ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 7, Issue – 4, July– 2024, Page No. : 93 - 103

Friction in Orthodontics

[1]Sunil Skariya, Post Graduate, Department of Orthodontics and Dentofacial Orthopaedics, St Gregorios Dental College, Kothamangalam, 686681, India

[2]Binnoy Kurian, Professor and HOD, Department of Orthodontics and Dentofacial Orthopaedics, St Gregorios Dental College, Kothamangalam, 686681, India

[3]Shikha B, Post Graduate, Department of Orthodontics and Dentofacial Orthopaedics, St Gregorios Dental College, Kothamangalam, 686681, India

[4]Dhanya M, Post Graduate, Department of Orthodontics and Dentofacial Orthopaedics, St Gregorios Dental College, Kothamangalam, 686681, India

Corresponding Author: Sunil Skariya, Post Graduate, Department of Orthodontics and Dentofacial Orthopaedics, St Gregorios Dental College, Kothamangalam, 686681, India

Citation of this Article: Sunil Skariya, Binnoy Kurian, Shikha B, Dhanya M, "Friction in Orthodontics", IJDSIR- July–2024, Volume –7, Issue - 4, P. No.93 – 103.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Friction is a critical factor in orthodontics, influencing the efficiency of tooth movement during treatments aimed at aligning teeth for functional and aesthetic improvement. It occurs primarily between archwires and brackets, impacting treatment duration and outcomes. Two main mechanics, segmental and sliding, manage tooth movement with varying friction levels. Physical variables such as archwire material, shape, and bracket design, along with biological factors like saliva and plaque, significantly affect frictional resistance. Balancing these variables is essential for optimizing treatment efficacy and minimizing complications such as anchorage loss. Despite challenges in clinical assessment, advancements in materials and techniques continue to refine friction management in orthodontic practice.

Keywords: Friction, Biological Factors, Biological Variables.

Introduction

Friction is a force that retards or resists the relative motion of two objects in contact. The direction of friction in tangential to the common boundary of the two surfaces in contact.

Frictional forces are unavoidable in our daily lives. If we were not able to counteract them, they would stop every moving object. About 20% of the petrol used in an automobile is needed to counteract friction, in the engine and in the drive train. On the other hand, if friction were totally absent, we could not drive an automobile, or walk or ride a bicycle. We could not hold a pencil, and even if we could, it would not write. Nails & screws would be useless, woven cloth would fall apart and knots would untie. Thus, friction may be considered as a necessary evil in our lives.

Keywords: Brackets; Ceramic; Friction; Sliding mechanics; Stainless steel, Nickel titanium, Resistance to sliding.

Friction in Orthodontics

Orthodontics is the specialty of dentistry which deals with the alignment of the teeth in order to achieve optimal function and esthetics. This often entails extraction of certain teeth in order to relieve arch length-tooth material discrepancies as well as to improve the patient's profile. In a typical extraction case involving extractions of 1st premolars, the first step is the proper alignment of all the remaining teeth, using flexible archwires of round cross-section, following which the anterior teeth are retracted along a rigid rectangular archwire, to provide 3dimensional control and prevent unwanted tipping movements. This step of space closure is often the Nemesis of the orthodontist, as it is often the aim of the orthodontist to retract the anterior teeth without allowing the posterior teeth to move forward. -an attempt to subvert Newton's Third Law of motion, so to speak. The presence of friction only serves to complicate an already tedious situation.

Orthodontic tooth movement during space closure is achieved through 2 types of mechanics. In the first type ie. Segmental or sectional mechanics, use is made of closing loops fabricated in either a full or sectional archwire. The major advantage of loop mechanics is the lack of frictional forces between the bracket and archwire during space closure. The disadvantages associated with this technique are the time consumed in fabricating loops, as well as undesired tooth rotations in the sagittal & transverse planes, resulting in increased leveling requirements.

