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Friction in orthodontics

The College of Dentistry, University of Baghdad, Department of Orthodontics in Partial Fulfillment for the Bachelor degree of Dental Surgery

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Certification of the Supervisor

I certify that this project entitled "**Friction in Orthodontics**" was prepared by **Ali Hussein Ali** under my Supervision at the College of Dentistry/University of Baghdad in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

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Dedication

To my father for his support,

To my kind mother for her patience,

To my brothers and sisters and for their encouragement.

Acknowledgment

First and foremost, praises and thanks to **Allah** Almighty for helping me to fulfill my dream, for his blessings throughout my work to complete it successfully.

I would like to extend my deepest respect and gratitude to the Dean of College of Dentistry, University of Baghdad, **Prof. Dr. Raghad Al-Hashimi.**

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FF	friction force
µ	coefficient of friction
FN	normal forces
BI	binding
NO	notching
SS	stainless steel
TMA	titanium molybdenum alloys
FE	effective friction

Introduction

Orthodontic therapy with fixed appliances using the straight-wire technique has gained popularity nowadays due to its advantages, including a shorter treatment time, greater comfort for the patient and better control of the position of the teeth in the three planes of space **(Mazzeo *et al.*, 2013)**. The straight-wire technique is based on sliding mechanics, in which frictional force plays an essential role. According to some authors, during sliding mechanics, between 12% and 60% of the orthodontic force applied to a tooth is dissipated in the form of static frictional force and orthodontic tooth movement occurs only when the orthodontic force exceeds the existing friction force at the bracket-archwire-ligation system interface. The greater the frictional force in the orthodontic system, the more percentage of applied orthodontic force is lost and therefore the actual force transmitted to the teeth decreases **(Thorstenson. and Kusy, 2001)**.

Under these conditions, to overcome the frictional force and initiate the periodontal response, the practitioner must proportionally increase the intensity of the orthodontic force. The use of additional forces can favor the appearance of root resorption and interfere with the process of bone remodeling, causing delay and even limitation of orthodontic movement **(Li *et al.*, 2018)**.

Furthermore, an excessive orthodontic force changes the balance between the areas of action and reaction, which can further affect the orthodontic anchorage. Thus, when choosing the components of the fixed orthodontic appliance, it is important to evaluate the variables involved in the variation of frictional force. Mechanical variables include, among other parameters, specific bracket characteristics, such as material and configuration in terms of ligation system conventional or self-ligating. Regardless of the ligation system, the metallic brackets are considered to produce less frictional force compared to ceramic brackets **(Kanagasabapathy *et al.*, 2021)**.

Aesthetically pleasing appliances are one of the most preferred aspects of orthodontic treatment. Aesthetic brackets are high friction are currently produced and used with great regularity, therefore, it is necessary for orthodontists to off er esthetic alternatives to metal brackets to accomplish treatment objective today. Self–ligating brackets are increasingly replacing conventional brackets due to their proposed reduced friction compared with conventional brackets especially when joined with smaller arch wires used in the initial leveling and alignment stage **(Voudouris *et al.*, 2010)**.

Determining the approximate magnitude of frictional force associated with those esthetic and self–ligating brackets in different clinical situations can assist in identifying the actual force employed in moving teeth, thus enabling the orthodontists apply light forces to the periodontium while stimulating maximal biological forces in the tooth being moved and minimal bone remodeling in the anchorage teeth **(Queiroz *et al*., 2012)**.

Aims of the study

Is to illustrate about the friction in orthodontics , its types, its effect in orthodontics, and the factors that increase it, how to reduce it.

Chapter one

Review of literature

1.1 What is friction.

Kusy (2005) defined friction as the resistance to the movement of two or more contacting bodies. Several factors influence the friction and it is very difficult to isolate individual factors **(Wichelhaus *et al.*, 2005).**

defined as the force that resist movement, in which two surfaces slide over each other, and has a multifactorial nature **(Braga *et al.*, 2011),**as illustrate in (**figure 1).**

