Orthodontic wires: knowledge ensures clinical optimization

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Abstract

The wide range of orthodontic wires available in the market can raise doubts about the best choice for different clinical situations. Thus, knowledge of their mechanical properties can facilitate the choice of wire required to achieve a given orthodontic movement based on the treatment phase. The evolution of wire manufacturing technology and the development of new orthodontic techniques have led to the search for better quality alloys, more biologically effective for the teeth and supporting tissues. This article summarizes the main characteristics of the wires used in orthodontics, their history, mechanical properties and clinical application, according to specific treatment phases.

Keywords: Orthodontic wires. Mechanical properties. Shape memory effect. Orthodontics.

INTRODUCTION

To be competent, orthodontists should have the manual skills of a craftsman and an in-depth knowledge of orthodontic science. Professionals, however, might wonder, "Would learning about orthodontic wires improve my skills or expand my customer base?" If manual skills alone were sufficient then great craftsmen would make excellent orthodontists. Therefore, knowledge of orthodontic wires allows the professional to perform more efficient movements and avoid damage to teeth and supporting tissues.

Orthodontic mechanics is based on the principle of elastic energy storage and its conversion into mechanical work through tooth movement. Each time the orthodontic appliance is adjusted it stores and controls the transfer mechanism and distribution of forces. An optimal control of tooth movement requires the application of a system of special forces which is properly supported by accessories, such as orthodontic wires.

Despite the considerable number of brands available in the market and their powerful commercial appeal the most widely used consist of four groups of alloys, namely:

Stainless steel; a variety of nickel-titanium (NiTi) alloys (superelastic, thermodynamic and with the addition of copper); beta-titanium alloys and aesthetic composites, recently launched in the market . It is therefore essential that orthodontists acquire some knowledge of the mechanical properties and composition of wires so they can make the best informed choice for clinical use.

HOW ORTHODONTIC ARCH WIRES EVOLVED
When gold was king

Since the old days, when the first professionals glimpsed the possibility of moving teeth they employed wires. Edward Angle was undoubtedly the patron of Orthodontics worldwide. The specialty was the first to be recognized by the science of Dentistry and celebrated its 100 years anniversary during the American Association of Orthodontists (AAO) conference of Chicago, USA, in 2000.

Initially, in 1887, Edward Angle used nickel-silver alloys in his orthodontic accessories. Subsequently he replaced them with copper, nickel and silver-free zinc alloys. Eventually, gold alloys became his favorite choice[18].

Until the early 1930s, type IV gold alloys were the most widely employed in the manufacture of orthodontic accessories. In those days, 14 to 18-carat gold was routinely used for wires, bands, hooks and ligatures as well as iridium-platinum bands and wires. The advantage of using gold alloys lay in the fact that since they can be heat treated their stiffness can be altered by about 30%, in addition to their excellent resistance to corrosion[18].

In Brazil, gold alloys were used by the pioneers of Brazilian Orthodontics, then professors at Universidade Federal do Rio de Janeiro, until the early 1950s (Fig. 1).

The advent of stainless steel

Stainless steel was introduced into orthodontic practice in 1929, when Renfert, a North American company, began selling wires made from these alloys, which were produced by a German company named Krupp[2].

In the 1931 AAO Conference, Norris Taylor and George Paffenbarger introduced steel as a substitute for gold claiming it featured greater resilience and was less likely to break under stress. In 1933, the founder of Rocky Mountain Orthodontics, Archie Brusse, suggested for the first time the clinical application of stainless steel in orthodontics during the meeting of the American Orthodontic Society in Oklahoma City. Since then, the rivalry between gold and steel formally began. Economic factors undoubtedly helped to determine the worldwide acceptance of steel over gold[18].

In Brazil, stainless steel began to be utilized in the manufacture of orthodontic accessories in the late 1940s. Until then, fixed orthodontic appliances were still made of gold. The first course of orthodontics as a specialty in Brazil was spearheaded by the Federal University of Rio de Janeiro (UFRJ) as an outgrowth of the discipline of orthodontics taught in the regular graduate dentistry course. In 2008, the course celebrated its 50-year anniversary. Its founder was Professor Dr. José Édimo Soares Martin - patron of Brazilian Orthodontics[30].

FIGURE 1 - **A**) Package of gold brackets. **B**) Glass containing eyelets, used to correct tooth rotations; dental tungsten needle to aid in welding eyelets; gold band with welded eyelets **C**) Bracket welded to a band, both in gold (Source: material obtained from the files of UFRJ professors, Drs Antonio Carlos Peixoto da Silva and Hélio de Oliveira Fernandes - both members of the group of Brazilian Orthodontics pioneers).