The second type, sliding mechanics, involves either moving brackets along an archwire or sliding the archwire through brackets & tubes. This results in decreased adverse rotational movements but leads to friction, which results in delay in tooth movement, increase in anchorage requirements, or both. Therefore, the name friction mechanics is often associated with it.

The portion of applied force lost due to resistance to sliding can range from 12- 60%. High frictional forces affect the efficiency of treatment, result in increased treatment time, & compromise results because of loss of anchorage. It will also impact on the M/F ratios of teeth and consequently their centers of rotation.

Variables Affecting Frictional Resistance During Tooth Movement

The variables affecting frictional resistance to tooth movement may be classified broadly as physical and biological variables and further classified as follows.

Physical Variables

1. **Archwire**

- Material
- Cross sectional shape/ size.
- Surface texture.
- Stiffness.

2. **Ligation of archwire to bracket**

- Ligature wires.
- Elastomerics
- Method of ligation/Self ligating brackets

3. **Bracket**

- Material
- Manufacturing process.
- Slot width and depth.
- Design of bracket: single/twin.

- First order bend (in-out)
- Second order bend (angulation).
- Third order bend (torque).

4. **Orthodontic appliance**

- Inter bracket distance.
- Level of bracket slots between adjacent teeth.
- Forces applied for retraction.

5. **Biological Variables**

- Saliva
- Plaque
- Acquired pellicle.
- Corrosion

With so many variables affecting the frictional force, it is difficult to accurately determine them in a clinical situation. This problem is further complicated by the wide array of brackets, wires and ligatures available which provide a multitude of combinations for use.

Physical Variables

Effect of archwire on kinetic friction:

- **Wire material**

Most studies have found stainless steel wires to be associated with the least amount of friction. This is further backed up by specular reflectance studies which show that stainless steel wires have the smoothest surface, followed by Co-Cr, β-Ti, and NiTi in order of increasing surface roughness. Kusy & Whitney (1990) (**14**)investigated the correlation between surface roughness & frictional characteristics. They found Stainless steel to have least coefficient of friction & the smoothest surface. However B titanium showed greater friction compared to Ni Ti, though the latter was rougher. Hence they concluded that surface roughness cannot be used as an indicator of frictional characteristics in sliding mechanics.

The reason whey β titanium has a higher coefficient of friction than NiTi is because of its higher titanium content (79W/W%), which results in increased adherence or cold welding of wire to bracket slot (slip-stick effect). Frank & Nikolai (1980)(**8**) found that Stainless Steel had less friction than NiTi at nonbinding angulations but as angulation increased & binding was present, SS showed more friction According to Thorstenson & Kusy (AJO –DO 2002), (**8**)the binding component appears to be influenced by the product E x I of the archwires (E= modules or elasticity & I = moment of inertia). Smaller, more flexible archwires such as 14 mil NiTi exhibit less binding (BI) than larger, less flexible archwires such as 19 x 25 mil SS wires.

Clinical consideration

Larger, stiffer archwires are generally used during final stages of treatment when retaining the tooth position is the objective. The additional resistance to sliding (RS) between the bracket & archwire might further prevent movement of teeth.

Loftus et al (AJO – DO Sept. 1999) (**4**)evaluated friction during sliding movement in various bracket-arch wire combinations. They reported that NiTi produced the least amount of frictions followed by SS &β-Ti in increasing order. As the angulation (& hence binding) of the wire was increased, there was greater increase in frictional forces with SS than with NiTi. They suggested that the flexibility of NiTi may contribute to a decrease in the normal force at the points or contact between **bracket & archwire**

Nishio et al (AJO-DO Jan 2004)(**6**) performed an in vitro study to evaluate frictional forces between various archwires & ceramic brackets. They found that β titanium showed the highest frictional force, followed by NiTi & SS wires. They suggest that elastic properties of the wire are secondary & surface texture has more influence on frictional force. Zufall & Kusy (Angle Orthod. 2000)(**7**)

Studied the sliding mechanics of composite orthodontic archwires with a coating of polychloro-p-xylene. The coating eliminated the risk of glass release from the wire. Also frictional & binding coefficients were within the limits outlined by the conventional orthodontic wire-bracket couples.

