidity - when heated to approximately oral temperature.[22]

CONCLUSION

Recent advances in orthodontic wire alloys have resulted in a wide array of wires that exhibit an amazing spectrum of properties. Stainless steel, cobalt chromium, nickel-titanium, beta-titanium and composite wires are used. These wires demonstrate a wide spectrum of mechanical properties and have added to the versatility of orthodontic treatment.

Stainless steel with high values for strength, low friction, and an almost smooth surface continues to be the mainstay archwire in orthodontic mechanotherapy.NiTi wires are the best choice when it comes to producing light and continuous forces, even in the face of extensive deflections. NiTi wires can save professionals chair time since they do not require leveling and alignment loops or bends and can remain active in the oral cavity for a long period of time.

Appropriate use of all the available wire types may enhance patient comfort and reduce chairside time as well as the duration of treatment.

Most importantly, however, a comprehensive knowledge of wires allows the orthodontist to make an informed - and therefore safer - choice of arch wires free from media manipulation.

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