Cobalt-chromium alloys

In the 1940s the Elgin Watch Company developed cobalt-chromium alloy, composed of cobalt (40%), chromium (20%), silver (16%) and nickel (15%), primarily used in the manufacture of springs for watches. In the 1960s, cobalt-chromium alloys were found their way into Orthodontic practice and were patented as Elgiloy® by Rocky Mountain Orthodontics[18].

These alloys have mechanical properties that are similar to stainless steel and compared with wires of the same dimensions they produce forces of similar magnitude[18]. However, in order to use their full response potential some heat treatment should be applied after preparing the bend and prior to tying the brackets with the wire. Most orthodontists never reaped the full benefit offered by these alloys and often cannot even distinguish them from stainless steel given their physical similarities.

A few years later, new alloys emerged
Beta-titanium alloy

Beta-titanium alloys are made from titanium. When subjected to heat treatment these alloys undergo changes in the structural rearrangement of their atoms, aka beta phase[11] titanium alloys.

Beta-titanium alloys have been used as structural material since 1952. Until 1979, however, wire drawing technology did not allow the manufacture of wires of orthodontically compatible cross-sections. In 1977, the beta phase of titanium was stabilized at room temperature[18].

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. It is commercially available as "TMA" (titanium molybdenum alloy) and, for many years, one company owned its sole manufacturing rights. Currently, the market offers a wider variety of commercial brands[11].

Nickel-Titanium (NiTi) alloys

Nickel-titanium alloys were developed by the U.S. Naval Laboratory in Silver Spring, Maryland, by researcher William Buehler. He was the first to observe the so-called "shape memory effect" typical of this material. This alloy had hitherto not yet been applied in Orthodontics[11,23].

In 1972, Unitek Corporation produced the NiTi alloy for clinical use under the trade name Nitinol®, composed of 55% nickel and 45% of titanium, in an equiatomic structure[3]. However, at that time, the alloy had no shape memory effect or superelasticity. Still, it was seen as a step forward towards achieving light forces in large activations. In 1976, several brands of nickel-titanium wires were launched in the orthodontic market and were characterized as materials of high elastic recovery and low stiffness, garnering widespread clinical acceptance due to these properties. These wires, however, featured no thermal activation or superelasticity.

The evolution of nickel-titanium alloys
Nickel-titanium superelastic alloys

In 1985 the clinical and laboratory use of a new superelastic nickel-titanium alloy was reported. It was called "Chinese NiTi" and was developed especially for application in orthodontics. The term "superelasticity" had not been used until that time. The Chinese nickel-titanium wire was the first to show superelastic potential. It was originally developed in China and after having its properties improved it was reported that this wire had greater elastic recovery and less stiffness than conventional nickel-titanium wires of the same cross section as well as less permanent deformation after deflection. Since then, a number of studies have been conducted in an attempt to produce orthodontic wires with similar properties, a goal achieved only in 1986 with the introduction of the "Japanese NiTi". These alloys were produced by the GAC Company (GAC Int., NY, USA) under the trade name

Sentalloy[6,8,24].

Thermodynamic nickel-titanium alloys

The commercial use of thermodynamic nickel-titanium alloys began in the 1990s. In addition to the properties of elastic recovery and resilience provided by superelastic wires, thermodynamic nickel titanium wires boast the additional feature of being activated by oral temperature.

Gradually thermodynamic nickel-titanium wires

The 1990s saw the emergence of gradually thermodynamic nickel-titanium wires since there is a consensus that the tooth's response to the application of force and the amount of tooth movement achieved are dependent on the periodontal surface area. This means that an ideal arch wire should not only generate constant and light forces but should also be able to vary the force magnitude according to the periodontal area involved. Thus, a range of different forces should be generated by the same arch wire in its different segments. The magnitude of force applied is graded across the entire arch wire length according to the size of the patient's teeth[18].

Copper, nickel and titanium alloy (CuNiTi)

In the mid-1990s, nickel-titanium wires with the addition of copper (CuNiTi) first became available on the market. They consist basically of nickel, titanium, copper and chromium. Due to the incorporation of copper these wires feature better defined thermal properties than NiTi superelastic wires while yielding an outstanding system of forces with increased control over tooth movement. These wires were first marketed by Ormco Corporation with three transition temperatures (27° C, 35° C and 40° C), enabling clinicians to quantify and apply loads that are appropriate to the orthodontic treatment goals[27].

