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Friction Mechanics- A Review

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Abstract **Review Article**

Conventional wisdom suggests that resistance to sliding (RS) generated at the wire-bracket interface has a bearing on the force transmitted to the teeth. The relative importance of static and kinetic friction and also the effect of friction on anchorage has been a topic of debate. Lot of research work has been done to evaluate the various factors that affect friction and thus purportedly retards the rate of tooth movement. However, relevancy of these studies is questionable as the methodology used hardly simulates the oral conditions. Lately studies have concluded that more emphasis should be laid on binding and notching of archwires as these are considered to be the primary factors involved in retarding the tooth movement. This article reviews the various components involved in RS and the factors affecting friction. Further, research work should be carried out to provide cost effective alternatives aimed at reducing friction.
Keywords: Binding, friction, notching.

INTRODUCTION [1]

Friction is the force that resists against the movement of one surface in relation to another and that acts on the opposite direction of the desired movement. The friction present during orthodontic sliding mechanics represents a clinical challenge to the orthodontists because high levels of friction may reduce the effectiveness of the mechanics, decrease tooth movement efficiency. Space closure is one of the most important steps in treatment after extraction.

Frictional system	Frictionless system
Performed on a continuous arch wire, including all teeth from molar to molar.	Teeth are moved as groups or individually with loops and selective mechanics like incisor intrusion and molar up righting are easier to perform.
Offers a statically indeterminate mechanics	More predictable mechanics in which amount of force and moment are measurable.
Use heavy forces	Use lighter forces as it increases the inter-bracket span and flexibility of wire.
Less chairside time is needed	Loop bending requires significant time
Straight wire causes less discomfort	Loops can cause discomfort to patient

Frictional Mechanics [1]

When two objects in contact are forced to move on each other, the resistant force that occurs at the contact surface opposite the direction of movement is friction. (Nanda)

The frictional force is proportional to force with which the contacting surfaces are pressed together and is affected by the nature of the surface at the interface (rough or smooth, chemically reactive or passive, modified by lubricants, etc.) (Proffit)

Friction is independent of the apparent area of contact. There are two components of friction – static and kinetic.

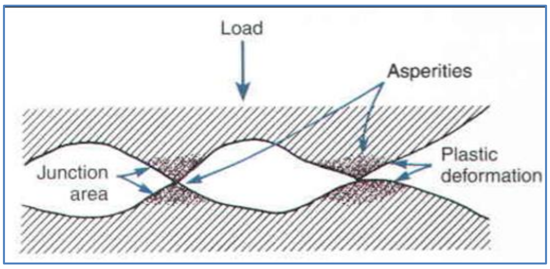
STATIC FRICTIONAL FORCE: Tangential force that does not cause any motion of the contacting parts. It reflects the force necessary to initiate movement.

KINETIC FRICITIONAL FORCE: Is the tangential force which acts between the sliding surface moving at a constant speed and it reflects the force necessary to perpetuate this motion.

Kinetic co-efficient of friction is smaller than static co-efficient of friction.

Kusy and Whitley divided resistance to sliding into 3 components:

Classical Friction (FR): Friction, static or kinetic due to contact of the wire with bracket surfaces. Proportional to applied force and affected by nature of contacting surface. All the surfaces have irregularities and real contact occurs only at a limited number of small spots called asperities at the surface. These spots carry all the load between two surfaces. When a tangential force is applied to cause one material to slide past the other, the junctions begin to shear. At low sliding speeds, a “stick slip” phenomenon may occur as enough force builds up to shear the junctions and a jump occurs, then the surfaces stick again until enough force again builds to break them.



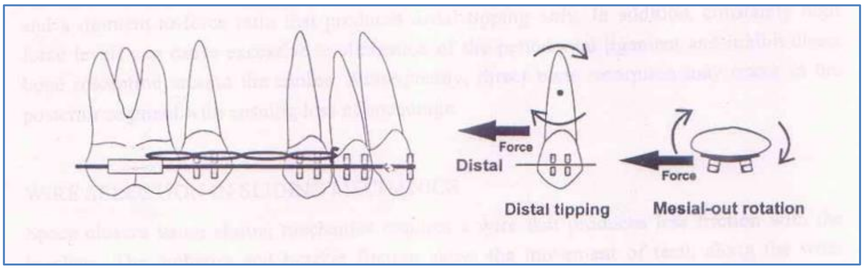
A single stick-slip cycle involves a stick state associated with elastic loading of the system, followed by a sudden slip corresponding to stress relaxation. Notching (NO) refers to the resistance to sliding from a permanent damage in the arch wire surface. Such damage can occur due to grooves formed by a combination of gouging and cutting into the wire surface (as for example when hard ceramic bracket edges cut into archwires). It further hinders sliding to such an extent that sliding may become impossible.