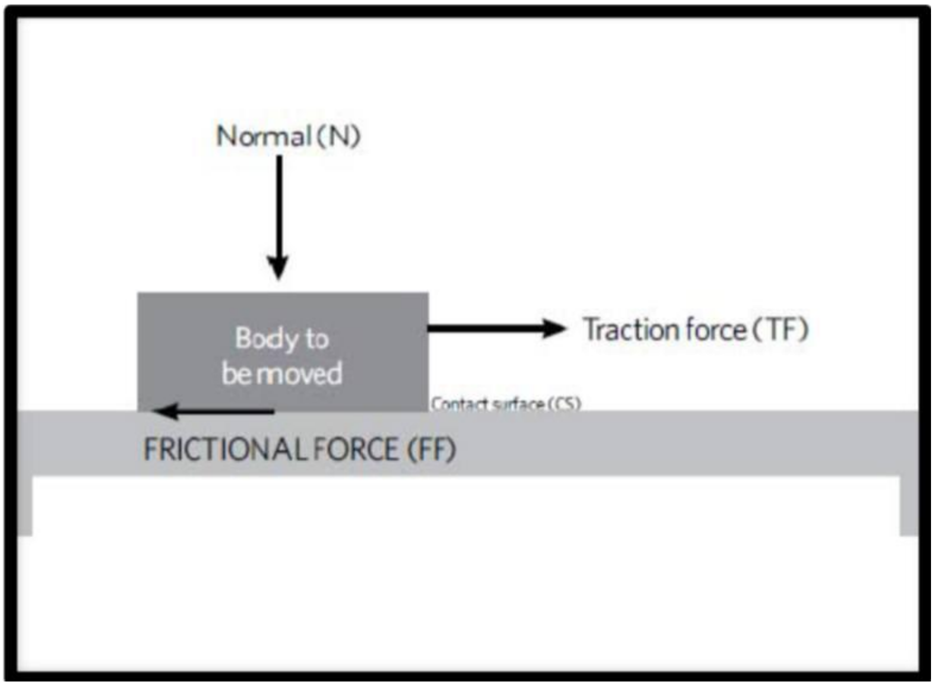

Figure 1: Different forces acting over a body under traction on top of a surface. Body to be moved, contact surface (CS), Traction force (TF), Frictional force (FF) **(Dickson *et al.,* 1994).**

1.2 Law of friction

The classic formulas below define a relationship between friction force (FF), coefficient of friction (μ), and forces operating at 90degrees to the arch wire (i.e., normal forces [FN]). M is a moment in loading by a couple and W is the bracket mesial–distal width **(Graber, 2017)**,as illustrated in (**figure 2).**

FF =μ× FN

FF = 2μ, M / W

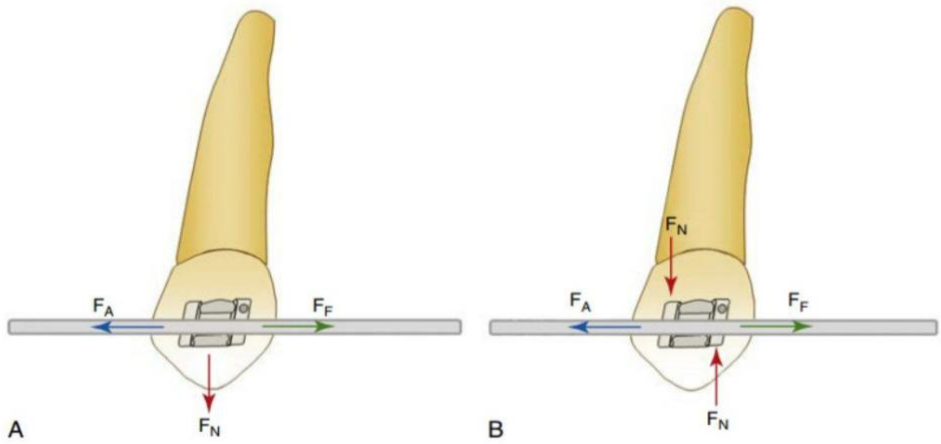

Figure 2: Normal forces (FN) in respect to an arch wire produce friction forces (FF). FA is the applied force. The force that the tooth feels is the applied force minus the friction force. A, FN is a single occlusal force. B, A couple or pure moment is applied to the bracket of the canine. These normal forces also lead to friction **(Graber, 2017)**

1.3 types of friction

A-Static friction: is the component of friction force that has to be overcomed to initiate motion. Or the force needed to initiate tooth movement.

B-Dynamic (kinetic) friction: is the component of friction that has to be overcomed to maintain motion. Or the force that resists motion. Because tooth movement along an archwire is not continuous but it occurs in a series of very short steps or jumps (**Frank and Nikolai, 1980).** Static friction is always greater than kinetic friction since it is harder to change a body from its initial situation than to maintain it moving, as illustrated in (**figure 3).**