AESTHETIC ORTHODONTIC WIRES

Since orthodontic treatments extend over a number of months the aesthetic appearance of the appliance is rated by patients as a significant factor worthy of consideration. The demand for aesthetics led several companies to begin production, in the late 1970's, of non-metallic brackets made from polycarbonate or ceramics. Currently, aesthetic brackets have become an inescapable reality of the orthodontic clinic, offering an alternative to metal brackets. However, the same is not true of aesthetic wires, which were seldom reported in the orthodontic literature until the mid-2000s[13].

Different types of aesthetic orthodontic wires have been launched on the market, such as: Teflon coated stainless steel wires, stainless steel wires coated with epoxy resin, orthodontic wires comprising a nylon-based matrix reinforced with silicone fibers, and orthodontic wires made from polymer composite material reinforced with glass fiber (Fig. 2).

Table 1 shows the development of orthodontic arch wires components throughout the history of orthodontics.

FIGURE 2 - Orthodontic appliance with aesthetic brackets. Composite wire reinforced with glass fiber on the upper arch and NiTi on the lower.

THE IMPORTANCE OF LEARNING ABOUT THE MECHANICAL PROPERTIES OF ORTHODONTIC ARCH WIRES

Many orthodontists choose their orthodontic wires based on clinical impressions. Ideally, however, the choice of arch wires should go hand in hand with knowledge of their mechanical properties. In the days when most orthodontists used only stainless steel arch wires with nearly identical moduli of elasticity for one and the same diameter, the tool most commonly used to gauge the amount of applied force was arch wire cross section variation. With the introduction of new alloys featuring different mechanical properties as well as nickel-titanium and beta-titanium alloys, orthodontists now have additional variables to control the magnitude of applied force[4].

The traditional arch wire sequence, given the same material, provided progressively larger load/deflection rates as arch wire cross section increased. However, the variation in wire diameter also produced variation in the slack between the wire and bracket slot. When using small sized cross section arch wires the resulting excessive slack could lead to lack of control over the movement of the tooth crowns and roots. When using materials that have different moduli of elasticity, orthodontists can determine the amount of slack between the arch wire and the bracket slot thereby reducing the number of arch wires required for alignment[4].

The ability to use rectangular cross-section arch wires with moduli of elasticity that are suited for the dental alignment and leveling phase enables orthodontists to maintain control over root position even during the early stages of treatment.

Nevertheless, there are situations in which round cross-section arch wires are the best choice, such as when the orthodontist desires first and second order movements or friction reduction[4].

The elastic properties of arch wires serve as

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

TABLE 1 - Development stages of orthodontic wires.

a parameter to indicate the most recommended treatment phase for each arch wire. No single arch wire is best for all phases. There is no such thing as an ideal arch wire[17].

Tooth alignment and leveling comprise the most important preliminary clinical phase in the fixed orthodontics procedure. Authors agree unanimously that continuous light forces are desirable to produce efficient, controlled and physiological tooth movement with minimal impact to the teeth and supporting tissues[15,23].

DEFINITION OF RESILIENCE

In the initial phase of treatment, resilience is an important mechanical property worthy of consideration by the orthodontist. Resilience is a property of arch wires whereby they store energy when deformed elastically, and release energy when unloaded[25]. It represents the stored energy available in the wire to move teeth during deactivation.

DEFINITION OF MODULUS OF ELASTICITY

Modulus of elasticity (rigidity) is another variable that influences the success of any given treatment phase. It can be defined as a measure of the rigidity of the material. It is determined by the binding forces that operate between atoms. Since these forces are constant for each metal structure, the modulus is one of the most constant properties of metals[29]. Clinically, it represents the magnitude of the force required to deflect or bend a wire. In an attempt to improve the biological environment for tooth movement and minimize the patient's discomfort the initiation of treatment requires low stiffness wires capable of producing lighter, constant forces during arch wire deactivation. However, during the finishing phase, stiffer arch wires - with a higher modulus of elasticity - should be used to contain the movements achieved in the earlier treatment phases[27].

DEFINITION OF ELASTIC LIMIT

Elastic limit refers to the maximum workload allowed. It is the maximum amount of stress that can be applied to a wire before it undergoes permanent deformation. It is the stress beyond which plastic deformation occurs and the material can no longer return to its original shape. A high elastic limit is desirable to prevent chewing forces from inducing plastic deformation or fracture[28].