- **Wire Size**

Several studies have found an increase in wire size to be associated with increased bracket-wire friction. In general, at non-binding angulations, rectangular wires produce more friction than round wires. However, at binding angulations, the bracket slot can bite into the wire at one point, causing an indentation in the wire.

However, with a rectangular wire, the force is distributed ever a larger area ie. the facio-lingual dimension, resulting in less pressure & less resistance to movement. This may account for the finding of Frank & Nikolai (8) that an 020" wire was associated with more friction than the 017 x 025" wire.

- **Wire stiffness & clearance**

Mechanically speaking, orthodontic wires are elastic beams, supported at one or both ends. Force applied on such an elastic beam causes a deflection, which is reversible within elastic limit of the material. Stiffer wires are less springy & deflect less for a given force.

Doubling the diameter of a wire increases the stiffness by a factor of 16, when supported at one end, & by a factor of 4, when supported between two brackets.

Doubling the length of a cantilever beam decreases stiffness by a factor of 8.

During canine retraction in a premolar extraction case the increased inter bracket span of unsupported wire over the extraction site decreases the stiffness of wire. Retraction force, therefore has a greater chance of deflecting the wire, resulting in buckling. To prevent such deflections, which may increase friction & chances of bracket binding, the diameter of wire should be increased to compensate for decrease in stiffness when interbracket span is greater than normal.

For rectangular wires, stiffness is also dependent on cross sectional dimension in the direction of bending. In other words a 017 x 022" wire is more springy in the vertical direction when it is placed edgewise rather than flatwise. Drescher et al (AJO-DO 1989**)(9)** stated that friction depends primarily on the vertical dimension of the wire. An 016" stainless steel round wire and an 016 x 022" stainless steel rectangular wire showed virtually the same amount of friction. This was however lower than that for 018X025" wires. The authors state that for mesiodistal tooth movement, rectangular wire is preferred because of its additional feature of buccolingual root control.

As the stiffness of a beam is dependent on the support at both ends of the beam, during canine retraction, the premolar and lateral incisor brackets should be tied tightly to archwire. This will increase the stiffness of the wire as well as increase friction in the premolar bracket, thus minimizing anchorage loss.

Rucker & Kusy (AJO-DO 2002) **(10**)compared the resistance to sliding of stainless steel multistranded archwires with that of single stranded leveling wires. (multistranded archwires have a moment of inertia (I) that is 4% to 20% that of a single wire of same material and dimension.) They reported that in the active region, the contribution of μk-FR to resistance to sliding is relatively unimportant. However the resistance to sliding is proportional to elastic binding (BI) that occurs. Coaxial 15.5 mil wire showed MBI which was least in value, even lesser than single SS 10mil and NiTi 12mil wires. The rectangular 8 19 x 25 mil wire had a μBI comparable with 14mil SS wire.

Effect of Ligation Technique on Friction

The normal force exerted by the ligature has a significant influence in determining the frictional resistance developed within an orthodontic system. This force has been estimated to be between 50-300g, and upto 375g in one study.

Various methods of ligation are available: - stainless steel ligatures, elastomeric modules, polymeric coated modules and finally the self-ligating brackets, which may be having a spring clip (Hanson SPEED and Adenta Time) which pushes the wire into place, or it may have a passive clip which does not press on the wire (Activa and Danson II brackets.)

- Elastomeric ligatures are adversely affected by the oral environment, and demonstrate stress relaxation with time and great individual variation in properties.
- Stainless steel ligatures can be tied too tight or too loose depending on the clinician's technique.
- Self-ligating brackets with a passive clip have been shown to generate negligible friction.

Edwards et al (BJO 1995)(compared the frictional forces produced when elastomeric modules were applied conventionally or in a "figure of –8" configuration, stainless steel ties or Teflon coated ligatures were used for archwire ligation. The "figure of 8" modules appeared to create the highest friction. There was no significant difference in mean frictional force between the conventional module and the SS ligature, but the Teflon coated ligature had the lowest mean frictional force.

