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Review Article

Oral hygiene prophylactic aids on the force degradation of Closed Coil Springs

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ABSTRACT:

Various parameters affect the force produced by the coil springs. The effect of alloy, wire size, lumen size, pitch angle (angle at which coils deviate from a perpendicular line to the long axis of the spring) of the coils and length of the springs on the load-deflection rate and stiffness have been investigated. The use of nickel titanium closing coils serves as one of many techniques for space closure, individual tooth retraction or protraction, distal movement of teeth, and traction on impacted teeth. Nickel titanium coil springs do not exhibit rapid force decay such as that seen with elastic chain or elastic modules, nor do they display the extremes in space closing forces of stainless steel coils or closing loops. Fluoride ions in the prophylactic agents have been reported to cause corrosion, discoloration and alteration of the mechanical properties of metallic wires, particularly when passivated wire surfaces break because of mechanical friction between brackets and wires.

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INTRODUCTION

Over the years, a variety of methods comprising of different materials have been used to close spaces between teeth as in the case of canine retraction after the extraction of premolars. These include latex elastics, coil springs, synthetic elastic modules, headgear, and recently magnets.[1]

Various parameters affect the force produced by the coil springs. The effect of alloy, wire size, lumen size, pitch angle (angle at which coils deviate from a perpendicular line to the long axis of the spring) of the coils and length of the springs on the load-deflection rate and stiffness have been investigated. In general these studies concluded that: (1) for a constant lumen size, an increase in wire size increases the load-deflection rate, (2) for a constant wire size, an increase in lumen size reduces the load-deflection rate, and (3) an increase in pitch angle leads to a higher load-deflection rate.[2-6]

The use of nickel titanium closing coils serves as one of many techniques for space closure, individual tooth retraction or protraction, distal movement of teeth, and traction on impacted teeth. Nickel titanium coil springs do not exhibit rapid force decay such as that seen with elastic chain or elastic modules, nor do they display the extremes in space closing forces of stainless steel coils or closing loops. Their use does not require reliance on patient cooperation, as does interarch elastic wear. It has been suggested that excessive force in space closure can produce adverse effects such as loss of incisor torque control and loss of tip and rotational control of upper molars with relative extrusion of their palatal cusps. The low constant force of nickel titanium springs may be more biologically compatible than the intermittent high forces delivered by elastic chain, which has been found to degrade by up to 50% after 4 weeks of activation. The rate of space closure has been found to be quicker and more consistent with nickel titanium coils than with elastic modules, with no observable differences in final tooth position.[5-7]

Although both beta titanium and SS alloys form corrosion-resistant passivation layers, these protective oxide layers can be chemically disrupted, leading to corrosion susceptibility. In addition to corrosion in artificial saliva and chloride media, it has been recently reported that both beta titanium and SS have exhibited corrosion in the presence of experimental fluoride-based solutions.[4-6]

One of the most important components of successful orthodontic treatment is the maintenance of good oral hygiene and caries control. Compromised oral hygiene can lead to enamel demineralization and decay. Daily topical fluoride is commonly prescribed by orthodontists to guard against this complication. Acidulated phosphate fluorides (APFs) have been used extensively to prevent demineralization or remineralization of white spot lesions around orthodontic brackets. However, fluoride ions in the prophylactic agents have been reported to cause corrosion, discoloration and alteration of the mechanical properties of metallic wires, particularly when passivated wire surfaces break because of mechanical friction between brackets and wires.[6-9]

REVIEW OF LITERATURE

Walker, Reis, Kula, Ellis and Fricke[9] studied the effect of fluoride prophylactic agents namely acidulated fluoride agent and a neutral fluoride agent on the loading and unloading mechanical properties and surface quality of β-titanium and stainless steel orthodontic wires. The results suggest that using topical fluoride agents with β-titanium and stainless steel wire could decrease the functional unloading mechanical properties of the wires and potentially contribute to prolonged orthodontic treatment.

Kao, Ding, Hong, Chou and Huang[10] investigated the toxicity of fluoride corrosion extracts of stainless steel and nickel-titanium wires on a human osteosarcoma cell line. The SS and NiTi wires were corroded by an electrochemical method with 0.2% pH-3.5 acidulated phosphate fluoride in artificial saliva, and pH-4 & pH-6.75 artificial saliva solutions. The extracts were analyzed for nickel, chromium, and titanium ions by the atomic absorption method. The cell survival rate was determined. They concluded that the corrosive solution of the extracts of either SS or NiTi wires in acidified NaF artificial saliva can cause cell toxicity and the best way to prevent toxicity is to change the wires after fluoridation or to remove the wires when applying fluoride.

Pun and Berzins[11] studied the Corrosion behavior of shape memory, superelastic, and nonsuperelastic nickel-titanium-based orthodontic wires at various temperatures and found that the corrosion rate of various nickel-titanium wires increase with temperature and different phases present may influence corrosion rate trends.

Segal, Hell and Berzins[12] studied the Influence of stress and phase on corrosion of a superelastic nickel-titanium orthodontic wire and concluded that Stress increased the corrosion rate in nickel-titanium and beta-titanium orthodontic wires. Alterations in stress/strain associated with phase transformation in superelastic nickel-titanium might alter the corrosion rate in ways different from wires not undergoing phase transformation.

Vidoni, Perinetti, Antoniolli, Castaldo and Contardo[13] studied the Combined aging effects of strain and thermocycling on unload deflection modes of nickel-titanium closed-coil springs and found that NiTi-based closed-coil springs may not have a superelasticity phase, and prolonged strain and thermocycling do not produce clinically relevant alterations in their deactivation forces.

