ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Friction in Orthodontics: A Review.

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ABSTRACT

Resistance to orthodontic tooth movement has been a subject of concern. Also termed friction, this phenomenon must be dealt efficiently to obtain acceptable results. For years, orthodontists and manufacturers have devised techniques and materials to overcome or minimize friction. A thorough knowledge of friction is essential if one desires to counteract it. This review discusses friction in orthodontics and its clinical implications.

Keywords: Friction, sliding mechanics, orthodontic tooth movement, brackets, archwires.

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INTRODUCTION

Orthodontic brackets and archwires together constitute important parts of an orthodontic appliance. Fixed orthodontic therapy utilises retraction archwires or sliding mechanics to help bring about tooth movement. Minimal friction is involved with the former, but the latter involves considerable amount of friction.

An understanding of the terminology in context of friction is imperative, as this insight enables appropriate utilization of orthodontic biomechanical principles as well as how it pertains to the orthodontic appliances[1].

Friction is a matter of concern as it represents a clinical challenge because high levels of friction can reduce the effectiveness of the mechanics, decrease tooth movement efficiency and further complicate anchorage control [2]. Sometimes low friction can be important, as in retracting a tooth along a continuous archwire or in consolidating space; sometimes high friction is needed, as in closing loop mechanics, anchorage, and 2-couple systems (torqueing arch)[y]. Often friction is not an issue, as in a 1-couple system (intrusion or extrusion arch) or for repositioning an impacted tooth with a cantilever[3]. Therefore, whenever orthodontic movement is to be brought about, it should be made as lower as possible, but still sufficient enough to promote OTM [2].

Friction and sliding mechanics

Friction can be defined as a force that delays or resists the relative motion of two objects in contact, and its direction is tangential to the common interface of the two surfaces [4]. It may also be explained as the resistive force between surfaces that opposes motion [3].

Friction is of two types

- Static – The smallest initial force needed to start a motion between two solid surfaces[4, 5].
- Kinetic (dynamic) – The force needed to resist the sliding motion of a solid object over another at a constant speed[5]

Kinetic friction is irrelevant in orthodontic tooth movement because continuous motion along an archwire rarely if ever occurs [3].

In orthodontic tooth movement, friction results from the interaction of an archwire with the sides of an orthodontic bracket or a ligature. Friction is usually a small part of the resistance to movement as a bracket slides along an archwire[3]. According to Kusy and Whitley, resistance to sliding (RS) may be (1) friction, static or kinetic (FR), due to contact of the wire with bracket surfaces; (2) binding (BI), created when the tooth tips or the wire flexes so that there is contact between the wire and the corners of the bracket and (3) notching (NO), when permanent deformation of the wire occurs at the wire-bracket corner interface[3].

When the orthodontic wire slides through the bracket slot and the tubes, some resistance to sliding always takes place at the bracket/wire interface. This phenomenon is observed during levelling and alignment, space closure and even during torque expression at the end of treatment. A percentage of the orthodontic force applied to the teeth is lost as static friction and the rest is transferred to the tooth and its periodontium, generating the actual OTM[2]. Kojima et al evaluated the influence of friction on OTM using the finite element method and reported that approximately 60% of the orthodontic force applied to a tooth is lost as SF[2]. Thus, the biological tissue response to the mechanical stimulus takes place only if the force is strong enough to overcome SF[2]. It was reported that in some situations, the effective force should be increased six fold to overcome frictional resistance[6]. Thus, increased frictional resistance may require the orthodontist to use excessive force, which can result in anchorage loss, patient discomfort, and injury to tooth supporting tissues during treatment [6].

Factors that affect friction during orthodontic tooth movement

Variables affecting frictional resistance in orthodontics include the following [1,7] :

Physical/mechanical factors:

- Archwire properties: a) material, b) cross sectional shape/size, c) surface texture, d) stiffness.
- Bracket to archwire ligation: a) ligature wires, b) elastomerics, c) method of ligation.
- Bracket properties: a) material, b) surface treatment, c) manufacturing process, d) slot width and depth, e) bracket design, f) bracket prescription.
- orthodontic appliances: a) interbracket distance, b) level of bracket slots between teeth, c) forces applied for retraction.

Biological factors

a) Saliva, b) plaque, c) acquired pellicle, d) corrosion, e) food particles.

However, saliva has been suggested as the major biological factor influencing SF, as it acts as a lubricant and plays an important role in friction reduction. This information is particularly important important when treating patients presenting with xerostomia or those who regularly take medications that can reduce the salivary production [2].

The accumulation of debris on the surface of orthodontic wires is also known to be a significant variable that may increase friction throughout orthodontic treatment. Deposits of biofilms have been reported on orthodontic archwires as early as 8 weeks of intraoral use[2]. This can be counteracted by the use of an ultrasound to clean stainless steel archwires for 15 seconds for with a steel wool sponge for one minute[2]. The third biologic variable is the biodegradation of the orthodontic material throughout orthodontic treatment [2].

Amongst the physical and mechanical properties of orthodontic brackets, the type of material used to construct the bracket also influences the amount of friction generated [1,2,7]. Currently, there are three major groups of bracket materials: metal, plastic, and ceramic [6]. Metal brackets present low friction coefficients[2,8,9]. Increased frictional resistance has been associated with polycrystalline ceramic and plastic brackets[6]. Of these two, plastic brackets are known to produce lesser friction than their ceramic counterparts[2]. The use of ceramic brackets is known to cause the highest levels of friction of all types. Owing to the esthetics of ceramic brackets, attempts were made to overcome their disadvantages. Therefore the metal-lined arch wire slot in the ceramic bracket was introduced [9]. The insertion of a metal slot in ceramic brackets has showed relatively good success in reducing the levels of SF[2]. Many studies show that ceramic brackets with SS slots have superior frictional qualities compared with those of conventional ceramic; however, they are not as efficient as metal brackets [8].