Dowling et al (BJO 1998) investigated the frictional forces of differently colored modules & found the clear modules to exhibit significantly lower friction than other modules. This study however was carried out in absence of saliva.

Khambay et al (EJO 2004)(**11)** compared the effect of elastomeric type and stainless steel ligation on frictional resistance and these were further compared with self-ligating Damon II brackets. There was no consistent pattern in the mean frictional forces across the various combinations of wire size, type, and ligation method. The polymeric coated module did not produce the lowest mean frictional force. The introduction of a 45° bend into the module (Alastik Easy-to-use) reduced mean frictional force to that of a SS ligature when using 19 x 25" SS wire. The use of metal ligatures with 7 turns produced the lowest friction confirming the findings of Bazakidon et al (AJO-DO 97). They concluded that the use of passive self-ligating brackets is the only may of almost eliminating friction.

Thorstenson & Kusy (AJO-DO may 2002):(**3**) investigated the RS for 3 self-ligating brackets with passive slides (Activa, Damon & Twinlock) and 3 self-ligating brackets with active clips (In-ovation, SPEED, Time), with second order angulation, in dry and saliva states. They reported that for second order angulations ≤θc, the RS of self-ligating brackets is small to non-existent regardless of saliva state, thus facilitating siding mechanics, but compromising root position. The RS of brackets with active clips was higher being in range of 12-47CN (dry state) and (22-54CN) wet State, respectively.

They reported that in the active state (θ>θc), the rate of binding is similar, regardless of presence of passive slide or active clip.

According to them "The desire to minimize the RS should be moderated by the necessity to control tooth movement".

Henao & Kusy (Angle orthod. 2004)(**12)** compared the frictional resistance of conventional & self-ligating brackets using various archwire sized. They reported that self-ligating brackets exhibited superior performance when coupled with smaller wires used in early stages of orthodontic treatment. However, when larger 016 x 022" and 019 x 025" AW were tested, the differences between self-ligating & conventional brackets were not so evident. This shows that self-ligating brackets have the ability to maintain low frictional resistance only upto a certain size of archwire. It also emphasizes the importance of leveling and alignment before using larger wires & sliding mechanics.

Effect of Bracket on Friction

- **Bracket material**

Angle used a gold prototype of edgewise brackets over 75 years ago. In 1933, Dr. Archie Brusse presented a table clinic on the first stainless steel appliance system. Since then, SS brackets have displaced gold. Because they were stiffer & stronger, SS brackets could be made smaller, in effect increasing their esthetics via their reduced dimension. Their frictional characteristics were so satisfactory that they are today's standard of the profession. However, conventional cast stainless steel has met its competitor in the sintered variety. The technology of sintering, the process of fusing individual particles together after compacting them under heat & pressure allows each bracket to be premolded in a smooth streamlined manner. The SS particles are compressed in a contoured, smooth, rounded shape as opposed to the older casting procedure in which the milling or cutting process left sharp, angular brackets, which were bulky and rough. Investigations comparing these two varieties with various archwire sizes at the Univ. of Oklahoma revealed that for most wire sizes, sintered stainless steel brackets produced significantly lower friction than cast SS brackets. (upto 38-44% less friction) This difference in frictional forces could be attributed to smoother surface texture of sintered SS material.

Plastic brackets first appeared in around 1970, and these were injection molded from an aromatic polymer called polycarbonate. These were meant to be esthetic but were subject to stains & odors. Moreover, these plastic brackets deformed plastically under load & showed creep with time.

About 10 years passed before the first ceramic brackets were developed. In spite of their superior esthetics, their frictional properties are far inferior to stainless steel. Highly magnified views have revealed numerous generalized small indentations in the ceramic bracket slot, while SS brackets appear relatively smooth.

