COMPARISON OF PHYSICAL CHARACTERISTICS BETWEEN STAINLESS STEEL, NICKEL TITANIUM, COBALT CHROMIUM, BETA TITANIUM ARCH WIRES

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ABSTRACT:

AIM & OBJECTIVE:- To evaluate the properties and then compare the data to identify a better efficient material

BACKGROUND:- Archwire are wires that conforms to the dental arch that can be used with dental brackets as a source of force in correcting irregularities in the position of teeth or even used to maintain existing dental positions. Recent advancements must be make it ideal for early to mid-stage treatment with moderate to severe crowding. This wire is best suited for the initial stage because it is easy to engage at lower temperatures. It includes improved surface hardness, reduces sliding friction no separate coation and excellent super-elastic qualities.

REASON:-This study will help to tabulate the comparison of characteristic between various arch wires used in orthodontics, thus providing a clear image whether the new material has added beneficiary values and also to which extent.

KEYWORDS: Arch wires, NiTi, Physical property, elasticity.

INTRODUCTION

Recent advances in orthodontic wire alloys have resulted in a varied array of wires that exhibit a wide spectrum of properties[1]. Up until the 193Os, the only orthodontic wires available were made of gold. Austenitic stainless steel, with its greater strength, higher modulus of elasticity, good resistance to corrosion, and moderate costs, was introduced as an orthodontic wire in 1929, and shortly afterward gained popularity over gold [2].Since then several other alloys with desirable properties have been adopted in orthodontics. These include cobalt-chromium, nickel-titanium, beta- titanium wires [3]. Presently the orthodontist may select, from all the available wire types, one that best meets the demands of a particular clinical situation. The selection of an appropriate wire size and alloy type in turn would provide the benefit of optimum and predictable treatment results. The clinician must therefore be conversant with the mechanical properties and the relevant clinical applications of these properties for these wires. Although several investigators have evaluated the mechanical properties of various wire types, a cohesive clinical interpretation of their findings is lacking [4]. This purpose of research pertinent literature in order to describe the mechanical properties and optimal clinical applications of stainless steel, cobalt-chromium, nickel-titanium, beta- titanium, The objective of this article is to provide the practicing clinician with the basic working knowledge on orthodontic wire characteristics and usage.

MATERIALS AND METHODS

The properties of orthodontic wires are commonly determined by means of various laboratory tests. Thus, wires have previously been investigated under tension in bending and torsion. Although these tests do not necessarily reflect the clinical situations to which wires are usually subjected they provide a basis for comparison of these wires [5]. Tests in bending provide some information on the behaviour of wires when subjected to first- and second-order bends. Similarly, results of torsional tests reflect, to a certain degree, wire characteristics in a third-order direction I Tension, bending, and torsion are uniquely different stress states and place varied demands on wire performance [6]. The properties of wires under these three stress states are therefore considered independently. Graphic description of stress against strain can be used to determine yield strength, modulus of elasticity, stored energy, and springback when the wire is subjected to tensile loading [7]. Similarly, graphic plots of bending moment against angular deflection or torsional moment against torque angle are used for the evaluation of these wire characteristics under conditions of bending and torsion, respectively

Several characteristics of orthodontic wires are considered desirable for optimum performance during treatment . These include a large springback, low stiffness, high formability, high stored energy, biocompatibility and environmental stability, low surface friction, and the capability to be welded or soldered to auxiliaries and attachments. A brief description of each of these desirable wire characteristics is provided.

I. Springback. This is also referred to as maximum elastic deflection, maximum flexibility, range of activation, range of deflection, or working range. Spring- back is related to the ratio of yield strength to the mod- ulus of elasticity of the material (Y S / E) [8] . Higher spring- back values provide the ability to apply large activations with a resultant increase in working time of the appliance. This, in turn, implies that fewer arch wire changes or adjustments will be required [9]. Springback is also a measure of how far a wire can be deflected without causing permanent deformation" or exceeding the lim- its of the material.

2. Stiffness or load dejection rate. This is the force magnitude delivered by an appliance and is proportional to the modulus of elasticity (E) [10] . Low stiffness or load deflection rates provide (1) the ability to apply lower forces, (2) a more constant force over time as the appliance experiences deactivation, and (3) greater ease and accuracy in applying a given force.

RESULT

Stainless steel wires

The yield strength to elastic modulus ratio (YS /E) indicates a lower springback of stainless steel than those of newer titanium-based alloys. The stored energy of activated stainless steel wires is substantially less than that of beta-titanium and nitinol wires. This implies that stainless steel. The yield strength to elastic modulus ratio (YS /E) indicates a lower springback of stainless steel than those of newer titanium-based alloys. The stored energy of activated stainless steel wires is substantially less than that of beta-titanium and nitinol wires [11]. This implies that stainless steel wires produce higher forces that dissipate over shorter periods of time than either beta-titanium or nitinol wires, thus requiring more frequent activations or arch wire changes[12]. Wires produce higher forces that dissipate over shorter periods of time than either beta-titanium or nitinol wires, thus requiring more frequent activations or arch wire changes.

