SHORT COMMUNICATION

Friction-An Overview

Utkarsh Upadhyay[1], Preeti Agarwal[1], Anju Loomba[1], Amol Hivalekar[1]

ABSTRACT

Friction is a force that retards or resists the relative motion of two objects in contact. The static frictional force is the smallest force needed to start the motion of solid surfaces that were previously at rest with each other, whereas the kinetic frictional force is the force that resists the sliding motion of one solid objective over another at a constant speed. In general, increasing wire size or cross-sectional shape (round or rectangular) for a constant bracket size increased the frictional resistance at binding and nonbinding angulations. Ion implantation of nickel titanium and beta titanium wires, as well as bracket surfaces are effective means to reduce friction.

Keywords: Coefficient of friction, Ion implantation, Bioforce Sentalloy, β-titanium

INTRODUCTION

Friction is a force that retards or resists the relative motion of two objects in contact. The direction of friction is tangential to the common boundary of the two surfaces in contact. As two surfaces in contact slide against each other, two components of total force arise; the frictional force component (F) and the normal force component (N) perpendicular to the contacting surfaces and to the frictional force component. Frictional force is directly proportional to the normal force, such that $F = \mu N$, where μ = coefficient of friction.[1,2]

The static frictional force is the smallest force needed to start the motion of solid surfaces that were previously at rest with each other, whereas the kinetic frictional force is the force that resists the sliding motion of one solid objective over another at a constant speed.

[1]Department of Orthodontics & Dentofacial Orthopedics, Saraswati Dental College & Hospital, Lucknow, India
Address for Correspondence:
Dr. Utkarsh Upadhyay
Saraswati Dental College & Hospital, 233 Tiwari Ganj,
Faizabad Road, Off Chinhat, Lucknow-227 105 (UP), India
Contact No: +919936880308
Date of Submission : 15-12-2010
Review Completed : 01-02-2011
Date of Acceptance : 04-02-2011

Variables affecting frictional resistance in orthodontic sliding mechanics include the following:

1. Physical/mechanical factors such as:
   i) Arch wire properties: a) material, b) cross-sectional shape/size, c) surface texture, d) stiffness.
   ii) Bracket to arch wire ligation: a) ligature wires, b) elastomeric, c) method of ligation.
   iii) Bracket properties: a) material, b) surface treatment, c) manufacturing process, d) slot width and depth, e) bracket design, f) bracket prescription (first-order/in-out; second-order/toe-in; third-order/torque)
   iv) Orthodontic appliances: a) interbracket distance, b) level of bracket slots between teeth, c) forces applied for retraction.
2. Biological factors: a) saliva, b) plaque, c) acquired pellicle, d) corrosion, e) food particles.

Archwire Type, Size, Surface Roughness, and Angulation of Testing:

In general, increasing wire size or cross-sectional shape (round or rectangular) for a constant bracket size increased the frictional resistance at binding and nonbinding angulations.[3] Nickel-titanium wires demonstrated less friction when compared with the stainless steel wires at higher degrees of second order angulation, however, no significant difference was shown in the friction between these wires at zero degrees angulation. The high friction of TMA was contributed to the 'cold welding' phenomena with stainless steel and to mechanical abrasion for its high friction in the alumina brackets.

Esthetic Arch Wires: The frictional characteristics of a polymeric esthetic archwire showed that the wire proved to be inadequate as an orthodontic wire substitute since not only [3, 4, 5] did binding prevent it from moving through the slot, but it also led to considerable plastic deformation and eventual failure at relatively low forces.[6] Tooth tone plastic coated nickel-titanium wires (Cerum Ortho Organizers, Calgary, AL) are also available. The wire feature a strain and crack resistant plastic coating followed by a silicone coating to help reduce friction. The wire is fabricated from a "raw" nickel-titanium wire that is 0.002 inches thinner and the coating is added to produce a wire with conventional dimensions. No controlled studies utilizing this esthetic wire have been published.

Wet and Dry Environment: When human saliva is present, frictional forces and coefficients may increase, decrease, or not change depending on the arch wire alloy tested.[4] The greatest differences between dry and wet states occurred with â-titanium (TMA) archwire, in which the kinetic coefficients of friction in the wet state were reduced to 50% of the values in the dry state. At this point they were comparable to nickel-titanium but still higher than stainless steel.[6]

Ion Implantation

Greenberg and Kusy[1] coated orthodontic arch wires with a polymer composite and a polytetra-fluorethylene-based coating (Teflon, Dupont Co.) and preliminary results showed a reduction in the coefficients of friction (μ). Unfortunately, the surface coatings tended to stain, peel off or crack on bending.[7]

As the titanium content of an alloy increases, its surface reactivity increases and the surface chemistry is a major influence on frictional behavior.[6] Thus, â-titanium, at 80% titanium, has a higher coefficient of friction than nickel-titanium at 50% titanium, and there is greater frictional resistance to sliding ("stick-slip" phenomena) with either than with steel.[4] A solution to this is to alter the surface zone of the titanium wires by implantation of ions into the surface, thereby altering the surface chemistry.[8] Implantation of boron or phosphorus into steel produce an amorphous, "glassy" structure on the surface of steel which is free from the grain boundaries of a steel surface and is impervious to pitting corrosion.[9]