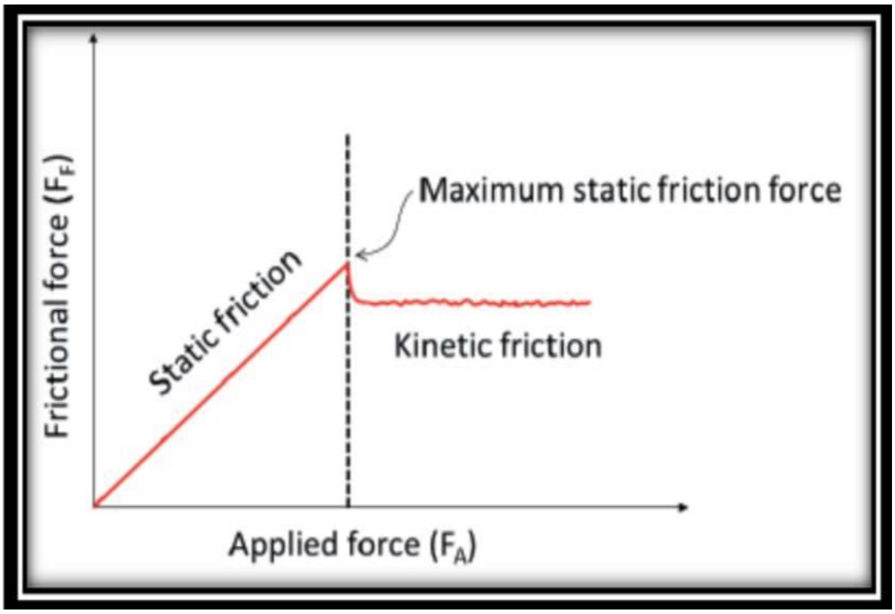

Figure 3 : Applied force against frictional force **(Burstone and Choy, 2015).**

1.4 Friction in orthodontics

Frictional force is present in the all stages of the orthodontic therapy notably during the closure of spaces, and it must be controlled because it hinders the movement of teeth **(AlSubie and Talic, 2016)**. When the friction is high, there will be a slow progress in the therapy and an increase in treatment time. Therefore, the orthodontist should apply a higher force to overcome the force of friction, but this is contradictory to the recommendation of using a light force for the initiating and maintaining the tooth movement **(AlSubie and Talic, 2016)**, the light force is important for the optimal biological response that lead to effective movement of teeth **(Gandini *et al.*, 2008)**, additionally, the use of high force to overcome the friction during anterior teeth retraction may increase the risk of posterior anchorage loss **(Chimenti *et al*., 2005)**.

Montasser *et al.* (2014) reported that because of the friction the percentage of the loss in the amount of applied force is from 12% to more than 70%. Burstone and Choy (2015) explained that in the following equation:

FE = FA – Frictional force (FF)

As it obvious from the equation; the frictional force make the effective force lower than the applied force, and when the spring apply a force equal to the frictional force, the tooth will not move **(Burstone, and Choy, 2015)**,as illustrated in figure 4.

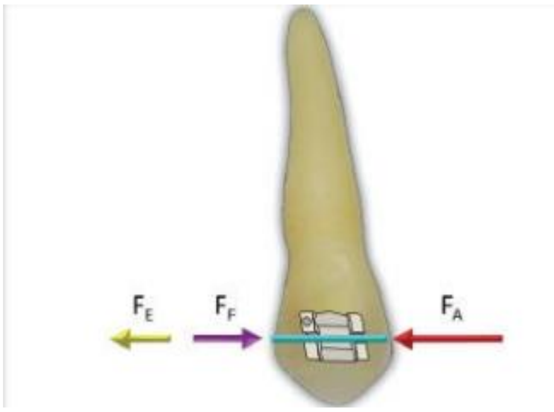

Figure 4: The tooth feels only the effective force (FE) **(Burstone and Choy, 2015).**

1.5 Types of Resistance to Sliding. (Kusy and Whitley, 1999).

Resistance to sliding (RS) categorized into 3 divisions:

a- Friction, static or kinetic (FR), when contact occurs between the orthodontic arch wire and surface of the bracket **(Kusy and Whitley, 1999).**

b- 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 (when a force is applied to a bracket to move a tooth, the tooth tips in the direction of the force until the wire contacts the corners of the bracket, and binding occur, as illustrated (**figure 5).**

c- **Notching (NO)** when permanent deformation of the wire occurs at the wire-bracket corner interface ,Notching can be noticed in cases when movement of tooth prevented as a result of notched arch wire catches on the corner of the bracket and in this case tooth movement return only when the notch was released as illustrated in(**figure 6).**