DEFINITION OF FORMABILITY, WELDABILITY AND FRICTION

Formability refers to the ability of wires to be bent into desirable shapes without fracturing or deforming permanently while weldability relates to a wire's ability to have other materials, including accessories, welded to it. Stainless steel alloys are easily weldable[10].

To achieve lower resistance to tooth movements and an improved response to the commands given through bends on the wires or pre-adjusted brackets, there should be no friction between wires and brackets[7].

THE IMPORTANCE OF BIOCOMPATIBILITY

Due to the fact that orthodontic wires are positioned close to the oral mucosa for long time periods they should be resistant to corrosion, should not allow the release of ions in the oral cavity or cause allergic responses. In other words, orthodontic wires must be biocompatible with oral tissues[22].

DEFINITION OF SHAPE MEMORY EFFECT

In conventional materials, when the elastic limit is exceeded and the load is removed, the material will show a permanent deformation of its crystalline structure represented by the macrostructural aspects of the shape (Fig. 3). However, alloys with "shape memory effect" undergo a reversal to the initial dimensions after deformation and reheating. It is as if the material "remembered" its original shape. This effect is called "Shape Memory Effect" and any alloy featuring this property is called "shape memory effect alloy." This phenomenon is characterized by a steady accumulation of force in the wire to the point of deformation. Similarly, when the wire is deactivated and returns to its original configuration the forces remain constant over a long period of time, which is clinically required to ensure physiological tooth movement[28].

Nickel-titanium alloys feature such property, which is applicable in Orthodontics.

There is a well known relation between shape memory effect and so-called "martensitic transformation", which can be defined as a change in the crystalline structure of nickel-titanium wires when tied to brackets. However, these wires show a tendency to return to the same original crystalline structure, which causes the return to the original wire shape as if they had never been deflected[28]. If the martensitic transformation is caused by the load applied to the wire, it can be called superelastic. If such return to the original crystalline structure is induced by oral temperature the wire displays a thermal activation property.
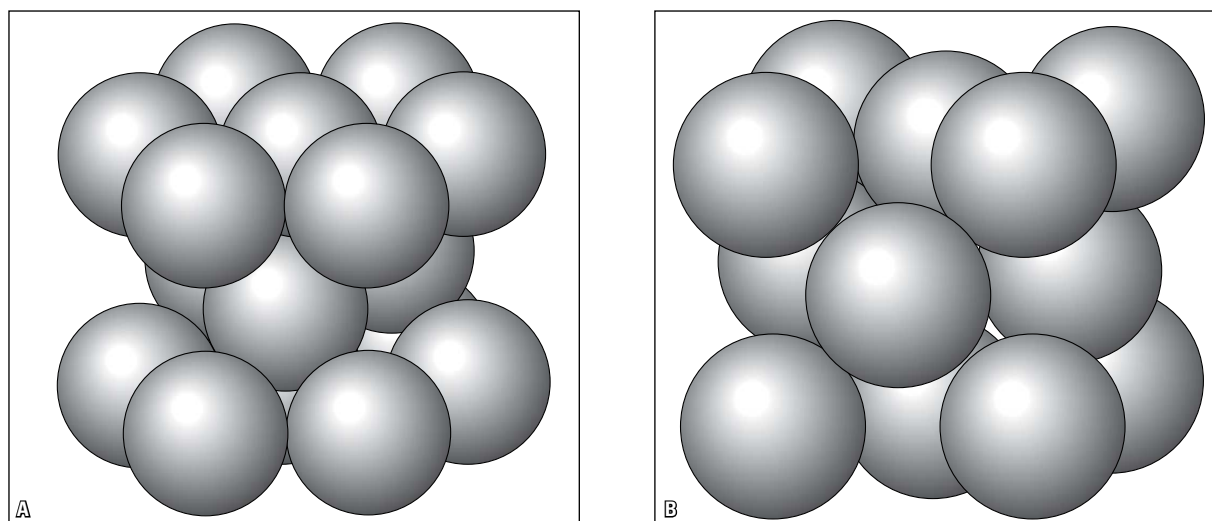
FIGURE 3 - **A)** Schematic representation of the compact hexagonal crystal structure of nickel-titanium alloys (martensitic phase). **B)** Schematic representation of the cubic crystal structure of face-centered nickel-titanium alloys (austenite phase).