Wichelhaus, Brauchli, Ball and Mertmann[14] studied the Mechanical behaviour and clinical application of nickel-titanium closed-coil springs under different stress levels and mechanical loading cycles and concluded that the strongly superelastic closed-coil springs with preactivation are recommended. In addition, the oral environment seems to have only a minor influence on their mechanical properties.

Maganzini, Wong and Ahmed[15] studied the Forces of various nickel titanium closed coil springs and suggested that only a few springs tested exhibited physiologic peak load forces and constant deactivation forces. The labeling of nickel titanium closed coil springs is confusing and misleading.

Pires, de Souza, Filho, Degan, dos Santos, Alberto and Tubel[16] also studied the force degradation of different elastomeric chains and nickel titanium closed coil springs and found that the force reduction of NiTi spring was the lowest among the materials. In the first day, force degradation of the elastomeric materials was even more significant, attaining the level of almost 26%, whereas the spring suffered a degradation of only 2.8%. After 28 days, a mean reduction of 16.1%, 63.2% and 64.0%, for the NiTi Spring, Memory chain and Plastic chain, respectively.

Ahrari, Ramazanzadeh, Sabzevari and Ahrari[17] studied the effect of fluoride exposure on the load-deflection properties of superelastic nickel-titanium-based orthodontic archwires and suggested that subjecting NiTi wires to fluoride agents decreased associated unloading forces, especially at lower deflections, and may result in delayed tooth alignment.

Lombardo, Toni, Stefanoni, Mollica, Guarneri and Siciliani[18] studied the effect of temperature on the mechanical behaviour of nickel-titanium orthodontic initial archwires and found that all nickel-titanium wires showed a significant change related to temperature in terms of behaviour and force for both traditional and heat-activated wires. Stress under high temperatures can induce permanent strain, whereas the residual strain detected at low temperatures can be recovered from as temperature increases.

Bezrouk, Balský, Smutny, Nosek, Záhora, Hanus and Polma[19] studied the Thermo-mechanical properties of NiTi closed coil springs--force degradation and force regeneration over time, viscous properties and concluded that Springs should be mechanically stabilized before their application. The degree of force degradation over time is insignificant for mechanically stabilized springs. Degradation or regeneration of force over time, mechanical stabilization or micro movements in the mouth don't cause any transition between individual stress-strain curve phases.

Escalona, Carreras, BarreraMora, Lasbrucci, and Gil-Mur[20] Studied the effect of temperature on the orthodontic clinical applications of NiTi closed-coil springs and concluded that the changes of the temperatures do not modify the superelastic behaviour of the NiTi closed-coil springs. The corrosion potential of NiTi in artificial saliva is decreasing by the rise of the temperatures.

DISCUSSION

Recent advances in orthodontic wire alloys have resulted in a varied array of arch wires that exhibit a wide spectrum of properties. The dynamic environment of the oral cavity also in turn exerts its influence on the performance of the orthodontic arch wires. The use of mouthwashes for maintaining oral hygiene has been reported as having a potential deleterious effect on fixed orthodontic treatment which may affect the treatment duration and outcome by affecting the mechanical properties and surface characteristics of orthodontic arch wires.[10- 13]

In oral cavity, many factors can have an effect on force production and force degradation of traction aids, such as saliva, temperature fluctuation, pH variation, fluoride ions and rinses, oxygen content, free radicals, salivary enzymes and masticatory forces. In the oral cavity the force degradation can be attributed to loss of energy due to deactivation and environmental influences such as presence of proteins, citrates and lactates, sugars and its breakdown products, lipids and other substances and inorganic ions like chlorides, sodium, potassium, magnesium, phosphates, bicarbonates, thiocynates, sulphates and minute amount of fluorides, iodides, bromides and ferrous ions. These components along with saliva, food and beverages, temperature changes (0-60 degrees) as well as atmospheric components can influence the metallurgic properties of the arch wire materials. Stainless steel wire has been previously shown to be susceptible to stress corrosion cracking in fluoride solutions because of hydrogen absorption and embrittment.[10- 13]

The pH of the electrolyte inside the pit decreases, which causes further acceleration of the corrosion process. Large ratio between the anode and cathode areas favours increase of the corrosion rate. Corrosion products ($Fe(OH)_3$) form around the pit resulting in further separation of its electrolyte.[15, 16]

The presence of chloride ions in artificial saliva in the present study may also be responsible for force degradation of stainless steel coil springs though changes in chloride ion concentrations may not be reflected with the use of chlorhexidine. On the other hand pitting corrosion generated by the chloride ions may make the steel more susceptible to corrosion with fluoride hence leading to an additive effect that is reflected in the 18% force reduction with fluoride mouthwash.[8- 10]

The degradation and loss of the oxide film expose the underlying alloy leads to corrosion and the absorption of hydrogen ions from the aqueous-based solution because of the high affinity of titanium with hydrogen. It has been reported that hydrogen concentrations in NiTi wires, as measured with thermal desorp¬tion analysis, linearly increased with time of immersion in fluoridated solution. The amount of hydrogen ranged from 100 to 1000 ppm when the wires were immersed in the fluoride solution from 2 to 24 hours. With increasing fluoride exposure, the tensile strength of immersed Ni-Ti alloy was also reduced to the critical stress level of martensite transformation.[15- 18]

CONCLUSION

Fluoride based mouthwash (Senquel®-AD) have a greater detrimental effect on the force values of both Nickel-Titanium and Stainless Steel closed coil springs as compared to the Chlorhexidine based mouthwash and Artificial saliva alone. Both flouride and chloride ion present in the mouthwash and Artificial saliva could account for the greater effect of immersion on Stainless Steel though further studies are needed to evaluate the combined effect of both the ions.

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