There are 3 stages in the active phase of moving teeth.

1. The first is the early stage of sliding as the tooth tips and contact of the wire with the corner of the bracket begins to occur; both friction and binding contribute to resistance to sliding: RS= FR+BI.
2. In stage 2, the contact angle increases between the bracket and the wire, when binding is the major source of resistance and friction becomes inconsequential: RS= BI.
3. In stage 3, if the contact angle becomes steep enough, notching of the wire occurs, and both friction and binding become negligible: RS= NO.

Mechanism of Action of Friction Mechanics [2]

To move a tooth bodily, the force applied has to pass through the center of resistance of the tooth. However as the force is applied at the bracket level of the crown, the concerned tooth experiences both force and moment. Moment of force is created in 2 planes of space. One moment tends to rotate the canine mesial out as the force application is buccal to the center of resistance and the other tends to cause distal tipping of the tooth as the point of force application is occlusal to the center of resistance.



The distal tipping contributes to the retraction by causing binding of the arc wire, which in turn produces moment that results in distal root movement. As the tooth uprights, the moment decreases until the wire no longer binds. The crown that slides along the arch wire again causes distal crown tipping that again causes binding. This process is repeated until the tooth is retracted or the force component is dissipated.

Methods of Anterior Teeth Retraction in Sliding Mechanics

There are two ways in which anterior teeth are retracted.

1. By retracting the canine first followed by retraction of other four anteriors enmasse.
2. Enmasse retraction of six anterior teeth.

Force Delivery Systems in Sliding Mechanics

1. Elastic module with ligature
2. E - chains
3. closed coil springs
4. J - hook head gear
5. Mulligan's V - bend sliding mechanics (JCO 1980 July 1994 Sep)
6. Employing Tip-edge Bracket on canines

Among the above mentioned force delivery system, commonly used are the elastomeric materials and the closed coil spring. They are either attached directly to attachments on the teeth (canine hooks) or more usually to hooks on the arch wire.

Methods of Applying Traction to the Arch Wire Include [3]

- Fabricated tie back loops (in shape of boot or inverted boot)
- Soldered brass hooks (0.7mm)
- Stainless steel hooks (0.6mm)
- Crimpable hooks
- Kobayashi hooks

Preposted archwires are also available

Tie back loops are difficult to bend in preformed archwires and negate many of their advantages. Soldering requires chair side or laboratory equipment and is time consuming. It may lead to annealing of the arch wire. Preposted archwires with soldered brass or SS hooks allow large inventory of stock and has cost implications.

Preposted Archwires

They are available in 3 sizes. The average distance between the hooks are 38mm in the upper arch and 26 mm in lower arch (this suits more than half of the patients).

Additional Sizes

41 mm (U) & 35 mm (L)
28 mm (U) & 24mm (L)

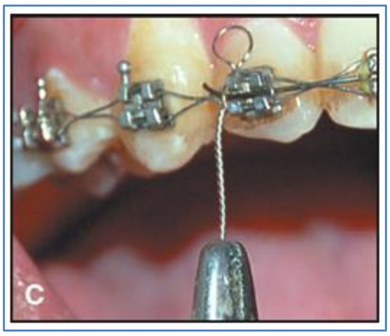
Crimpable Arch Wire Hooks

Crimpable arch wire hooks allow quick and simple placement of hooks in the desired position on the arch wire in (or) out of the mouth. Cost saving both in time and materials. It is associated with minimum discomfort.Excessive force during crimping caused GABLING of the wire and introduction of unwanted force into the wire.

GRIFFIN & FERRACANE (1998) examined the effect of addition of sandblasting and dental adhesive on the stability of the crimpable hooks. The combination increased the force required to dislodge the hook by a factor of 10. The typical crimping force was found to be 18 kg.

Kobayashi Hooks

Employed during canine retraction and in the settling phase. Prefabricated ones are also available. It can be custom made from 0.09" or 0.010" ligature wire.