KNOWLEDGE OF ORTHODONTIC WIRES APPLIED TO CLINICAL PRACTICE
When to use stainless steel alloys

Types 302 and 304 of 18-8 stainless austenitic wires are used in Orthodontics[9].

For the tooth alignment and leveling phase even steel wires with a smaller cross-section result in high loads, which are not consistent with physiological forces. At this stage of the orthodontic treatment the use of steel wires is possible through the incorporation of loops that increase the wire's activation range and disguise, as it were, the low resilience and high stiffness of the wire. The disadvantage of using loops lies in the fact that as these loops lose their original shape they change the direction of force vectors. Loops can also hinder hygiene by entrapping food particles. If not positioned properly, loops can damage adjacent soft tissues (Fig. 4, 5).

Thus, to offset their relatively low resilience (compared with other alloys), stainless steel wires need to be bent during the alignment phase in order to increase the amount of wire in the interbracket space and distribute the forces. Therefore, straight stainless steel arch wires would not be recommended in the initial stages of treatment without the use of loops[6].

Stainless steel wires boast excellent resistance to corrosion[16] and exhibit higher elastic limits and modulus of elasticity, which makes them more convenient than other alloys, especially in cases where more rigid wires are required, such as during the space closure and finishing phases (Fig. 6). These recommendations apply to both the Standard Edgewise and Straight Wire techniques.

Stainless steel wires feature excellent weldability and formability and - compared with all other alloys used in orthodontics - exhibit a lower friction coefficient.

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, stainless steel arch wires are extremely affordable.
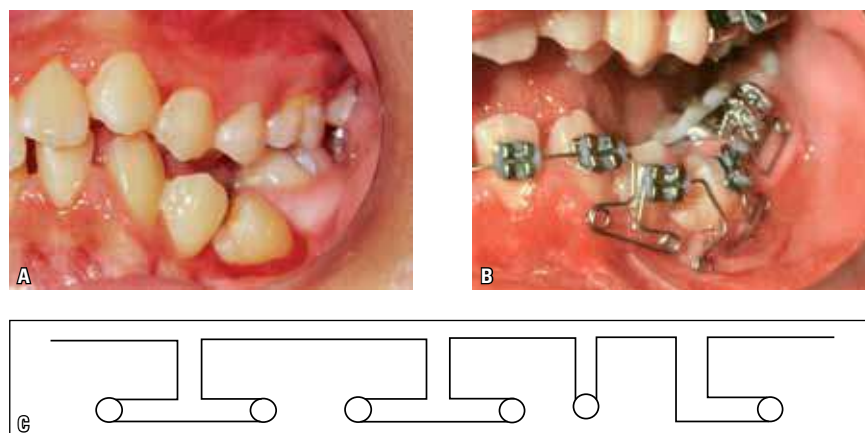
FIGURE 4 - **A**) Impaction of tooth 35 after removal of a dentigerous cyst in the region and misalignment of tooth 34. **B**) 0.014 Multiloop stainless steel arch wire for the alignment of an impacted second premolar and misalignment of the first premolar. **C**) Drawing of the loops made on the arch that is installed in the malocclusion shown in Figure **A**.
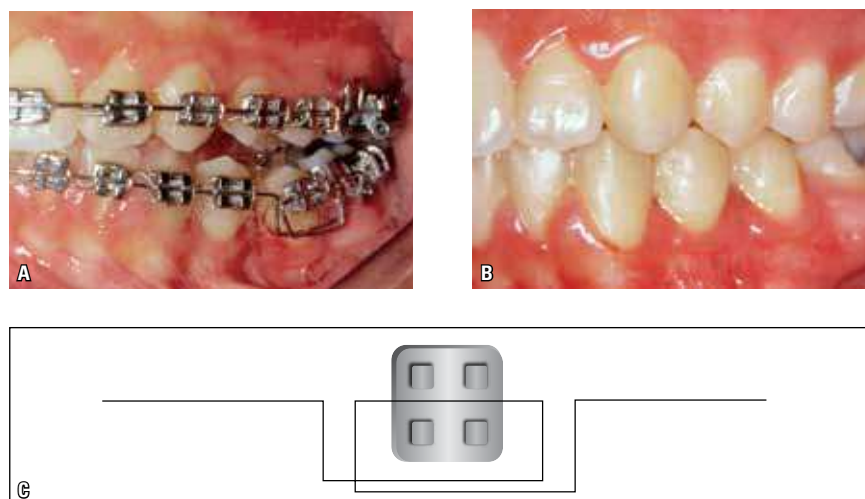