Wire	*Springback*	*Stiffness*
Stainless steel	Low	High
Cobalt-chromium	Low	High
Nickel-titanium	High	Low
Beta-titanium	Average	Average

COBALT CHROMIUM WIRES

The advantages of Co-Cr wires over stainless steel wires include greater resistance to fatigue and distortion, and longer function as a resilient spring. In most other respects, the mechanical properties of Co-Cr wires are very similar to those of stainless steel wires. Therefore, stainless steel wires may be used instead of Co-Cr wires of the same size in clinical situations in which heat-hardening capability and added torsional strength of Co-Cr wires are not required [13]. The high moduli of elasticity of Co-Cr and stainless steel wires suggest that these wires deliver twice the force of beta-titanium wires and four times the force of nitinol wires for equal amounts of activation. The resultant undesired force vectors are therefore greater with Co-Cr and stainless steel wires than with both types of titanium alloys[14]. Clinically, this may translate into faster rates of mesial movement of posterior teeth, thus placing greater demands on intra and extraoral anchorage.

NICKEL TITANIUM WIRES

The most advantageous properties of nitinol are the good springback and flexibility, which allow for large elastic deflections. The high springback of nitinol is useful in circumstances that require large deflections but low forces. It has generally been noted that nitinol wires have greater spring- back and a larger recoverable energy than stainless steel or beta-titanium wires when activated to the same amount of bending or torquing [15]. This results in increased clinical efficiency of nitinol wires since fewer arch wire changes or activations are required. Similarly, for a given amount of activation, wires made of titanium alloys produce more constant forces on teeth than stainless steel wires [16]. A distinct advantage of nitinol is realized when a rectangular wire is inserted early in treatment. This accomplishes simultaneous leveling, torquing, and correction of rotations. Heat treatment of nitinol results in substantial alterations in mechanical properties of the alloy[17]. Changes in crystallographic arrangement caused by heating produce the "memory" effect in this alloy. Andreasen and Morrow" described the "shape memory" phenomenon as the capability of the wire to return to a previously manufactured shape when it is heated through its transitional temperature range (TTR). This effect is realized by holding the wire in the desired shape while under- going high-temperature heat treatment. When subsequently cooled, the wire can be deformed within certain strain limits, from which it recovers its original shape if heated through its unique TTR[18]. This change from distorted to original form involves a transformation of nitinol from the martensitic to the austenitic phase.

BETA TITANIUM WIRES

The springback for beta titanium is superior to that of stainless steel. A beta-titanium wire can therefore be deflected almost twice as much as stainless steel wire without permanent deformation. Beta-titanium wires also deliver about half the amount of force as do comparable stainless steel wires ; for example, an 0.018 X 0.025-inch beta-titanium wire delivers approximately the same force as a 0.014 X 0.020-inch stainless steel wire in a second-order activation[19]. The former configuration has the added advantage of full bracket engagement and a resultant greater torque control than the smaller stainless steel wire. The good formability of beta-titanium wire allows stops and loops to be bent into the wire. However, Burstone and Goldberg" recommend that these wires should not be bent over a sharp radius. Helices that are commonly used with stainless steel to lower the load deflection rate of the appliance may not be necessary with beta-titanium wires because of their low modulus of elasticity and high springback[20]. This helps to simplify appliance design by eliminating the need to place loops and helices in the wire.

Wire type and composition	*Reference*	*Test type*	*YS* $\times 10^3$ *psi* ($\times 10^6$ *N/m²*)	*E* $\times 10^3$ *psi* ($\times 10^6$ *N/m²*)	*YS/E* $\times 10^{-3}$
Stainless steel—71% Fe, 18% Cr, 8% Ni, <0.2% C	Goldberg and Burstone[15]	Tensile	275 (1.89)	25,000(172.4)	11.0
	Asgharnia and Brantley[19]	Tensile*	188 (1.20)	24,400(168.3)	7.7
		Bending*	287 (1.98)	30,800(212.4)	9.3
		Tensile†	226 (1.56)	25,000(172.4)	9.0
		Bending†	330 (2.27)	32,800(226.2)	10.1
	Kusy et al.[16]	E: Bending* YS: Tensile*	227 (1.56)	28,000(193.0)	8.1
Cobalt-chromium—40% Co, 20% Cr, 15% Ni, 15% Fe, 7% Mo, 2% Mn	Goldberg and Burstone[15]	Tensile	319 (2.20)	29,000(200.0)	11.0
	Asgharnia and Brantley[19] (blue Elgiloy)	Tensile*	130 (0.90)	25,000(172.4)	5.2
		Bending*	210 (1.45)	31,000(213.8)	6.8
		Tensile†	180 (1.24)	28,000(193.1)	5.4
		Bending†	290 (2.00)	36,000(248.3)	8.0
Nickel-titanium—52% Ni, 45% Ti, 3% Co	Asgharnia and Brantley[19]	Tensile*	49 (0.34)	5,000 (34.5)	9.8
		Bending*	82 (0.56)	7,000 (48.3)	11.7
	Drake et al.[7]	Tensile*	45 (0.31)	4,300 (29.7)	10.4
		Bending*	65 (0.45)	4,300 (29.7)	15.1
	Kusy and Stush[5]	E: Bending* YS: Tensile*	86 (0.59)‡ 69 (0.48)§	6,440 (44.4)‡ 4,850 (33.4)§	13.3 14.2
Beta-titanium—79% Ti, 11% Mo, 6% Zr, 4% Sn	Goldberg and Burstone[15]	Tensile	170 (1.17)	9,400 (64.8)	18.0
	Asgharnia and Brantley[19]	Tensile*	95 (0.45)	9,400 (64.8)	10.1
		Bending*	165 (1.14)	12,500 (86.2)	13.2
	Drake et al.[7]	Tensile*	125 (0.86)	9,960 (68.7)	12.5
		Bending*	141 (0.97)	8,370 (57.7)	16.8
	Kusy and Stush[5]	E: Bending* YS: Tensile*	105 (0.72)	10,500 (72.4)	10.0