Single crystal ceramic brackets are derived by milling large single alumina crystals into the derived shape & size via ultrasonic or diamond cutting or a combination of these two processes. Polycrystalline ceramic brackets are sintered together using special binders to fuse the particles together. Laser speculance & SEM have shown mouocrystalline brackets to be smoother than polycrystalline ones, but their frictional characteristics were comparable.

Clinical significance

Since ceramic brackets on anterior teeth are often used in combination with stainless steel brackets and tubes on premolar and molar teeth, retracting canines along an archwire may result in greater loss of anchorage because of higher frictional force associated with ceramic than steel brackets. Greater caution in preserving anchorage must be exerted in such situation.

Zirconia brackets

In order to overcome the problem of brittleness & low fracture resistance associated with ceramic brackets, Zirconia brackets were offered as an alternative. But these were found to have friction coefficients equal to or greater than ceramic brackets. They also showed surface changes consisting of wire debris and surface damage to brackets after sliding of arch wires.

Metal lined ceramic Brackets

In the last few years, it has been recognized that ceramics have desirable esthetics but other materials have superior frictional characteristics. Consequently, as stainless steel and a gold liner have now been placed in a polycrystalline Alumina bracket. These metal inserted products capitalize on the best of both worlds, namely, pleasing esthetics and competitive frictional characteristics, both in the presence & absence of saliva.

Kusy & Whitley (Angle Orthod. 2001)(14) evaluated a stainless steel lined polycrystalline alumina bracket (Clarity, 3M*/Unitek) and an 18kt gold lined polycrystalline allumina bracket (Luxi, RMO Corp), and compared these with SS brackets as controls. They found that in the dry state, Luxi has the lowest resistance to sliding compared to Clarity and the SS brackets. This can be attributed to the presence of a non-oxidizing surface of 18kt gold. In the wet state, Luxi performs similarly to SS brackets, Clarity, shows higher resistance to sliding in the wet state.

Cacciafesta, et al (AJO-DO Oct 2003) (**15**)reported that when tested with SS, NiTi, and TMA wires, metal-insert ceramic brackets (clarity) generated significantly lower frictional forces than conventional ceramic brackets, but higher values than stainless steel brackets, in agreement with findings of previous report.

Thorstenson & Kusy (Angle Ortho 2003)(**16**) studied the influence of Stainless Steel inserts on RS of esthetic brackets with 2nd order angulation in dry & wet states. According to them, at angles when clearance no longer existed, the resistance to sliding for esthetic brackets with & without inserts generally increased with angulation at a rate equal or greater than SS brackets-except for polycarbonate brackets which underwent elastic deformation and then had lower RS. They concluded that the addition of SS inserts did not considerably improve RS over esthetic brackets without inserts.

Titanium brackets

These were introduced to the profession in response to reports about corrosion of stainless steel brackets & sensitivity to nickel present in the alloy. Kapur, Sinha & Nanda (AJO-DO 1999) 9(17) compared the levels of frictional resistance generated between titanium & SS brackets, using a universal Instron machine. The results of the study showed that SS brackets had higher static & kinetic frictional force values as the wire size increased. (Rectangular SS wire). For the titanium brackets however, friction decreased as wire size increased. They stated that the desirable qualities of Ti such as low rigidity, superelasticity & shape memory allow early engagement of full size wire during treatment, allow the bracket to elastically deform, and create a reactive working environment for 3-D control of orthodontic tooth movement with rectangular wires.

Kusy & Q'Grady (AJO-DO 2000)(**20**) compared the resistance to sliding of Stainless Steel & titanium brackets using SS &β-Ti wires. They reported that although RS increased with angulation & normal force, the passive layer in both types did not break down. Titanium brackets remained comparable to SS brackets in the active configuration & are a suitable substitute for SS in sliding mechanics.

Bracket slot width

Bracket slot width refers to the bracket dimension in the mesial distal direction. The effect of bracket width on friction has been controversial. Some studies have found bracket width to have no effect on friction. While others have found frictional resistance to increased with bracket width. Yet others have reported a decrease in friction with an increase in bracket width.