FIGURE 5 - **A**) Second premolar alignment and leveling continued (Fig. 4A) with 0.016" stainless steel wire and a box loop. **B**) Finished case (note gingival contour after removal of orthodontic appliance). **C**) Drawing of box loop in Figure **A**.
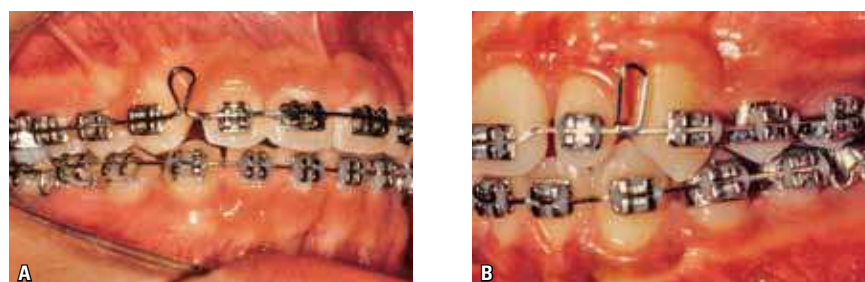

FIGURE 6 - 0.019 "x 0.025" stainless steel arch wire for upper incisor retraction: **A**) Drop-shaped loop and **B**) Reverse drop-shaped loop (reverse loop).

When to use multi-stranded stainless steel arch wires

By using multi-stranded stainless steel arch wires one can employ stainless steel arch wires in the initial stage of tooth alignment and leveling without the need for loops. These wires feature mechanical properties that differ considerably from conventional single-strand stainless steel wires even when similar diameters are compared[19].

Multi-stranded wires can be braided, twisted or coaxial. All have similar properties and great potential for use in the early stages of orthodontic treatment[27].

The elastic recovery of multi-stranded wires is 25% higher than that of a conventional stainless steel wire of identical diameter[19]. The rigidity of interbracket segments is much lower than that of conventional stainless steel wires of identical diameter[16].

When comparing conventional stainless steel wires with multi-stranded wires of similar diameter it is safe to state that the latter have one fifth the modulus of elasticity of the former, and an activation range 150 to 200 times greater than the former.

Stainless steel multi-stranded wires share some mechanical properties with nickel-titanium alloys[27].

The resilience of multi-stranded wires is considered high. However, their low elastic limit makes them susceptible to plastic deformation by external forces, such as chewing[16,20].

When subjected to identical stress these wires exhibit a much higher degree of permanent deformation than nickel-titanium[24].

With the purpose of saving chair time professionals often neglect to contour multi-stranded arch wires according to intercanine and intermolar widths as well as the shape and width of the patient's arch. 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.

WHEN TO USE BETA-TITANIUM ALLOYS

Beta-titanium alloys have greater resilience than stainless steel wires of identical cross-section and approximately twice the stiffness of nickel-titanium wires. These wires, however, have less than half the modulus of elasticity and weldability of stainless steel wires. Therefore, similarly to stainless steel wires beta-titanium alloys can have hooks and other accessories welded to them, albeit with a certain amount of difficulty. Besides, the boast excellent formability[11]. Thus, loops can be fashioned to close spaces or move specific teeth while producing much smaller loads than similar loop designs made with stainless steel (Fig. 7). These wires generate more friction than stainless steel wires but less friction than NiTi wires. Their clinical application would be best suited in situations where load distribution is lighter than what stainless steel alloys typically generate. Also in situations that require stiffness and formability, e.g., intermediate stages of treatment, such as space closure. Moreover, these wires have proven an ideal solution for patients with hypersensitivity to chromium and nickel, which are components of all other orthodontic alloys[5,11].