* As received.
† Heat treated to 900° F (482° C).
‡ Round wires.
§ Square and rectangular wires.

DISCUSSION

The practical applications of orthodontic wires can be optimized by carefully selecting the appropriate alloy type and wire size to meet the demands of a specific clinical situation. Kusy5' and Kusy and Greenberg have recommended a sequential use of arch wires selectedfor optimal use of the mechanical properties of their constituent alloys[21]. The authors suggest that for initial leveling requiring wide-ranging tooth movements, a 0.016inch nitinol wire outperforms a 0.0175 inch triple-stranded stainless steel wire, an 0.018-inch round nitinol wire is superior to a 0.014-inch round stainless steel wire, and an 0.018-inch square nitinol wire outperforms a 0.014-inch round stainless steel wire[22]. However, in a recent report, Kusy and Stevens57 noted that 0.015~inch triple-stranded wires demonstrate a greater working range than either nitinol or beta- titanium wires of similar or greater dimensions. The authors also indicate that multistranded wires compare more favorably with titanium wires than suggested by previous research and may provide a viable alternative to the more expensive titanium wires for initial leveling[23]. The intermediate stages of treatment require closing loops, gable bends, and attachments. Beta-titanium wires meet these demands while providing greater range of activation than stainless steel or Co-Cr wires. In torsion, the formability and stiffness of stainless steel and Co-Cr wires far exceed those of the titanium wires, thereby making these alloys the finishing wires of choice[24]. The lower friction between stainless steel or Co-Cr wires and brackets suggest that these wires may be more suitable than other alloys for movement of teeth along a wire. Until the recent introduction of new types of orthodontic alloys, increments in wire stiffness during treatment were instituted by progressively increasing the cross-section of stainless steel wires. Burstone refers to this as "variable cross-section orthodontics."

The author further states that advances in orthodontic wire alloys have made it possible to control wire stiffness by varying material properties-namely, the modulus of elasticity[25]. This is known as "variable modulus orthodontics." Burstone formulates his concepts by stating that the overall stiffness of the orthodontic appliance (S) is determined by the wire stiffness (Ws) and design stiff- ness (As) as represented by: s = ws x As

Design stiffness (As) is dependent on factors such as interbracket distance and the incorporation of loops and coils into the wire[26]. Changes in wire stiffness (Ws), on the other hand, can be brought about by altering the cross-sectional stiffness (Cs) and/or the material stiff- ness (MS) as designated by the formula: Ws = MS x Cs

where the cross-sectional stiffness is determined by a cross-sectional property such as moment of inertia of the wire and the material stiffness is dependent on the modulus of elasticity of the alloy. Therefore, an increase in appliance stiffness (S) can be brought about not only by change in appliance design or increase in cross- sectional thickness of the wire, but also by selecting a material with a higher modulus of elasticity. The relationship of material stiffnesses for stainless steel, cobalt-chromium, nickel-titanium and beta-titanium wires are in the ratio of 1:1.2:0.26:0.42. Several advantages of "variable modulus orthodontics" have been suggested as follows:

1. The amount of play between bracket and wire is not dictated by the desired wire stiffness, but is under full control of the clinician. This implies that the orthodontist determines the amount of bracket/wire play desired before selection of the wire. Once the cross-sectional size and shape have been established, the desired stiffness can be implemented by selecting an alloy with an appropriate material stiffness[27].

2. The low moduli of elasticity of the newer orthodontic alloys permit the use of light, rectangular wires even during the early stages of treatment. Rectangular wires are preferable over round wires because they can be better oriented in the bracket in such a way that forces work out in the proper directions. They further aid in patient comfort by preventing loops from turning into the cheeks and gingiva. Rectangular wires also maintain better control over root position by delivering both moments and forces.

3. The use of newer orthodontic alloys with their lower moduli of elasticity offers substantial advantages with a Q.Q22-inch bracket slot.

4. The selection of an appropriate alloy type and wire size may reduce the number of arch wires needed for alignment by reducing bracket/wire play early in treatment[28]. In addition, since the titanium wires also work more efficiently and over longer periods of time because of their greater springback, the number and frequency of arch wire changes are reduced.

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