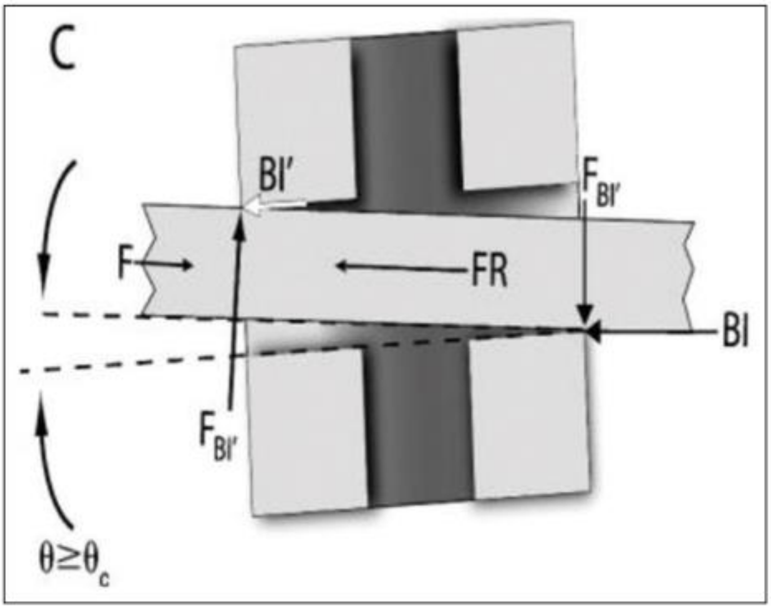

Figure 5: Binding of archwire with bracket wings **(Prashant et al., 2015)**

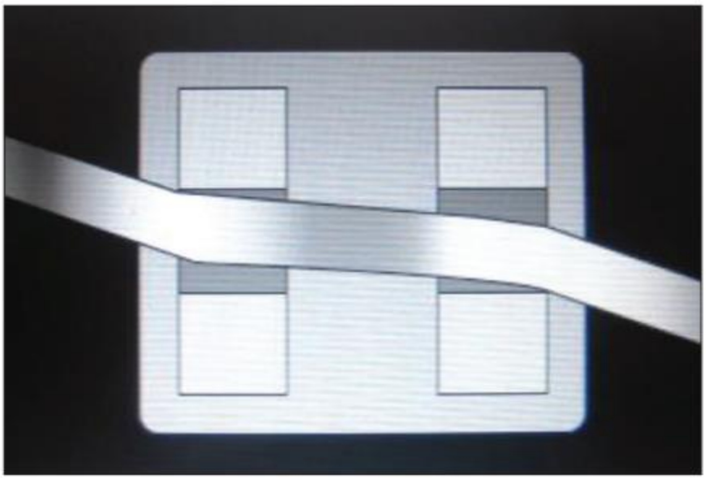

Figure 6 : Notching of archwire **(Prashant *et al.*, 2015)**

1.6. The mechanism of friction

No matter how all surfaces are smooth because they have irregularities that are large on molecular scale, and a real contact between two surfaces take places only at a limited number of small spots at the peaks of surface irregularities termed Asperities (**Burrow, 2009)**

Those spots carry the whole load between the two surfaces. A local pressure at the asperities may be sufficiently great, even under light loads, to cause appreciable plastic deformation in ductile materials such as metals. This lead to the formation of junctions between the asperities which is the junctional areas that carry the entire load between the two surfaces. Thus the real or true area of contact is only a small fraction of the apparent contact between the two surfaces. When a tangential force is applied to cause one material to slide across the other, the junctions begin to shear. At low sliding speed, a "stick-slip" phenomenon may occur as enough force build-up to shear the junctions and a jump occur, then the surfaces stick again until enough force again build to break them. The force essential to shear all the junctions will be proportional to the shear strength of the material at the junction. Two other factors affecting the resistance to sliding; the interlocking of surface irregularities; and the extent to which the asperities on the harder material plow into the surface of a softer one. In practice, if the two materials are relatively smooth and not greatly dissimilar in hardness, friction is largely determined by the shearing component **(Profit *et al.*, 2013).** as illustrated in (**figure 7).**

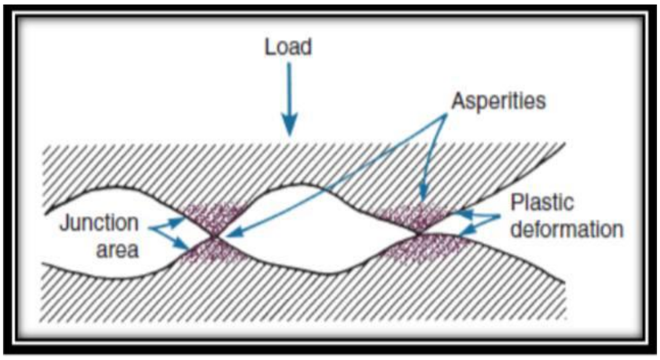

Figure 7: Illustrate the mechanism of the frictional force **(Proffit *et al.,* 2019).**

1.7. Factors Affecting Friction

Several variables can directly or indirectly contribute to the frictional force levels between the bracket and the wire and are listed as follows. **(Kusy and Whitley, 1997).**

- Archwire
- Bracket
- Ligation
- Biological factors.