Force Delivery System

Composition and structure

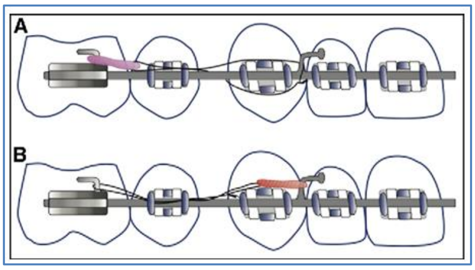
Elastomeric modules and E-chains are polyurethanes, which are thermosetting polymers. The polymers possess rubber like elasticity and have long chain which are lightly cross-linked. The cross-links between chains must be relatively few to facilitate large extension with no rupture of primary bonds.

1. ELASTIC MODULES WITH LIGATURE

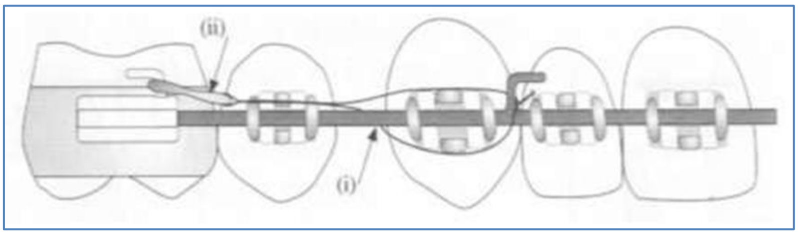
Activetiebacks

This method was popularized by BENETT & MCLAUGHLIN. They recommend placing 0.019" x 0.025" SS in a 0.022 slot for at least one month with passive tie backs before attempting space closure.Hooks of 0.024" SS or .028" brass are soldered to upper and lower archwires.

An elastic module is stretched by 2-3mm (ie) twice its normal length and it usually delivers 0.5 - 1.5mm of space closure per month. Tie backs are replaced every 4-6 weeks**.** Modules generate 50-100 gm of force if module was pre stretched before use. If used directly from manufacture without pre-stretching force delivered is greater. There are 3 methods of placing active tie backs with elastic modules.



Type 1: active tiebacks: This is the most frequently used method. The .019x .025 rectangular steel arch wire is placed, with modules or wire ligatures on all brackets. The elastomeric module is attached to the first or second molar hook. A .010 ligature is used, with one arm beneath the arch wire. This makes the active tieback more stable, and helps to keep the ligature wire away from the gingival tissues. An elastomeric module is stretched to twice its size.



Type 2: active tiebacks this follows the same principle as type 1, but the elastomeric module is attached to the soldered brass hook on the arch wire. The .019x.25 rectangular steel arch wire is placed with elastomeric modules or wire ligatures on all brackets, except the premolar brackets. A .010 wire ligature is attached to the first or second molar hook, with several twists in the wire, and then attached to an elastomeric module on the arch wire hook. Finally, a normal module is placed on the premolar brackets to cover the tieback wire and the arch wire.

Trampoline Effect

It has been shown that space closure can continue for several months in a patient who has failed to present for normal adjustments even when the elastomeric module is in poor condition and delivering very little force. This might be due to a trampoline effect which occurs during mastication and which can result in an intermittent pumping activation. This jiggling motion is greater in the lower arch and in low – angle cases with heavier masticatory forces. These presumed differences would conveniently meet clinical requirements as normally more forces are required for lower space closure and in low angle cases.

2. E-Chain (Elastomeric Chain)

It was introduced in 1960 and used in orthodontics for canine retraction, diastema closure, rotation correction and arch constriction. Most of the elastomeric chains generally lose 50% - 70% of their initial force during the 1st day of load application and at 3 weeks retain only 30 – 40% of their original force.

In view of the wide variation of initial force levels of different types of power chains, a force gauge should be used to determine the desired initial force. To overcome the problem of rapid force decay rate and provide for a more constant and consistent force delivery, prestreching of elastomeric chains has been suggested.

Configurations

Elastomeric chains are available in 3 configurations
Closed loop chain
Short filament chain
Long filament chain

Clinical Considerations While Using Elastics for Retraction of Canines

A common mistake is to change the elastic chain or module too often, thus maintaining high force levels and a moment to force ratio that produces distal crown tipping only. This also causes excessive mesial out rotation of the canines. Constantly high force levels can cause excessive hyalinization of the periodontal ligaments and inhibit direct resorption around the canine. If the posterior segment undergoes direct bone resorption at the same time, loss of anchorage may result. It is therefore recommended that elastic modules or chain should be changed at an intervals of 4-6 weeks to optimize sliding retraction of the canine.

