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# TRIBOLOGY IN ORTHODONTICS: PAST, PRESENT AND FUTURE

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**Abstract:** Tribology is the study of friction, wear, and lubrication of interacting surfaces in relative motion. While it is a field commonly associated with engineering and materials science, tribology also plays a role in orthodontics. Orthodontics is a branch of dentistry that focuses on the correction of dental and facial irregularities. It involves the use of various appliances, such as braces, wires, and aligners, to move teeth into their desired positions. Tribology principles are relevant in orthodontics because the interaction between different components, such as brackets, archwires, and ligatures, can affect the efficiency and effectiveness of tooth movement. A review of various studies has showed that there is not a consistent trend in the frictional resistance shown by the various types of brackets. Also studies in wet environment show differences when artificial saliva and whole fresh human saliva is used. So a comparison of different studies should be made only after giving adequate weightage to the above said parameters. Plastic brackets have definitely staged a comeback in

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the front composite brackets after being side lined initially after their introduction, due to their inherent disadvantages of discolouration and deformation. The new generation of polycarbonate brackets, both the metal slotted and the fiber and ceramic reinforced ones, have definitely sorted out their earlier disadvantages, even though still much refinements are required in areas of metal slot- polycarbonate junction. Some studies have clearly pointed out this and might account for the increased frictional values noted in these metal slotted composite brackets. With an increasing demand for efficient esthetic brackets, refinements are bound to come and we can conclude that polycarbonate composite brackets are here to stay.

**Keywords:** Tribology, Orthodontic, Archwire, Brackets

**Introduction:** Tribology is the study of friction, wear, and lubrication of interacting surfaces in relative motion. While it is a field commonly associated with engineering and materials science, tribology also plays a role in orthodontics.(1,2)

Orthodontics is a branch of dentistry that focuses on the correction of dental and facial irregularities. It involves the use of various appliances, such as braces, wires, and aligners, to move teeth into their desired positions. Tribology principles are relevant in orthodontics because the interaction between different components, such as brackets, archwires, and ligatures, can affect the efficiency and effectiveness of tooth movement. .(3,4)

**Aspects of Tribology:**(5-8)

**Friction:** Frictional forces between the archwire and brackets are essential for transmitting forces to the teeth. However, excessive friction can impede tooth movement and increase treatment time. Orthodontic manufacturers have developed low-friction brackets and coatings on archwires to reduce friction and improve the efficiency of tooth movement.

**Wear:** Orthodontic appliances undergo wear due to the repetitive forces and movements involved in orthodontic treatment. Wear can occur on the bracket surfaces, archwires, and other components. Understanding the wear characteristics of different materials used in orthodontics helps in selecting durable materials that can withstand the demands of treatment.

**Lubrication:** Lubrication is important in reducing friction and wear in orthodontic appliances. Lubricants, such as orthodontic waxes or gels, are sometimes used to reduce friction between archwires and brackets. These lubricants help to minimize the forces required for tooth movement and increase patient comfort.

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**Material selection:** The choice of materials in orthodontics is crucial for achieving desired clinical outcomes. Tribological properties of materials, such as surface roughness, hardness, and coefficient of friction, influence their performance in orthodontic appliances. Materials with appropriate tribological characteristics are selected to minimize friction and wear, thereby optimizing treatment efficiency.

**Surface modifications:** Surface treatments and coatings can be applied to orthodontic appliances to modify their tribological properties. For example, applying diamond-like carbon (DLC) coatings on archwires can reduce friction and wear. Surface modifications can enhance the performance and longevity of orthodontic appliances.

Overall, tribology plays a significant role in orthodontics by influencing the efficiency, comfort, and durability of orthodontic treatment. Understanding the principles of tribology helps orthodontists select appropriate materials, design efficient appliances, and optimize treatment outcomes for their patients.

As a speciality, orthodontics has witnessed an awareness pace of development in almost all its facets, from philosophy to mechanotherapy. The vast change in mechanotherapy can be largely attributed to the many advances in bioengineering. Man’s sense of esthetic perception, which runs back to prehistoric period, is well documented it is only natural that this be extended to the mechanotherapy.

Metal brackets have been used in traditional orthodontics for a long period but poor esthetics of metal brackets has been a problem in clinical use.