1.7.1. Archwire

1.7.1.1.Archwire Dimension

As a wire dimension increases, the contact between the wire and the bracket slot increases. Several studies have proved that large wires produce more friction during sliding through the brackets, smaller wires produce less friction because of the greater free space in the slot and their larger elasticity **(Drescher *et al.,* 1989; Kusy and Whitley, 1997).**

1.7.1.2. Archwire Shape

Yanase *et al*. (2014) reported that the force of friction raises as the archwire shape changed from round to square to rectangular, and they observed in their study that the force of friction of SS archwire with a gauge of 0.016X0.022 inch was greater than SS wires with a gauge of 0.016 inch.

1.7.1.3. Archwire Material

Stainless steel arch wires have generally been the most widely used wires in orthodontics and it has been found that stainless steel wires have a lower bracket-wire friction than other types of wires **(Krishnan and Kumar, 2004a).** Other common alloys have been developed in the last decades because they have good properties such as Elgiloy, NiTi, and TMA arch wires **(Kusy and Whitley, 1997).**

1.7.1.4. Archwire surface texture

Surface roughness of orthodontic appliance considered one of the main factors of the material effect on the frictional force, and hence, it influences the performance of these appliances **(Choi *et al.*, 2015)**. However, **AlSubie and Talic (2016)** reported that friction generated by arch wires not always a reflection of their surface roughness. A study by Kusy et al. in 1988 considered the first study about the effect of the surface roughness on friction, their results revealed that decreased roughness was not sufficient to reduce friction.

1.7.1.5. Stiffness of Archwire

Archwire stiffness is correlated with wire dimensions, the shape of its cross-section, and its composition. It is affected by the wire length between brackets as identified by the inter bracket distance and the addition of bends, helices, or loops to the wire **(Proffit *et al.*, 2019).**

1.7.2. Brackets

1.7.2.1.Bracket Material and Design

Although not as esthetically pleasing as plastic or ceramic brackets, the stainless-steel brackets were an esthetic improvement over previously used bands and become most brackets used thereafter **(Proffit *et al*., 2013).**

Stainless steel brackets have lower frictional forces when compared with ceramic brackets; which may be contributed to the smooth surface of stainless steel brackets **(Kusy and Whitley, 2001; Cha *et al*., 2007; Williams and Khalaf 2013).**

Titanium brackets were introduced to be more biocompatible than stainless steel and withstand several conditions in the oral environment. Although the rougher surface of these brackets than stainless steel, they have coefficient of friction similar to that of stainless steel brackets in the passive configuration due to the chemistry of the surface layer that is passivated with a layer of carbon, oxygen, titanium and nitrogen, similar to the passivated layer of stainless steel brackets which could be the reason of reduced friction. With the increased demand for esthetic orthodontic, several types of brackets have been introduced such as ceramic, polycrystalline alumina, single crystal alumina, and polycarbonate brackets **(Smith *et al*., 2003).**

Pillai *et al.* (2014) compared the frictional resistance of self-ligating ceramic, composite and stainless steel brackets, and found that composite brackets have less friction resistance while ceramic brackets show maximum frictional force as compared to stainless steel and composite brackets.

Some manufacturers made ceramic brackets with a stainless steel slot to reduce friction with the archwire **(Nishio et al., 2004).**

1.7.2.2.Slot Size

Proffit *et al* (2019) suggested that to reduce friction during sliding mechanics; at minimum 2mm of clearance must be present between the archwire and the bracket slot, and the more clearance is better, therefore, during sliding of teeth the use of 0.022-inch slot bracket is better than using the 0.018-inch slot bracket because it allow using a heaver gauge archwire that give more strength during sliding with excellent clearance.

1.7.2.3.Bracket Width

Several studies demonstrated the effect of bracket width on frictional resistance force, since they are available with different widths. By increasing the mesio-distal width, the friction with the archwire is increased **(Frank and Nikolai, 1980; Husain and Kumar, 2011).**

1.7.3. Ligation

Iwasaki *et al.* (2003) using an intra-oral device, calculated that 31–54% of the total frictional force generated by a premolar bracket traveling along a 0.019 × 0.025 inch SS archwire was due to the friction of ligation. SS ligatures were used universally for the greater part of the 20th century until the introduction of elastomeric ligatures. **Frank and Nikolai (2006)** compared the two ligation mechanisms and found that frictional resistance increased as the ligature applies greater force to the wire. They found that there was an insignificant difference between elastomeric ligation and a SS ligature tied with a force of 225 g.