WHEN TO USE NICKEL-TITANIUM ALLOYS

For the tooth alignment and leveling phase nickel-titanium (NiTi) alloys feature extremely interesting properties. The unique properties inherent in these alloys are a high elasticity limit, low modulus of elasticity (low rigidity) and high resilience. These alloys can sustain a very wide deflection and return to their original shape while generating moderate and uniform forces. Both superelastic NiTi wires and thermally active wires as well as those to which copper has been added are more resilient and less rigid than other alloys. This means that these wires are the best choice[15] when
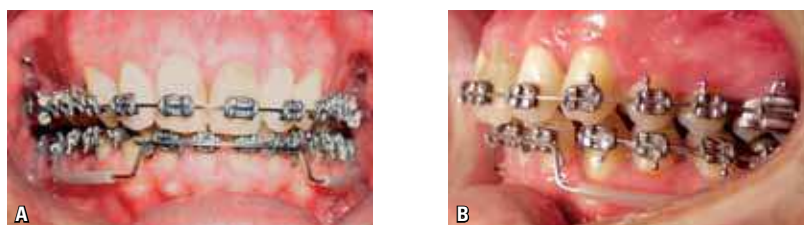
FIGURE 7 - Burstone-type incisor intrusion arch made of beta-titanium alloy and positioned on a utility arch: **A)** front view and **B)** side view
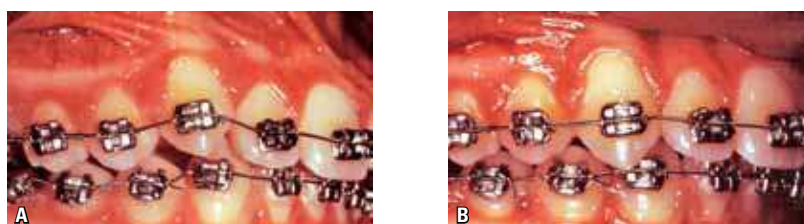

FIGURE 8 - Superelastic NiTi wire used in dental arch alignment given its adequate resilience and lower rigidity than other alloys while producing light and continuous forces.

it comes to producing light and continuous forces, even in the face of extensive deflections (Fig. 8).

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. These alloys feature low formability and bends can cause them to fracture. Thus, additional resources should be used for stops in the posterior region to prevent tooth projection. Since these alloys cannot be reshaped they are sold in pre-contoured forms. Professionals should therefore pay close attention to the original width of the patient's arches and always stock different arch forms to meet the needs of each particular case. Given the fact that these alloys will not respond to first, second and third order bends they should be used primarily in the Straight-Wire technique.

NiTi alloys are not weldable and have a higher friction coefficient with brackets when compared with stainless steel. In vitro studies have shown that nickel-titanium superelastic alloys boast excellent elastic properties and generate continuous forces when subjected to loading, even in the presence of increased deflection. This feature has made these wires extremely popular for use in the leveling and alignment of teeth[23].

In addition to the properties of elastic recovery and resilience of superelastic wires, thermodynamic nickel-titanium wires exhibit an additional characteristic, i.e., heat activation. 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[26].

On the other hand, since CuNiTi are manufactured for use under three transition temperatures (27° C, 35° C and 40° C) they can be used for different treatment[26] purposes, as described in Table 2.

With the launch of CuNiTi alloys on the market, orthodontic treatment protocols that

combine these wires with the use of self-ligating brackets have emerged. These protocols aim to achieve more biologically compatible treatments thanks to the deployment of physiological forces as well as shorter treatment time.

Currently, the Damon System® is the most popular brand of self-ligating brackets on the market. Unlike conventional mechanics, the designers of this system advocate that it is possible to move teeth without bone loss. In such cases, biological dynamics would purportedly enable a physiological adaptation of the alveolar bone in response to the orthodontic treatment. This issue, however, is still fraught with controversy in the literature.

FEATURES OF AESTHETIC ARCH WIRES
Teflon coated stainless steel arch wires

Teflon coating imparts to the wire a hue which is similar to that of natural teeth. The coating is applied by an atomic process that forms a layer of about 20-25µm thickness on the wire. This layer then undergoes a heating process and acquires a surface with excellent sliding properties and substrate adhesion[14]. Materials used for wire coating should fulfill the requirements of being easily applied in thin layers, resistant and having a low friction coefficient. They should also be biocompatible, pleasantly aesthetic and consistent with the translucency of aesthetic brackets and the different hues of the teeth[17].

Manufacturers of orthodontic materials are currently investing in the search for the ideal wire coating, one that would combine aesthetics and mechanical efficiency. The different types of coatings can change some wire properties, such as friction. It should also be noted that Teflon coating protects the underlying wire from the corrosion process. However, since this coating is subject to flaws that may occur during clinical use, corrosion of the underlying wire is likely to take place after its prolonged use in the oral cavity.