Advantages

Inexpensive
Relatively hygienic,
Can be easily applied without arch wire removal
No patient co-operation required

Disadvantages

Absorb water and saliva and permanent staining takes place
Stretching causes permanent deformation.

The loss of force (FORCE DECAY) with time leads to variable forces levels during the treatment, this results in decreased effectiveness.

3. Closed Coil Springs

Coil springs were introduced to the orthodontic world as early as 1931. During the manufacturing process, the material is subjected to winding that includes tensional and torsional components and hence spring properties may be slightly different from the wires made from the same material. The various materials that have been used for making springs are Stainless steel, NiTi, Co-Cr Ni alloy.

a. Stainless Steel Coil Springs

Stainless steel coil springs are efficient methods of retraction. They apply more predictable levels of forces compared to elastic based systems described before. They are easy to apply However, stainless steel springs have a relatively higher load deflection rate compared to some other material springs like NiTi springs. So, as the space starts to close, there is some force degradation due to lessening activation.

Moreover, the force applied depends to some extent on the level of activation. Hence there may be a tendency to apply excessive force initially by over activation. Thus, the amount of activation has to be monitored to maintain ideal force levels.

b. Niti Closed Coil Springs

Nickel titanium alloys were introduced to the dental profession by William. P. Bleur in the 1960's. He demonstrated the unique combination of properties of shape memory and super elasticity in addition to low modulus of elasticity, moderately high strength, high resilience and less corrosion. Optimal force for space closure is 150 gm when using nickel titanium coil springs. Nickel titanium springs produce more consistent space closure than elastomeric modules.

The force degradation is very less due to the low load deflection rate. They deliver constant amount of force till they reach the terminal end of deactivation stage and generally close space with single activation. They are available in lengths of 9 mm and 11mm.Springs should not be expanded beyond the manufacturers recommendations (22 mm for the 9 mm springs, and 36 mm for the 11 mm springs). If spaces are closed too rapidly, incisor torque can be lost, and requires several months to regain at the end of space closure.

Accurate control of anterior teeth during space closure in sliding mechanics is essential to the success of orthodontic treatment. When the line of action of force passes below the center of resistance of anterior teeth, a backward moment acts on anterior teeth, resulting in tipping and extrusion of incisors

Advantages

Can be easily placed and removed without arch wire removal

Do not need to be reactivated at each appointment

Patient co-operation not required.

Disadvantages

Relatively unhygienic compared to elastic force systems.

4. Direct Headgear Retraction

J hook headgear, either of the straight pull or high pull type is clipped on the arch wire mesial to the canines to slide them distally. Straight pull headgear allows swifter canine retraction than the high pull type. However, this may cause anterior extrusion (Perej *et al*., 1980; Hickham 1974) and unfavorable occlusal plane rotations (Bowden 1978). This might specially be a problem in high maxillomandibular angle cases. High pull headgear may cause more bodily retraction. However, it is not as efficient for distal movement, needing prolonged periods or wear for modest results. During the retraction, direction of force may be varied between straight pull and high according to the individual requirements of the case.

Advantages

Anchorage conservation is good. Additional molar support by head gear may be done. Overjet reduction might occur during canine retraction due to the distal force and binding of the arch wire. Can be applied to both upper and lower arches simultaneously.

Disadvantages

As force application is intermittent this is slower than other methods of canine retraction.Highly dependent on patient co-operation. The molar and buccal segment correction is usually a later event in treatment compared to other systems. Canine tipping and anterior extrusion can occur with the straight pull headgear.

Mulligan's V Bend Sliding Mechanics

Introduced by Mulligan in the 1970's. The basic principle was to apply different moments to the teeth via bends in the continuous arch wire while force for retraction was applied by auxiliaries like elastic chain, coil spring etc. In the 0.018 slot, 0.016 SS wire is used for retraction while in the 0.022 slot, 0.016, 0.018 or 0.020 wires may be used. makes use of alpha and beta moments to provide the anchorage during cuspid retraction.An off-centered bend placed in the arch wire span between two edgewise brackets creates unequal moments and forces on the two teeth. The tooth closer to the bend experiences a greater moment and an extrusive force, and vice versa, When the two are tied together by an elastic element such as an elastic thread or an elastic chain, the tooth experiencing the greater moment resists displacement more than the other, thus acting like an anchor tooth.