Chimenti *et al.* (2005) compared the frictional resistance seen with different sized elastomeric ligatures. They concluded that there were no significant differences between small and medium sized ligatures. Frictional force produced was found to be 13–17% greater with large sized elastomers.

Polymeric coated super slick ligatures were introduced in 2000. Manufacturers claimed that these ligatures generated lesser RS than conventional elastomers. It was claimed that coated modules produced 50% less friction than all other ligation methods except self-ligating brackets. However, when the different bracket and elastomeric module combinations were compared by **Griffiths *et al*. (2005)** significant differences were observed. In all but two combinations, round modules provided the least RS, rectangular modules the greatest and super slick modules in between the two.

Recently Teflon coated ligatures are being used with ceramic brackets to negate the esthetic problems associated with SS ligature wires and frictional disadvantages of transparent elastomers **(De Franco *et al*., 1995)**.

A new low force ligation system made of special medical polyurethane was introduced recently that markedly reduces the friction produced. The wire is free to slide as in a passive self-ligating bracket and it is claimed to cause lesser discomfort to the patient **(Fortini *et al*., 2005)**.

1.7.3.1.Self-ligation

Many practitioners have touted the many benefits of self-ligating brackets since Stolzenberg introduced the Russell attachment in 1935. It is claimed they are more hygienic, more efficient during adjustments, and even reduce treatment time because of reduced friction **(Damon, 1998)**. Within the last 10 years, there has been an explosion of new self-ligating bracket designs and interest by the orthodontic community **(Prashant *et al*., 2015)**

The debate over whether a self-ligating bracket should have an active or passive ligation mechanism has been around since their development. Proponents of an active clip claim that it provides a "homing action" on the wire when deflected, providing more control with the appliance. Those who advocate a passive clip state that there is less friction in the appliance during sliding mechanics because the slot provides more room for the archwire, and they provide no active seating force **(Damon, 1998)**.

When a small round wire lies passively in the slot, the self-ligating brackets produce significantly less friction than conventionally ligated brackets **(Cacciafesta *et al.,* 2003)**. Design of the self-ligating mechanism can affect friction when teeth have first-order misalignments. Furthermore, as the size of the wire increases, the friction produced by an active bracket will become more than that produced by its passive counterpart **(Pizzoni *et al*., 1998)**.

According to **Dragomirescu et al., (2022)** self-ligating brackets generally produced significantly lower static frictional forces than conventional ones. This observation is in line with a significant amount of research on this topic **(Henao *et al*., 2004; Kumar *et al.*, 2014)**. From a quantitative perspective, our results showed that in tests performed with 0.01600 NiTi arch wires, frictional forces were four times higher for conventional metal brackets compared to the self-ligating metal brackets. The difference between the results was even greater in the case of ceramic brackets, those with conventional ligation system being associated with frictional forces 5.82 times higher than self-ligating ones. The significant reduction in static frictional force, especially in case of thin and flexible wires, is mainly due to the elimination of elastomeric ligatures. The fastening system of the passive self-ligating brackets acts as a fourth (mobile) wall of the bracket, creating a passive lumen to hold the archwire in the bracket slot, without actively exercising forces on the wire,as illustrated in (**figure 8)**. **(AlSubie and Talic, 2016)**.