A shift in focus to appliance esthetics was brought about by an increasing number of demanding adults seeking orthodontic treatment. Even though the credit for introducing polycarbonate transparent brackets goes to **Newman**, these brackets gained an increased popularity only by mid-80’s. The first plastic brackets were manufactured from unfilled polycarbonate and introduced during the early 1970's. These brackets faced problems of creep deformation when transferring torque loads generated by archwires to the teeth. Discoloration of these brackets with clinical aging was another noted problem.

The orthodontic biomaterial scenario is flooded with modifications and newer innovations to overcome these drawbacks of plastic brackets. The modifications include ceramic- reinforced, fiberglass reinforced and metal slot –reinforced polycarbonate brackets.

Metal slot-reinforced polycarbonate brackets have been claimed to deliver desired torque on the teeth under clinical conditions. Problems have been reported with the integrity of the slot periphery as well as the metal slot significantly affecting the bracket – arch wire sliding friction. Better debonding properties also have been claimed for these brackets.

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**Frictional Characteristics:** Whenever sliding mechanics are used in orthodontics, friction is generated between the brackets and the arch wire and has a major impact on the force ultimately delivered to the teeth.The cause of frictional resistance between archwire and brackets is multifactorial and varies with archwire size and material , mode of ligation[9], bracket width, angulation of wire to bracket[10] and many more.

Although innumerable studies have been conducted in this regard, all the studies can be broadly classified into the following four major methods.

1. Arch wire sliding through contact flats, limiting the studies to influences of materials only
2. Arch wire sliding through bracket slot
3. Arch wire siding through bracket with different second and third order angulations.
4. Brackets submitted to a sliding force in an equivalent resistance force system, which allowed a certain freedom of tipping resulting in diminution of applied force in attempt to simulate the impact of biological resistance to tooth movement.

One of the earliest reported studies on friction of plastic brackets by **Riley et al[7]**, compared the effect of wire size, bracket material, type of ligation and length of time on the magnitude of frictional force operating. One interesting finding was an increase in frictional forces with steel ligatures compared to plastic modules, especially with plastic brackets.

This was contrary to the findings of **David et al[11]** who reported lower frictional values with Teflon coated stainless steel ligatures as compared to elastomeric modules with both ceramic and stainless steel brackets.


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**Berger**[9] reported lower frictional values for ceramic reinforced plastic brackets (Lexan™, American Orthodontics) as compared to stainless steel brackets with both stainless steel and elastomeric ligation for the various archwire dimensions studied. The only exception was with 0.016 x 0.022 archwire – elastomeric tie combination, which he explained might be due to the increased surface contact. Changing from round to rectangular wires and increasing wire sizes of rectangular wires were found to increase the friction[7,8,22,25,26,32].

Study by **Woodside and Wiess**[8] looked at three different parameters, with three different brackets (Transcend- Ceramic, Silicon- Plastic and Spirit – Ceramic with metal slot). Wire alloy (stainless steel, TMA, NiTi), wire size ad cross section (0.018" and 0.019x 0.025") and second order angulation (0º and 10º). In their study the plastic bracket was showing less friction than the ceramic bracket and was comparable to metal inserted ceramic bracket.

The effect of different archwires, lubrication and angulation was studied by **Tselepis et al**[4]. they found the highest friction for polycarbonate racket with stainless steel wire at 10º angulations in dry condition among the various combinations evaluated. This was clearly a disadvantage as it could produce sever drain of anchorage and improper utilization of space when these brackets will be used for space closure.

**Bazakidou et al**[12]did a detailed study on the newer generation composite brackets and evaluated their friction in comparison with ceramic and metal brackets for selected wire alloy- size combinations with elastomeric and stainless steel ligatures in a dry environment. In this set up each bracket was mounted on plastic pedestals which had a ball bearing assembly and was fixed with a frame to the lower cross head of the Instron machine. The wire was held in a C shaped rod and it was tightened at a constant load of 300 gms. This set up was attached to the load cell. The rate of the movement was 0.02 inch per minute and each test was carried out for two minutes. He reported that the lowest values were for a ceramic – reinforced composite bracket without metal insert slot (SS, 0.017x 0.025-78.5g, NiTi, 0.017x 0.025-103g) and the highest for polycrystalline ceramic bracket (SS,0.017x0.025-121.3g) coming in between, when stainless steel, NiTi and B-Ti wires in three different dimensions each (0.018", 0.017x0.025" and 0.019 x 0.025") were drawn through 0.022" slots of these brackets. No distinct trend in frictional resistance between the composite brackets with and without metal inserts was reported.