It is known that the frictional force tends to increase with rectangular cross-section wires in comparison with round wires[9]. Bracket size, slot depth and width are also factors that influence the amount of friction registered during sliding mechanics[2]. Wider the bracket, greater is the friction due to the greater area of surface contact between the bracket and the wire. Also, increased wire angulation is associated with increase in friction [3]. The other mechanical properties that influence frictional resistance are cross section of wires, their diameters and the surface roughness [1]. The various metal alloys used as archwires are stainless steel (SS), Nickel Titanium (NiTi) and TMA. TMA wires are associated with increased roughness, high friction and intermediate spring-back, stiffness [10]. On the other hand, SS wires and NiTi wires exhibit lower frictional levels than TMA, with SS being the least [2,10]. Another major factor that influences friction is the method of ligation [2]. Steel or elastic ligatures behave differently to friction, thereby showing varying results, due to their ligation methods [2]. The metal ligature produces less frictional force in comparison with elastomeric ligatures; however, friction depends on the tying force between the metal ligature and orthodontic archwire, differently from elastomeric ligatures [9]. SS ligatures generate higher amounts of SF than elastic ligatures if ligated tightly[2]. However, if they are loosely inserted, small gaps between the wire and the bracket slot remain leading to smaller SF values [2]. With regard to elastic ligation, it has been reported that elastic ligatures with decreased surface roughness generate lower friction levels and when done as the number '8' results in maximum levels of all frictions [2].

Recently introduced orthodontic materials to reduce friction

Conventionally used stainless steel brackets in combination with stainless steel archwires are the gold standard for sliding mechanics [1] due to their reduced friction levels. The advances in orthodontic appliances focused on production of minimal frictional resistance. These innovations may be explained as advances in design innovations and surface treatments [2]. The introduction of the self-ligating bracket can be explained as one of the breakthroughs in design innovations. Though introduced in the early 1930s it has been gaining popularity in recent years. SLBs present a clip incorporated to its buccal surface that locks the wire within the slot and transforms the bracket in a tube-like device, thus eliminating the need for elastic or steel ligatures[2]. The claim of reduced friction with self-ligating brackets is often cited as a primary advantage over conventional brackets because the usual steel or elastomeric ligatures that also contribute to friction are not necessary[1]1. Self-ligating brackets can be divided into 2 main categories, active and passive, according to their mechanisms of closure. Passive SLB present a clip that does not press the arch wire against the internal walls of the bracket slot[2]. On the contrary, active or interactive SLB present a spring clip that pushes wires of greater diameter against the bracket slot[2] allowing for rotation and torque control [11]. It is claimed that passive designs generate even less friction than active ones [11]. Because of the reduced friction and hence less force needed to produce tooth movement, self-ligating brackets are proposed to have the potential advantages of producing more physiologically harmonious tooth movement by not overpowering the musculature and interrupting the periodontal vascular supply. Therefore, more alveolar bone generation, greater amounts of expansion, less proclination of anterior teeth, and less need for extractions are claimed to be possible. Other claimed advantages include full and secure wire ligation, better sliding mechanics and possible anchorage conservation, decreased treatment time, longer treatment intervals with fewer appointments, chair time savings, less chair-side assistance and improved ergonomics, better infection control, less patient discomfort and improved oral hygiene[11]. However, SLBs have some disadvantages, including higher cost, possible breakage of the clip or the slide, higher profile because of the complicated mechanical design, potentially more occlusal interferences and lip discomfort, and difficulty in finishing due to incomplete expression of the archwires [11]. It is being said that research companies and scientific studies are devising methods to improve the limitations of SLB[2]. Recently, a polyurethrane elastic ligation system has been introduced, termed 'Slide', this when combined to a conventional bracket forms a tube-like structure [2]. This newly-designed elastic ligature may be used to generate a low-friction system when conventional brackets are used. Another possible advantage of this system would be the possibility to selectively use this ligature in one tooth or in some teeth were lower levels of friction are desired[2]. In addition to introduction of newer materials altogether, recent advances have also explored surface treatments as possible avenues for reduced friction [2]. A recently introduced elastic ligature named Metafasix is known to incorporate an engineering process similar to the one used to fabricate stents for coronary heart disease, consisting of a water resistant polymeric coating, which makes it extremely slippery in the presence of saliva. A reduction of approximately 60% of friction with these elastic ligatures has been reported [2]. Recently, a 'Diamond-like carbon' (DLC) surface coating of SS and NiTi orthodontic wires have been suggested [2]. A study reported that the DLC-coating process reduces frictional force. The harder surface of the DLC-coated wires is not only known to reduce friction but also the effects of binding and notching. In addition, the DLC layer on SS and NiTi wires showed a lower elastic modulus than the surface layer of the wires. It is suggested that DLC coated wires with a lower elastic modulus might show superior flexibility, which is a desirable characteristic of an orthodontic wire [12]. The same technology was recently tested to improve the clinical performance of SS brackets and the results were found to be promising [2].

CONCLUSION

Frictional forces pose clinical challenges. In order to minimize them, they should be understood so that they can be effectively controlled. Their increase may be an advantage when used for anchorage, but harmful because of their effects in sliding mechanics. The effects of biologic and mechanical variables on orthodontic tooth movement should be evaluated. The combination of SS archwires with SS brackets still dictates the gold standard. Use of ligation materials and methods resulting in minimal friction should be adopted. Newer technological innovations seem promising, be it in material or surface treatment advancements. However, the cost of these materials is still significantly higher than the traditionally used materials and their real cost to benefit remains scientifically questionable.

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