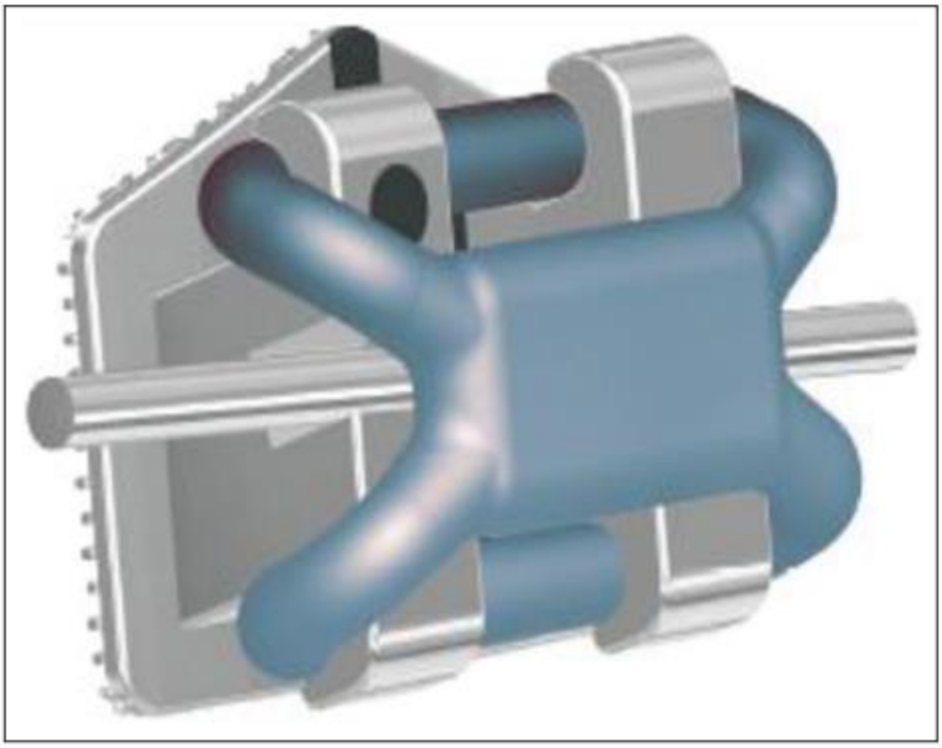

Figure 8: Low force ligation system **(Prashant et al., 2015)**

1.7.4. Biological factors

1.7.4.1.Saliva

Baker *et al.* (1987) had studied the effect of saliva on friction and concluded that human saliva reduced the frictional force by 15–19%. However, **Kusy *et al.* (1999)** suggested that saliva can act as a lubricant or an adhesive depending on the archwire-bracket combination. They also said that artificial saliva was the least effective fluid in reducing friction when compared to human saliva and water.

Andreasen and Quevedo (1970) concluded that saliva played an insignificant role in lubricating the surface of the archwire in the bracket slot. The explanation they gave for this finding was that the archwire touches the bracket at only two points, where the pressure is relatively great. The lubricant could be expelled from the area of contact, allowing no lubrication between the archwire and bracket to exist. Artificial saliva acted as a lubricant bringing about 15 to 19% reduction in force values, when measuring the static frictional forces generated between stainless steel brackets and archwire. These findings were supported by latter studies (**Husain and Kumar, 2011)**

1.7.4.2.Plaque and calculus

Frictional testing in most cases includes dry and relatively clean samples (i.e., wires and brackets), and therefore no biofilm or calcified regions are included. The adsorption of these intraoral integuments might greatly reduce the coefficient of friction by generating a boundary lubrication effect (i.e., through salivary protein adsorption and plaque accumulation). Then again, calcified integuments might increase the surface roughness and resistance to sliding **(Eliades and Bourauel, 2005).**

1.7.4.3.Corrosion

In most orthodontic patients dental biofilm gathers up on the appliances and on the teeth surfaces, the reason behind that is the presence of these appliances hinder the oral hygiene. The consequence of the biofilm accumulation for a long period of time is an improvement in the anaerobic status, hence, much favoring appliance corrosion **(Pazzini *et al*., 2009)**,

Even though pitting corrosion occurs on recovered NiTi wire surfaces, no major effects on the mechanical properties of the wires have been clinically identified. This absence of major effects occurs despite the apparent alteration of the surface of the alloy involving a notably high increase in roughness, as observed in the atomic force microscope images **(Vaughan *et al*., 1995).**

1.7.4.4.Mastication

The force of occlusion play a role in the friction that generated during the orthodontic treatment; as when the teeth contact each other thousands of times a day (as a person chews, speaks, or swallows) the teeth and the appliance will move relative to one another **(Shah *et al*., 2019)**.

Iwasaki *et al* (2003) tried to simulate the masticatory function ex: vivo by repetitive vertical displacements of an archwire under various loads (25, 50, 100, 150, 250, and 400 g), she and her co-workers discovered that the constant repeated vertical displacements of archwire cause a reduction in the resistance of sliding of the archwire through the bracket slots and the reduction was 85% when the loads between 100g and 250g, while with small loads (25g) the reduction in friction was more than 50%.

A variable that likely plays a role in orthodontic friction are the forces of occlusion. With teeth contacting thousands of times a day during chewing, speaking, and swallowing, it is likely that the teeth and the orthodontic appliance are repeatedly moving in relation to one another. **Braun *et al*. (2007)** added random perturbations to the bracket or wire to assess their effects on frictional resistance. They found that each time the bracket or wire was tapped, the frictional resistance was essentially reduced to zero. They concluded that, while masticatory forces did reduce frictional resistance, they did so unpredictably and inconsistently.

1.7.4.5.Biodegradation

The biodegradation that the orthodontic materials suffer throughout the orthodontic treatment. A recent evaluation of some important properties of brackets and elastic ligatures after their use brought some light to some of the questions related to the biodegradation of orthodontic materials **(Regis *et al*., 2011)**. The examination of metallic brackets post-orthodontic treatment revealed alterations such as corrosion, structural fatigue and plastic deformation. Different levels of biofilm were registered at the surface of these products and carbon, oxygen, calcium and phosphorus were found superficially.

