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THE EFFECT OF INITIAL ARCHWIRES SELECTION ON ORTHODONTIC TREATMENT EFFICINECY AND OUTCOME

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Abstract:

Initial orthodontic archwires perform the desired tooth movements in the phase of alignment and leveling during the fixed orthodontic treatment by applying force to the teeth. The force should be light and continuous which will result in maximum tooth movement, with minimal root resorption and pain. This literature review aims to explore the current knowledge about initial orthodontic archwires.

A literature search was conducted on the following electronic databases: PubMed, Cochrane Library, and Google Scholar, as well as grey literature sources, were reviewed. The search resulted in the selection of relevant peer-reviewed articles, clinical trials as well as academic sources such as textbooks, that provide a comprehensive overview of the topic.

The review highlights the importance of selecting the appropriate archwire material, wire size, and shape for optimal and predictable orthodontic treatment outcomes.

It also emphasizes the impact of these variables on force generation in order treatment optimization. Lastly, discuss the advantages and disadvantages of archwire customization, a current global trend that should provide better treatment outcomes in a shorter period of time and improved patient comfort. Overall, careful selection of initial archwire is important in achieving successful treatment outcomes customized per patient needs and treatment goals.

Key words: orthodontic wires, alloys, elastic modulus, orthodontic force

Introduction

Initial orthodontic archwires play a crucial role in orthodontic treatment as they provide the foundation for tooth movement and alignment. The goal of the first stage of orthodontic treatment besides aligning misaligned teeth into the arch is to specify and control the anteroposterior position of the incisors, the posterior width of the arches, and the form of the dental arches [1].

Comprehensive orthodontic treatment can be divided into three stages. The first stage, which is alignment and leveling, is followed by the working stage which involves the correction of molar relationship and space closure, and last, the finishing stage [1].

Therefore, if the proper alignment phase does not precede, not any pivotal phase cannot be finished accurately. For that reason, this stage is of great importance, thus any acceleration in this phase can have a direct consequence on the final treatment goal, and ultimately the patient experience.

The efficiency of initial archwires is determined by several factors such as material properties, wire shape, and size as well as the force generated [1].

The use of high-quality, biocompatible materials with optimal spring back tends to increase efficiency and provide more consistent and predictable tooth movement, with fewer archwire changes [2].

Contemporary orthodontics strives to provide treatment that fits the individual patient's needs and treatment goals. The application of light and continuous forces when using initial archwires can help to reduce treatment time and improve overall treatment outcomes [1].

Clinically, the optimal force will result in maximum tooth movement, with minimal root resorption and pain, the two most commonly reported side effects from fixed orthodontic treatment [3].

Materials Properties

For an ideal orthodontic archwire several characteristics should be considered: aesthetics, biostability, friction, formability, weldability, resilience, and spring back. To date, no ideal archwire, or archwire that is suitable for all stages of the orthodontic treatment has been produced. When the archwire is used in treating patients, its elastic property ratio indicates that each alloy excels at a particular juncture- whether it be in the initial, intermediate, or final stage of the treatment [4].

Recent advances in orthodontics philosophies and orthodontics materials resulted in the production of a wide range of orthodontic archwires with different mechanical properties [2]. The evolution of orthodontic archwires starts with gold and its alloys.

Continues with stainless steel arch wires, from which the multistranded stainless steel wires are used as a material of choice during the initial alignment and leveling. The use of multiple strands of steel wire is a way to improve the performance of the steel during the initial alignment. This manufacturing process makes the multistranded steel wires more flexible, releasing lower forces when deflected and making them able to sustain large deflections compared to the standard stainless-steel wires [5].

The advantages of stainless-steel wires are the lower cost, the absence of nickel in their composition as a potential allergen and the low friction which offer lower resistance in tooth movement. On the other hand, stainless steel archwires have lower spring back in comparison with newer nickel titanium wires and lower stored energy, which will result in higher forces that dissipate over shorter period of time requiring more frequent activations or arch wire changes [2].