Initially, only the cuspids and molars are fitted with .022 slot brackets and tubes, so that a long arch wire span is available to create favorable disparity between the moments on the molar and the canine, A continuous 0.018" size arch wire runs from one side molar to the other. A bend of approximately 45 degrees is placed in the arch wire close to the molar tube on both the sides If the bend is placed off-center it creates a short and a long segment.

The shorter segment is more rigid and hence applies greater moments. So, if maximal canine retraction is required the bend is placed very close to molar. The longer span of wire towards the canine allows some tipping to occur as the moment is less. Thus the canine gets retraced by tipping and up righting. As the canine retracts, the bend goes on becoming less off centered and mesial crown up righting moments on the canine increase.

After the space closes completely, another V bend of the same magnitude is placed in the arch wire just distal to both the cuspids. The two bends together have a centered V bend like effect, resulting into opposite moments on the molar and the cuspid teeth without causing any vertical forces. The moment on the cuspid tooth uprights its root.

Effects of Overly Rapid Space Closure

Space closure typically occurs more easily in high angle patterns with weak musculature. The rate of closure can be increased either by increasing the force or using thinner arch wire. However more rapid space closure leads to loss of control of torque, rotation or tip.

Advantages of the Frictional System

Straight wires are easy to apply, thus requiring less chair time. Patient discomfort (hygiene problems, soft tissue irritation) is less common compared with looped wires. The whole dental arch can be controlled with only one arch wire. Leveling can be performed easily with highly flexible NiTi wires.

Disadvantages of the Frictional System

Unpredictable Mechanics-Any interaction between wire, brackets, and ligatures causes friction-anchorage loss is more likely to occur. Occlusal plane inclination and interocclusal relationships may need to be controlled by intermaxillary elastics, microimplants, or headgear Canine distalization along flexible archwires or excessive force application may cause extrusion of incisors, resulting in anterior deep bite. En masse retraction is difficult without headgear, which requires considerable patient cooperation.

CONCLUSION

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 in others.

The potential risks of friction and binding are now reduced but not totally eliminated from sliding mechanics. However it remains the most widely used method of canine retraction in clinical practice. So the orthodontist must be aware that even with best arch wire / bracket combination (SS / SS), at least 40 gms of friction must be included in the force applied to the tooth to initiate movement during sliding mechanics.

REFERENCES

- Angolkar, P. V., Arnold, J. V., Nanda, R. S., & Duncanson Jr, M. G. (1992). Force degradation of closed coil springs: an in vitro evaluation. *American journal of orthodontics and dentofacial orthopedics*, *102*(2), 127-133. doi:10.1016/0889-5406(92)70024-5
- Gerson, L. U. R., Helder, B. J. (2016). Understanding the basis of space closure in orthodontics for a more efficient orthodontic treatment; *dental press J orthod, 21*(2), 115-25
- Griffin, J. T., & Ferracane, J. L. (1998). Laboratory evaluation of adhesively crimped surgical ball hooks. *The International journal of adult orthodontics and orthognathic surgery*, *13*(2), 169-175.
- Marcotte, M. R. (1976). Prediction of orthodontic tooth movement. *American Journal of Orthodontics*, *69*(5), 511-523.
- McLaughlin, R. P., Bennett, J. C., & Trevisi, H. J. (2001). Systemized orthodontic treatment mechanics.
- Nanda, R. S., & Tosun, Y. S. (2010). Biomechanics in orthodontics. *Principles and practice. Hanover Park IL: Quintessence Publishing Co*, 38-9.
- Nattrass, C., Ireland, A. J., & Sherriff, M. (1998). The effect of environmental factors on elastomeric chain and nickel titanium coil springs. *The European Journal of Orthodontics*, *20*(2), 169-176.
- Samuels, R. H. A., Rudge, S. J., & Mair, L. H. (1998). A clinical study of space closure with nickel-titanium closed coil springs and an elastic module. *American Journal of Orthodontics and Dentofacial Orthopedics*, *114*(1), 73-79.
- Tripolt, H., Burstone, C. J., Bantleon, P., & Manschiebel, W. (1999). Force characteristics of nickel-titanium tension coil springs. *American journal of orthodontics and dentofacial orthopedics*, *115*(5), 498-507.