CuNiTi	INDICATIONS
at 27°C	When a higher force magnitude is required to be constantly and rapidly conveyed to the teeth during deactivation, due to the fact that these wires are activated at lower than body temperatures their shape memory effect shows up immediately after tying, promoting fast alignment and leveling of malpositioned teeth. It is recommended that these wires be cooled (in a freezer or by applying "Endo-ice") at least one hour prior to insertion in the bracket slot to prevent premature activation when tying.
at 35°C	When moderate and constant forces are desired to align, level and rotate malpositioned teeth these wires are subject to deformation at temperatures lower that 20°C and would return to their original shape when exposed to oral temperature. Due to the fact that these wires are activated at body temperature they do not initiate reverse phase transformation as fast as wires manufactured at 27°C. Since only moderate forces are generated, rectangular arch wires can be used during the initial treatment phases. These wires should be cooled prior to insertion. Their efficacy can be noted within approximately one month after insertion.
at 40°C	When light, intermittent forces are required, 40°C CuNiTi arch wires are the best choice. Their use is recommended as the first arch wires for pain hypersensitive patients presenting with severely malpositioned teeth for whom rigid arch wires would be contraindicated either because of ligature issues or due to the generation of biologically incompatible forces. Since these wires are activated at 40°C patients should be instructed to use warm mouth rinse several times a day to further enhance the activation.

TABLE 2 - Aplicações clínicas dos fios de CuNiTi fabricados com diferentes temperaturas de ativação.

Stainless steel wires coated with epoxy resin

The coating process is performed through deposition by incrustation at the base of the wire using epoxy resin of about 0.002" thickness. With this procedure, a strong adhesion

between the coating and the internal wireless develops, thus preventing the wire from sliding underneath the coating layer.

The authors assessed the mechanical properties of aesthetic wires by comparing metal NiTi wires with aesthetically coated wires of the same diameter. The results of the comparison were as follows: Aesthetic wires fractured under lighter loads than non-coated; the three groups of wires tested in this study showed the widest thresholds, indicating that they were superior to non-coated wires;

The working limit of non-coated wires (GAC, Masel and TP brands), and the GAC and Masel aesthetic wires accumulated higher amounts of similar energy during activation. The non-coated TP wires accumulated a higher amount of energy during activation than could be endured by their resilience properties with variations between groups due to different activation loads. Aesthetic wires exhibited significantly higher activation thresholds than non-coated wires, demonstrating superior properties insofar as this feature is concerned. The deactivation thresholds of aesthetic wires were lower than those of non-coated wires, which demonstrates their superior performance regarding these properties[21].

Orthodontic wires consisting of a nylon-based matrix and reinforced with silicone

This wire was launched in 2000. Known commercially as Optiflex® (Ormco Corp.), it was not recommended for clinical use and its mechanical properties were inferior to metal wires.

Orthodontic wires made of polymeric composite reinforced with glass fiber

Polymer composites are routinely used as dental restorative materials mainly due to their biocompatibility and aesthetic qualities. This combination of favorable aesthetic and mechan-

ical properties motivated the manufacture of orthodontic arch wires from a fiber-reinforced unidirectional polymer. This arch wire has the advantage of blending in with tooth color and being as rigid as metal arch wires. The elastic recovery of the composite wire should be sufficient to promote proper tooth movement, i.e., the wire should recover its original shape after being tied to the teeth.

Research with composite wire prototypes suggest that these arch wires could work well during the early and intermediate stages of orthodontic treatment. Research results show that composite arch wires have a stable modulus of elasticity. Since 1997 scholars have predicted that with the introduction of aesthetic composite materials metal wires will likely be replaced in most orthodontic applications, just as metal alloys were replaced by aerospace industry composites[17].

In 2003, Huang et al.[13] compared composite wire with metal Ni-Ti wire (Reflex®, TP Orthodontics Inc.). The results showed that the mechanical performance of the prototype was comparable to that of metal wire.

However, some contraindications regarding the of aesthetic wires should be highlighted, such as: Transverse fractures, stress fractures with fiber detachment, fractures flush with the surface of the polymer/fiber interface, compression fractures originating in bends located in the fibers and fractures flush with the intralaminar surface[21].

The use of arch wires whose size can remain constant while their mechanical properties are undergoing changes that facilitate in achieving the goals of each treatment phase, could theoretically lead to fewer arch wire replacements. In order to play this role satisfactorily the arch wire in question needs to have the necessary endurance to remain in the oral cavity for a time period equal to or greater than is usually the case with other arch wires.

CONCLUSIONS

Acquiring scientific knowledge of orthodontic wires can be a daunting task. Ultimately, however, it becomes fascinating insofar as it enables professionals to choose the best possible treatment protocol for the patient thereby rendering treatment more effective, faster, less costly and less likely to cause damage to teeth and supporting tissues. 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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