Nickel-titanium has been a huge success when was first recognized during the 70s by Andreasen. It is able to deliver light forces over a long range. The material is characterized by low stiffness, light force, and elasticity, and possesses an equal loss of force per unit deactivation. Nickel-titanium wires exhibit two unique properties: shape memory and super elasticity [2,5]. Today, there are three groups of commercially available NiTi archwires that differ in their stress-strain relationships: martensitic stable, austenitic active and martensitic active [4].

“Nitinol”, a stabilized nickel titanium alloy composed of 55% nickel and 45% titanium aimed to address the need for lighter forces and greater working range, but this material did not possess shape memory effect, a remarkable property of an orthodontic archwire [5].

Superelastic NiTi archwires have austenite crystal structure. They provide constant force delivery at increasing wire deflection. Therefore, they are good choice in large deflections. The disadvantage is the low formability, cannot be soldered or welded and the higher price. Superelastic NiTi wires are not intended to go phase transformation at mouth temperature, so their superelasticity results from stress induction [5].

Thermoelastic nickel titanium alloys were developed during the 90’s. In addition to the property of maintaining the constant load of superelastic wires, thermoelastic NiTi wires have the ability of being thermally active, a property that is responsible for shape memory once heated through the transition temperature [6].

This characteristic makes the placement of the wire in crowded dentition a significant advantage, but according to Proffit when this wire reaches the oral temperature there is no reason to expect thermally sensitive wire to perform better than one without this feature.

Bioforce archwires have been developed to go one step further, by generating different forces along the length of an archwire. Graded thermally active wires provide lighter forces of approximately 80 g anteriorly and heavier forces of 300 g posteriorly.

The development comes as a consequence of the opinion that the response of a tooth to force application and the rate of tooth movement is dependent on the surface area of the periodontium. This means that the ideal arch wire would not only deliver constant and low force to misaligned teeth, but it should also be capable of varying its level of force delivery, consistent with the area of periodontium involved [6].

Coaxial archwires combine the advantages of multistrand stainless-steel archwires and superelastic wires. They are made of individual strands that are laced together in a long spiral to maximize flexibility and minimize force delivery. The superelasticity enables the wire for full bracket engagement with extremely low unloading force delivery [7].

Two systematic reviews study the clinical efficacy of different initial orthdontic archwires [3,8].

The systematic review of *Riley* conducted in 2008, includes 7 clinical trials that compare multistranded stainless steel wires versus nickel-titanium arch wires, or different nickel-titanium archwires regarding the rate of alignment.

The review suggests that there have been few clinically significant differences between the studied archwires, but still, due to lack of data for conducting a meta-analysis, there are insufficient information to make clear recommendations regarding the most efficient alignment archwire. One of the studies in the review, conducted by *West et al.* showed that NiTi was significantly quicker at aligning teeth in the lower labial segment than multistranded stainless steel wire, but it also states that the clinical significance of the difference is small [9].

Another study from the review by *Evans et al* suggested that in the case of multistranded stainless steel and NiTi archwires, differences may not have been found because the NiTi wires were not clinically deformed enough to take advantage of their superelastic properties [10].

The Cochrane review by *Wang et al.* conducted in 2018, includes 12 randomized controlled trials [3].

The objective of the review is to examine the efficacy of different initial archwires in terms of rate of alignment, pain, and root resorption. The trials are grouped into six main comparators: multistranded stainless steel versus superelastic nickel-titanium arch wires, multistranded stainless steel versus thermoelastic nickel-titanium arch wires, conventional nickel-titanium versus superelastic nickel-titanium arch wires, conventional nickel-titanium versus thermoelastic nickel titanium arch wires, superelastic nickel-titanium versus thermoelastic nickel titanium arch wires, single-strand superelastic nickel-titanium versus coaxial superelastic nickel-titanium archwires.