Frank & Nikolai (AJO 1980**) (8**)related greater friction with a wider bracket to the fact that binding occurs frequently at smaller degrees of angulation with wider brackets than with narrow brackets.

Kapila et al (AJO-DO 1990) **(21)**reported that 018” slot sized medium twin brackets were associated with 1.5 times more friction than narrow single brackets, while wide twin brackets produced twice as much friction. Medium twin & wide twin 022” brackets also produced more friction than narrow single 022” brackets.

They suggested that with a wider bracket the elastomeric ligature was stretched more than with a narrow bracket, producing almost twice as much friction, due to greater normal force exerted on the wire.

Drescher et al (AJO-DO 1989**)** Beduar et al (AJO-DO 91) & Omana et al (JCO 1992) **(9),** suggested that with a narrow bracket, the tooth could tip considerably before binding occurred & once binding occurred it was of a severe nature, which resisted further sliding of the archwire. Bracket width is closely related to interbracket distance. The narrower the bracket, the greater the interbracket wire, and the greater the flexibility of the wire. This may result in greater chance of binding with the more flexible wire. Also, narrow brackets have the disadvantage of less rotational & tipping control due to smaller section of archwire engaged within the slot.

- **Second order bend (angulation)**

Resistance to sliding occurs when closing a regaining space with sliding mechanics. In the passive condition, ie. when the archwire and bracket have clearance, classical friction (FR) is the only existing component of RS. In this condition, the angulation (θ) between the archwire & the bracket is less than the critical angle (θ_c) where the wire contacts both ends of the bracket slot.

When clearance disappears and an interference fit occurs, ($\theta = \theta_c$) binding arises as a second component of RS.

Frictional forces are determined in vitro by keeping a fixed second order bracket- wire deflection system are not likely to be representative of the in vivo condition. In the clinical situation, second order deflections of wire between brackets held in series can have significant effects on bracket wire friction.

Frank & Nikolai (1980) **(8)** found that frictional resistance increased in a NON LINEAR manner with increased bracket angulation.

Ogata et al (AJO DO 1994) also noted that as second order deflection increased, frictional resistance was found to increase for every bracket-wire combination evaluated by them. The friction increased appeared in 2 phases:

1. With lower deflections: - A smooth sliding phase appeared in which friction increased in an approximately linear manner.
2. As deflection increased further: A binding phase occurred in which friction increased at a higher, non-linear rate.

Clinical Significance

For patients requiring maximum anchorage protection, complete leveling of the arch prior to using sliding mechanics is imperative. This will reduce the force required for retraction of the teeth because the frictional resistance will be decreased.

Articolo & Kusy (AJO-DO 1999)**(18)** studied the resistance to sliding as a function of five angulations (0°, 3°, 7°, 11°, 13°) using a different combinations, of SS, monocrystalline, or polycrystalline ceramic brackets against SS, NiTi or β-Ti archwires. When the couples were in the passive configuration at low angulation, all stainless steel wire bracket couples had the least resistance to sliding. When angulation was >3°, active configuration emerged and binding quickly dominated, with RS increasing over 100 fold.

Under these conditions, couples of SS had the highest RS. While couples of the more compliant alloys such as NiTi had the least.

- **The role of third order torque:**

When torque is applied to the wire, its projected size is larger than the actual size of the wire. This further decreases the clearance between the archwire & the bracket and contributes to frictional resistance to sliding.

Kusy (AJO-DO 2004) (19)evaluated the onset of binding for 3 scenarios

a) Second order angulation alone.

b) Third order torque only.

c) Combination of second order angulation & third order torque.

He found that each wire-slot combination has a common maximum torque angle, independent of bracket width. He suggests that the use of a metric 0.5mm slot might have some advantages with regard to torquing. Wires can be used that apply lighter forces while maintaining angulation and torque capabilities, which were once possible only with larger wires.

Biologic Variables

Saliva

It is suggested that saliva or a saliva substitute serves as an excellent lubricant in the sliding of the bracket along the wire.