**Thorstenson et al**[13] evaluated the friction in stainless steel inserted plastic ceramic and composite brackets. In this study wire was drawn relative to the bracket at a fixed force of 300 cN and poly tetrafluoroethylene bearings were used to simulate the two contiguous

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brackets. The brackets were mounted on stainless steel cylinders such that the effects of the prescription were eliminated. In this study, when clearances existed between wire and bracket the frictional properties of the esthetic brackets with SS inserts (Polycarbonate with stainless steel insert and polycarbonate alumina with SS insert) were between those of stainless steel brackets and those of conventional esthetic brackets (polycarbonate and polycrystalline alumina brackets)

The average frictional resistance values in the dry state for the passive configuration were 38cN for the conventional polycarbonate and SS brackets, 60 cN conventional polycrystalline alumina and 65cN for the ceramic reinforced polycarbonate bracket with stainless steel insert (Spirit MB™), 42 cN for the polycarbonate bracket with stainless steel insert (Plastic™), 48 cN for the polycrystalline alumina with stainless steel insert (Clarity™) when 0.018x0.025 stainless steel wire was drawn through 0.022" slots of these brackets. When clearances did not exist the friction of the esthetic brackets with and without inserts increased and became comparable to the greater than that of stainless steel. Thus these inserts even though it did not reduce the friction compared to stainless steel it did improve the strength and rigidity of the plastic brackets. This shows that stainless steel inserts do not generally mimic the SS brackets, but can best, approach near about the FR of the stainless steel brackets. Thus in the above studies[13], conventional polycarbonate brackets were showing less friction than the newer composite brackets, with or without metal inserted slot.

Thus the newer metal inserted polycarbonate brackets, even though are expressing better rigidity and capability for proper torque expression than the conventional ones, these comes at a price of increased friction.

The latest entrant into the field has been the self-ligating polycarbonate bracket (Oyster, Gestenco international, Gothenburg, Sweden)

**Cacciafesta V et al[14]**, studied these brackets and demonstrated that stainless steel self-ligating brackets generated significantly lower static and kinetic frictional forces than both conventional stainless steel and polycarbonate self- ligating brackets, which showed no significant differences between them.

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Beta- titanium archwires had higher frictional resistances than did stainless steel and nickel-titanium archwires. No significant differences were found between stainless steel and nickel-titanium archwires. All brackets showed higher static and kinetic frictional forces as the wire size increased. In patients with esthetic demands, polycarbonate self-ligating brackets are a valuable alternative to conventional stainless steel and ceramic brackets.

**Conclusion:**

1. The resistance to sliding in Orthodontics is multifactorial. It is directly influenced by the types of materials used and affects orthodontic tooth movement efficiency. The presence of friction is unfavourable in many clinical situations. However, it may be very important for others.
2. The biological variables influencing friction seem to have been overlooked by orthodontists. Simple factors such as the accumulation of debris over the wire surface and the brackets' biodegradation registered after intraoral use may be as important as the type of material used when friction in Orthodontics is considered.
3. The physical or mechanical variables that influence friction formation during OTM are more frequently researched than the biological variables. They should be carefully taken into consideration during the different stages of the orthodontic treatment to increase efficiency in different clinical situations.
4. The technological innovations used to develop new low-friction materials such as the design alterations and the surface treatments seem to present good potential to reduce friction in specific clinical situations. However, the cost of these materials is still significantly higher than the traditionally used materials and their real cost to benefit remains scientifically questionable.
5. The need to increment orthodontic materials research, especially performing studies with the greater direct clinical application is undisputed. These studies would help clinical orthodontists to better understand the performance of all materials available and to critically follow the new products introduced in the market. Therefore, the orthodontist would be able to identify which of these new materials may actually contribute to diminishing the clinical limitations of some orthodontic materials.

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