The group comparing single-strand superelastic nickel-titanium versus coaxial superelastic nickel-titanium archwires showed moderate quality evidence that coaxial superelastic NiTi can produce greater tooth movement over 12 weeks. This review was also unable to conduct a meta-analysis due to the heterogeneity of the design of included studies.

Size and Shape

Besides the archwire material, the size and shape are of great significance in determining archwire properties. These two variables are primarily chosen by the specific patients' needs and treatment goals. According to *Proffit*, decreasing the diameter of a beam by 50% would reduce the strength of a beam by the same percentage [1]. Even though the strength will be reduced, the combination of material properties and geometric factors will play a crucial role in the performance of the beam. On the other hand, when the diameter is increased, the range of the wire decreases proportionally and the springiness decreases as a fourth power function [11].

Generally, initial archwires are round with their diameter increasing from 0.012 to 0.018 inches depending on the irregularity associated with the dentition. A randomized clinical trial compares the efficacy of two different diameters of CuNiTi archwire, 0.014 and 0.016 inches archwire [12].

Results suggest that there may be some differences in treatment outcomes between the two groups, even though they are not statistically significant. Also, the study shows that alignment is not independent of time despite the superelasticity of the CuNiTi archwire. In terms of reducing the Little Irregularity Index, 0.014 inches CuNiTi archwire showed a greater reduction, even though not statistically significant. The reasons for improved efficacy might be better wire engagement or less friction.

Another interesting finding is that different archwire sizes could be more effective than the others at particular directional movements.

The archwire cross-section shape can be round, square, or rectangular. Also the form of the archwire represented by its curvature can be different, from prefabricated in different forms to customized per patients teeth. Both aspects dictate the amount and direction of the force that is generated on the teeth.

Initial orthodontic archwires, usually round ones after aligning and leveling of the teeth are replaced with Ni-Ti rectangular or square archwires that aim to express the torque. The difference between a round and rectangular archwire is the area of contact with the bracket. When there is more wire-bracket contact, more force is generated to the tooth and more significant tooth movement is expected [13].

The archwire form can be customized as per the patient's needs or preformed from a variety of commercially available products. When choosing a preformed archwire, it is recommended that the arch form matches the pretreatment dental arch of the patient, especially in the mandibular arch. Generally, arch forms are classified into tapered, square, and ovoid types [14].

The treatment of a crowded dental arch, where no tooth size reduction or tooth extraction is planned, aims to increase the arch perimeter by transverse expansion and proclination. These arch form changes depending on the magnitude may have an impact on the long-term stability, especially when it comes to overexpansion of the inter canine dimension and excessive mandibular incisor proclination [15].

Besides the stability, archwire form has an impact on the orthodontic force delivered to the teeth of the mandibular dental arch. One study examines the force delivered to central incisors, canines, and first molars according to the classification of preformed archwire forms.

The study finds a correlation between inter canine width and force levels distributed to mandibular teeth, resulting in unfavorable orthodontic force being delivered to the mandibular incisors in labial inclination when using a preformed archwire with an inter canine width that is narrower than the dental arch[16] For these reasons, the initial arch form is of great importance while creating the orthodontic treatment plan and choosing the most appropriate initial archwire.

Customization

The traditional orthodontic treatment that practices the straight wire philosophy uses prefabricated brackets in conjunction with prefabricated archwires that come in different, predefined sizes and shapes. As we can see the archwire material, size, and shape have an impact on orthodontic treatment and the evolving technology aims to deliver customized orthodontic treatment based on the individual patient needs and treatment goals.