Baker et al (AJO-DO 1987)(22) using an artificial saliva substitute found a 15% to 19% reduction in friction.Kusy et al (Angle Orthod 1991): found that saliva could have lubricous as well as adhesive behavior depending on which archwire-bracket combination was under consideration. Stainless steel wires showed an adhesive behavior with saliva & a resultant increase in the coefficient of friction in the wet state. The kinetic coefficients of friction of the β-Ti archwire in the wet state were 50% of the values of the dry state. This probably occurred because saliva prevented the solid to solid contact between the β-Ti archwires and SS brackets, & thus prevented the slip-stick phenomenon from occurring. (The slip-stick phenomenon occurs when β-Ti wire slides through SS brackets & the TiO_2 layer breaks down, adheres & breaks away).

Therefore, especially in adult patients, a history of xerostomia or reduced salivary flow, oral radiation therapy, or anticholinergic medication should be noted as possible factors in varying the force levels necessary to more teeth.

Reducing Friction & Improving Arch Mechanics Through Surface Chemisty

Two principal approaches are available for improving arch mechanics:

1. **Coating onto the surface**

This includes metal plating, chemical vapor deposition solvated polymers, plasma deposition (PD), and diamond like coatings (DLC)

2. **Implanting into the substrate**

This includes carburizing, nitriding, ion implantation (II), and a hybrid process of II called ion beam assisted deposition (IBAD)

- **Ion Implantation**

A ballistic process in which any element can be embedded into the surface of substrate. The principal advantage of the process is that surface properties can be tailored while bulk properties & tolerances remain uncharged. Today Ion implantation (II) is used commercially to reduce static & kinetic coefficients of friction of β-Titanium wires. The implantation of ions causes amorphisation of the surface by forming a coherent, metastable case protecting the bulk material. This reduces the slip-stick phenomenon. The implantation of stainless-steel brackets with N+/C+ resulted in a systematic reduction in friction, when tested against archwires made from titanium alloys. (Kusy, Andrews 1990)

- **Plasma Enhanced parylene**

In the plasma process, materials are energized until they are ionized. If diparaxylylene is vaporised, pyrolised into paraxylene and injected into a vacuum chamber containing the orthodontic appliance it can polymerise onto these surfaces as a pinhole free, clear, chemically inert polymer in a coating as thin as 2.5μm.

To date, PEP coatings have shown outstanding potential when apply to PCA and tested against SS wires. Also, when β-Ti archwires were tested against, PEP coating, the μ values were half that of control couples. So far, PEP coating remains the only viable candidate as a biocompatible, biostable coating for orthodontic applications.

- **Diamond like carbon (DLC)**

The use of "diamond like carbon" is an attempt to combine the best properties of diamond (i.e hardness) with the best properties of graphite (low frictional coefficient). However, the major disadvantage associated with it is poor esthetics. Also, the results achieved with DLC coated couples have proved to be disappointing.

Conclusion

An appreciation of the magnitude of friction is crucial for the orthodontist who employs sliding mechanics during treatment. High levels of friction in bracket- wire may result in binding of the bracket accompanied by little or no tooth movement. Further, binding of an anterior tooth under retraction may lead to a tent pegging effect, with the applied force being optimal for posterior tooth movement instead, resulting in loss of anchorage. New bracket designs, manufacturing techniques, have been introduced to reduce friction. For clinicians who use esthetic or tooth-colored brackets such as ceramic or plastic brackets, it is important to know the level of friction generated by these brackets before initiating tooth movement. Selection of various wire shapes & sizes also allow the clinician to regulated the amount of friction. Addition of torque in the posterior segment of archwire also helps to presence posterior anchorage. Complete leveling of arch is an important factor in reducing friction during tooth movement as deflections of as little as 0.5mm between brackets can significantly increase friction. When retraction of teeth is done with a rectangular wire, it is prudent to first achieve torque control &them drop back to a smaller wire size & initiate sliding mechanics. This could prevent binding of wire edges into bracket slot and inhibition of movement.