Commercially available brackets of two different manufacturers presented up to 20% more friction than their out of the box correspondents. Differently than the brackets, elastic ligatures showed similar levels of friction both brand new or after different times of intraoral use **(Crawford *et al.*, 2010)**.

1.7.4.6.Topical fluoride

Utilizing topical fluoride in existence of SS brackets/arch wires or nickel titanium arch wires can raise the force of friction because these agents have fluoride ions that are capable of damaging the oxidized layer that formed on the surface of the stainless steel and nickel titanium, hence, causing a corrosion and roughening of the surfaces of these alloys **(Alavi and Hosseini, 2012)**.

1.8.Adverse effects of friction:

The harmful effects of friction on orthodontic treatment can be expressed as follows:

A. Effect of Friction on Anchorage

The force essential to bring about orthodontic tooth movement must be able to overcome the friction as well as move the tooth. This applied force has a reactive effect on the molars that moves them in a mesial direction. This is clinically undesirable response and can be considered as anchorage loss. Therefore, the development of materials with low coefficient of friction for straight wire mechanics are extremely desirable because they can reduce the strain on anchorage **(Nightingale and Sandy, 2001; Chementi *et al.,* 2004).**

B. Effect of Friction on Treatment Time

Apart from the obvious biologic and anatomic obstacles that affect the rate of tooth movement, there are the physical issues of bracket, wire and ligature friction. The type of bracket, wire or ligature utilized during treatment might limit how quickly the teeth will move and consequently the duration of treatment. As the teeth move more rapidly treatment time is decreased **(Rossouw *et al.*, 2003; Tecco *et al*., 2005).**

C. The Effect of Friction on Archwire and Bracket Material

Eliades *et al.* (2000) examine the surface appearance of NiTi wire specimen after its intraoral exposure to a period of nine months along with sliding of canine. Crevices and increased porosity are apparent together with signs of delaminating; they contributed these effects to friction created during movement. They also noticed the destruction of grain arrangement along with a reduction in the grain size of the intraorally exposed wire in contrast with the intact structure of an as-received sample. Interestingly this appearance is much different from that of the typical wire surface shown after in vitro aging through the application of electrolyte or artificial saliva solutions. The underlying mechanism involves the cold-welding at the interfaces under pressure which results in rupturing of the contact points (wear-oxidation pattern).

In an in vitro study conducted by **Al-Nasseri (2000)** to assess frictional forces of different bracket/archwire combinations, he explained that after testing a stainless steel bracket, magnification of the slot surface showed build-ups of archwire material on the "scraping" edge, while longitudinal scratches and beveling were seen on the distant slot edge and higher magnification of the edge showed breakage and chipping of bracket material. After testing a ceramic bracket, archwire debris were seen as shiny spots on the floor of the slot and further magnification showed multiple flakes of archwire material attached close to the slot edge.

Chapter Two

Discussion

The value of friction vary from one material to another being the lowest in stainless steel arch wire especially when used with stainless steel brackets ,followed by chrome cobalt and nickel-titanium arch wire which produce more friction than stainless steel but in similar amounts, while titanium and molybdenum alloy produce the maximum amount of friction (**Frank and Nikolai, 1980; Drescher et al., 1989; Kusy and Whitley, 1999).**

Pillai *et al.* (2014) compared the frictional resistance of self-ligating ceramic, composite and stainless steel brackets, and found that composite brackets have less friction resistance while ceramic brackets show maximum frictional force as compared to stainless steel and composite brackets.

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Chapter three

Conclusions and Suggestions

3.1.Conclusions

• The resistance to sliding in Orthodontics is multifactorial. It is directly influenced by the types of materials used and affects orthodontic tooth movement efficiency.

• Stainless steel conventional brackets have produced lower static frictional forces than those made of polycrystalline alumina. So, from the perspective of an orthodontic system with low frictional forces, metal brackets are preferable to aesthetic ones.

•. The stainless steel wire produce less amount of friction than Elgiloy and NiTi ,while the TMA produces the highest amount of friction.

3.2.suggestions

• In Vivo study of frictional values produced by stainless steel brackets

.• New Systems to reduce the friction.

_ nickel-titanium (NiTi) wires that are coated with a low-friction material, such as a diamond-like carbon (DLC) coating. These wires have been shown to reduce friction between the wire and the brackets,

_ self-ligating brackets. These brackets use a built-in clip to hold the archwir in place, eliminating the need for elastic or metal ties.

_ some bracket systems have a reduced slot size, which can reduce the amount of wire-to-bracket contact and therefore decrease friction.

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