With the development of CAD/CAM technology and more recently 3D printing technology, a lot of effort is directed toward creating customized archwires tailored to patients' teeth and jaw. The archwires can be bent or shaped to accommodate patient-specific needs and provide precise tooth movement with less patient discomfort. This is supposed to result in more effective and efficient orthodontic treatment. The advantages of customized orthodontic archwires are not only personalized care but also reduced chair-side time and extended periods between two return visits [17]. The disadvantage on the other hand, besides the increased cost, is the precision of the computerized systems. As far as some systems are transparent on their data about the precision of the implementing setups, for a large number of clinically used systems no such information is available [18]. Another potential disadvantage is the longer fabrication time and complexity of fabrication, which requires advanced skills and expertise in wire bending and shaping by an orthodontist since human-computer interaction is required throughout the entire 3D process [17].

Force Generation

The force generated by an archwire is crucial in providing optimal orthodontic treatment. Different initial orthodontic archwires deliver different forces depending on their material, shape, and size. Proffit[1] describes the ideal alignment arch wire as one that provide light, continuous force of approximately 50 gm to produce the most efficient tipping. Heavy force, in contrast, should be avoided. The concept of optimal force have been extensively debated and at present the precise force level is still not known. Ren et al. in their systematic review of the literature concluded that there is no evidence concerning optimal force levels in orthodontics [19,20].

Quantifying the force is difficult because of individual variation in tissue response, root morphology and the type of tooth movement [10,19].

In order to evaluate the mechanical properties of orthodontic archwires, laboratory tests are used. The results provide a theoretical frame for further comparison.

Stainless-steel archwires due to their stiffness and strength often generate non-physiological force. On the other hand, multistrand stainless steel wires distribute lighter forces on the teeth. Nickel-titanium archwires provide light forces, greater working range, and constant force on different deflections [5]. Thermoelastic NiTi archwires when reaching the body temperature return to the original shape, providing a consistent force over time [6].

The study of *Quintão et al.* compares the forces generated by multistrand stainless-steel archwires, superelastic and thermoelastic NiTi initial archwires [21]. Study results suggest that all three investigated archwires release light forces and are suitable for the initial phase of the fixed orthodontic treatment, with the lowest force generated by the multistrand stainless steel archwire (1.94N), and it is followed by thermoelastic and superelastic Ni-Ti archwire.

Reddy et al. compare the force generated by co‑ axial multistranded stainless steel wires, nickel–titanium, and copper–nickel–titanium archwire and also investigate the effect of wire dimension on the force that is generated. 0.016 nickel–titanium showed the highest load‑ deflection forces, whereas 0.014 co‑ axial wires showed the least [22].

Results show that load-deflection forces are directly proportional to the cross-section of the wire. The study suggests on a high amount of force loss in co-axial wires, which is attributed to their lack of super elasticity and shape memory.

Gatto et al. evaluate the mechanical properties of superelastic and thermal nickel–titanium (NiTi) archwires. Study results suggest that thermal archwires exerted significantly lower working forces than superelastic wires of the same size [23].

Additionally, the study emphasizes the effect of the wire size on the force generated by the wire. With increasing archwire dimensions a statistically significant increase in working forces for both superelastic and thermal wires is observed. These results are in accordance with study results of *Parvizi and Rock*, where thermally active wires produced less force that the non-thermally active wire [24]. Also, the wire size had a significant effect on the force produced.

Conclusion

The selection of an appropriate initial orthodontic archwire is crucial for the overall orthodontic treatment. The archwires come in different materials, sizes, and shapes. All these factors have an impact on the force that is generated on the teeth and consequently the rate of tooth movement.

Too much force can cause root resorption, pain, and tissue hyalinization. Too little force will cause no results or very slow tooth movement. During the initial phase of the fixed orthodontic treatment round, small-diameter archwires are used, since they can provide light and continuous force.

Nowadays, nickel-titanium initial archwires are generally preferred choice due to their cost-effectiveness, shape memory and super elasticity that should provide constant force in different deflections over extended periods of time.

Careful selection of an initial orthodontic archwire that will fulfill patients' needs and treatment goals is essential during treatment planning. It is an orthodontist's responsibility to have a profound knowledge of all aspects of clinical and mechanical properties of orthodontic archwires to provide optimal, safe, and successful orthodontic treatment.

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