Finally, the multitude of possible appliance combinations in sliding mechanics pose a serious challenge in producing a force system which is optimal for tooth movement. Mechanical & biologic factors must be considered in producing the appliance best suited for the patient. Frictional force levels must be taken into account to successfully achieve treatment objectives.

References

1. Halliday, Resnick, Walker Fundamentals of Physics 6th edition. John Wiley & Sons Inc. 2001.
2. Ravindra Nanda. Biomechanics in clinical orthodontics. W.B. Saunders Co. 1997.
3. Thorstenson, Kusy. G. Effect of archwire size & material on the resistance to sliding of self ligating brackets with the second order angulation in the dry state. AJO DO 2002; 122: 295-305.
4. Loftus B., Artun, Nichols, Alonzo, Stoner. Evaluation of friction during sliding tooth movement

in various bracket arch wire combinations. AJO DO 1999; 116: 336-45.

5. P.EmileRousseou. Friction: An overview. Seminars in Orthodontics: Vol 9 No 4 (2003). 218-22
6. Nishio, da Motta, Elias, Mucha. In vitro evaluation of frictional forces between archwires & ceramic brackets. AJO-DO 2004; 125 : 56-64.
7. Zufall S, Kusy R. Sliding mechanics of coated composite wires & the development of an engineering model for binding. Angle orhtod. 2000. 70: 34-47.
8. Frank C, Nikolai R. A comparative study of frictional resistances between orthodontic bracket & arch wire.
9. Drescher D, Bourel C., Schumacher H. Frictional forces between bracket & archwire. AJO-DO 1989: 96 : 397-404.
10. Rucker B. Kusy R. Resistance to sliding of stainless steel multistranded archwires & comparison with single stranded leveling wires. AJO-D0 2002; 122: 73-83.
11. Khambay, Millett, Mc Hugh. Evaluation of methods of archwire ligation on frictional resistance. EJO 2004; (26) 327-332.
12. Henao S, Kusy.R. Evaluation of frictional resistance of conventional &self ligating bracket designs using standardized archwires & Dental typodonts. Angle Orthod. 2004; 74: 202-211.
13. Thorstenson, Kusy R. Comparison of resistance to sliding between different self ligating brackets with second order angulation in the dry & saliva states. AJO DO 2002; 121: 472-82.
14. Kusy R. Whithey J. Frictional resistances of metal lined ceramic brackets versus conventional stainless steel brackets and development of 3-D friction maps. Angle Orthod. 2001; 71:364-374.
15. Cacciafesta, Sfondrini, Scribante, KlevsyAurichio- Evaluation of friction of conventional & metal insert ceramic brackets in various bracket archwire combination. AJO DO 2003; 124 (4): 395-402.
16. Thorstenson G., Kusy R. influence of stainless steel inserts on the resistance to sliding of esthetic brackets with second order angulation in dry & wet states. Angle Orthod. 2003. 73(4): 418-30.
17. Kapur R, Sinha P, Nanda R; Comparison of frictional resistance in titanium & stainless steel brackets. AJO DO 1999; 116:271-4.
18. Articolo, Kusy. Influence of angulation on the resistance to sliding in fixed appliances. AJO DO 1999; 115:39-51.
19. Kusy,R. Influence of binding of third order torques to second order angulation. AJO DO 2004; 125: 726-32.
20. Evaluation of titanium brackets for orthodontic treatment: Part II—The active configuration R.P. Kusy, BS, MS, PhDa P.W. O'Grady,
21. Evaluation of friction between edgewise stainless-steel brackets and orthodontic wires of four alloys BDS, MS Sunil Kapila 1BDS,
22. Frictional changes in force values caused by saliva substitution Kevin L. Baker, D.D.S.,M.S. Lewis G. Nieberg, D.D.S.,M.S.D.,M.S. Allan D. Weimer, D.D.S.,M.S.Milford Hanna, Ph.D.