A recent study by Mendes and Rossow[10] evaluated the effects of ion implantation on archwire and/or bracket surfaces and compared this treatment with other friction reducing modalities.Arch Wire Materials tested in this study include:

- Stainless steel 0.016 inch round (Rocky Mountain Orthodontics)
- Stainless steel 0.016 x 0.022 inch rectangular (Rocky Mountain Orthodontics)
- Nitinol: 0.016 x 0.022 inch Nickel-titanium (Unitek/3M, Monrovia, CA)
- Pearl coated Nitanium: 0.016 x 0.022 inch Nickel-titanium with plastic silicon coating (Cerum Ortho Organizers, Calgary, Alberta)
- Bioforce Sentalloy with Ionguard: 0.016 x 0.022 inch Nickel-titanium with nitrogen ion implanted surface (GAC International). The ions are implanted using a patented Ionguard process (Spire Co.)
- TMA: Beta-titanium (Ormco Co.)
- TMA colors (purple): 0.016 x 0.022-inch â-titanium with nitrogen and oxygen ion implanted surface (Ormco Co.).

The results of this study suggested that ion implantation of nickel titanium and beta titanium wires, as well as bracket surfaces are effective means to reduce friction. An even greater reduction in friction can be obtained by offsetting the friction from the elastomeric ligation as with a bracket design that of the Synergy bracket (RMO) and the use of ion implanted wires. Low friction properties of active self-ligating brackets (SPEED) necessitate the utilization of the correct combination of archwire and bracket.[7]

The stainless steel 0.016 inch round wire had the lowest friction overall. While other wires may have had comparable levels of friction depending on the bracket used, there was no other wire that had a significantly lower level of friction. Similarly, the untreated TMA had the highest friction overall.The nickel-titanium wire with the plastic and silicon coating (Cerum) had either a similar or lower level of friction than untreated nickel-titanium and rectangular stainless steel, depending on the bracket used. This wire was the only one that had a level of friction that was comparable to round stainless steel ($P < 0.05$) for all brackets except Speed (Strite Industries). It is important to note that when stainless steel 0.016 inch round wire was compared with 0.016 x 0.022 inch rectangular stainless steel, the round wire had the lower friction in most cases. Thus ion implantation of the bracket may offer a means of gaining the advantages of the control offered by a rectangular wire while benefiting from the low frictional characteristics of a round wire.[7]

The clinical applications of this research are numerous.[10] The ability to reduce friction in the system should facilitate quicker and more physiological tooth movement with subsequent reduced treatment times. Selective application of ion implanted brackets and untreated brackets to different teeth may provide additional anchorage control. The ability to change the appearance of wires and brackets provides the clinician with a means to help satisfy patients' demands for orthodontic appliances that are esthetic without the problems associated with ceramic brackets. In addition, the ability to alter the frictional characteristics of nickel-titanium and â-titanium (TMA) wires provides the clinician with wires that can be used during early aligning procedures that have frictional characteristics similar to stainless steel.

REFERENCES

1. Kusy RP, Whitley JQ. Effects of sliding velocity on the coefficients of friction in a model orthodontic system. Dent Mater 1989; 5:235-240.

2. Kusy RP, Whitley JQ. Coefficients of friction for archwires in stainless steel and polycrystalline alumina bracket slots. I. The dry state. Am J Orthod Dentofac Orthop 1990; 98 :300-312.
3. Andreasen GF, Quevedo FR. Evaluation of frictional forces in the 0.022 x 0.028 edgewise bracket in vitro. J Biomechanics 1970; 3:151-160.
4. Prosoki RR, Bagby MD. Erickson LC. Static frictional force and surface roughness of nickel-titanium arch wires. Am J Orthod Dentofac Orthop 1991; 100:341-348
5. Sachdeva RCL, Miyazaki S. Superelastic Ni-Ti alloys in orthodontics. In: Duerig TW, Melton KN, Stockel D, Wayman CM, eds. Engineering aspects of shape memory alloys. London: Butterworth-Heinemann. 1990: 452-69.
6. Peterson L, Spencer R, Andreasen G. A comparison of friction resitance for nitinol and stainless steel wire in edgewise brackets. Quintessence Int 1982; 13:563-571.
7. Kusy RP, Andrews S. Tribological properties of ion implanted model orthodontic appliances. In Spalvins T, Kovacs WL (eds): Ion Nitriding and Ion Carburizing Metals Park, OH: ASM International, 1991, pp 119-129.
8. Sioshansi P. Tailoring surface properties by ion implantation. Materials Engineering 1987; Feb; 19-23.
9. Omana HM, Moore RN, Bagby MD. Frictional properties of metal and ceramic brackets. J Clin Orthod 1992; 26: 425-432.
10. Mendes K and Rossow E. Evalidation of manufacturer's claim. Semin Orthod 2003; 9:236-250.