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FRICTION MECHANICS IN ORTHODONTICS : A REVIEW ARTICLE

Orthodontics

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ABSTRACT

Resistance to sliding (RS) at the wire-bracket interface significantly influences the force delivered to teeth during orthodontic treatment. While friction—both static and kinetic—has long been studied for its impact on anchorage and tooth movement, many experimental setups fail to replicate true oral conditions, limiting their clinical relevance. Recent findings highlight the greater role of binding and notching, rather than friction alone, in hindering tooth movement. Effective space closure demands a clinician's ability to predict and control force systems, with careful consideration of periodontal response. The choice between frictional and frictionless mechanics should be guided by a sound understanding of the case-specific biomechanics. Ongoing research is needed to develop cost-effective, clinically applicable strategies to minimize resistance and enhance treatment efficiency.

KEYWORDS

friction, space closure, biomechanics

INTRODUCTION:

Space closure can be achieved using one of the two methods, either sliding mechanics (frictional mechanics) or closing loops (frictionless mechanics). The use of those two methods depends mainly on the treatment plan, appliance used, and the clinician's preference. Closing loops were mostly used for space closure with standard edgewise appliances [1,2] due to the presence of archwire bends (i.e., first-, second-, and third-order bends) which made the use of any other method of space closure impossible [3]. The introduction of the pre-adjusted edgewise appliance by Andrews eliminated the need for these bends giving rise to what is known as the straight-wire technique [4] which allows for the use of sliding mechanics requiring movement between the archwire and the bracket, which is resisted by friction, binding and then notching [5].

The different methods to close spaces, reduce procumbency, overjet, and eliminate extraction sites by antero-posterior therapy is generally categorized as Retraction mechanics.[6]

The strategy used in retraction mechanics must be based on a careful diagnosis and treatment plan made according to the specific needs of the individual. Two step retraction and en mass retraction are two most used mechanics in anterior retraction. In two step retraction of canine teeth is done followed by retraction of all four incisors and en mass retraction involves retraction of all six teeth [7].

FRICTION:

Friction is the resistance to motion that occurs when an object moves tangentially against another [8]. Friction opposes every action that an orthodontist takes to move teeth (Fig 1).[30]

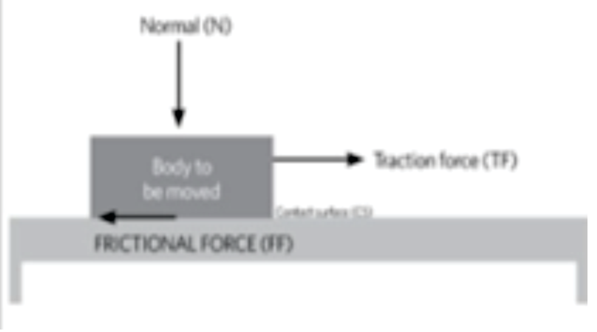

Figure 1

TYPES OF FRICTION:

There are 2 types of friction:

1. Static: Static friction opposes any applied force. Its magnitude is exactly what it must be to prevent motion between 2 surfaces, up to the point at which it is overcome and movement starts.[5]

2. Kinetic: Kinetic friction, which usually is less than static friction, then opposes the direction of motion of the object.

In orthodontic tooth movement, friction (static or kinetic) results from the interaction of an archwire with the sides of an orthodontic bracket or a ligature.

RESISTANCE TO SLIDING:

1. Friction, static or kinetic (FR) : due to contact of the wire with bracket surfaces[5]
2. Binding (BI) : created when the tooth tips or the wire flexes so that there is contact between the wire and the corners of the bracket (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 occurs.[9]
3. Notching (NO) : when permanent deformation of the wire occurs at the wire-bracket corner interface. This often occurs under clinical conditions. Tooth movement stops when a notched wire catches on the bracket corner and resumes only when the notch is released.[10]

FRICTION MECHANICS:

Sliding mechanics is attractive due to its simplicity. However, the efficiency of this modality of space closure may be compromised due to friction. Clinically, there are numerous factors that may cause friction which include, among others, bracket slot width, bracket composition, wire size, wire composition, wire-to-slot ligation method, interbracket distance, and relative interface motion between the bracket and the archwire[11-13]
Clinical studies support the view that resistance to sliding has little to do with friction; instead, it is largely a binding-and-release phenomenon that does not change considerably with conventional and self-ligating brackets(Fig 2).[29]

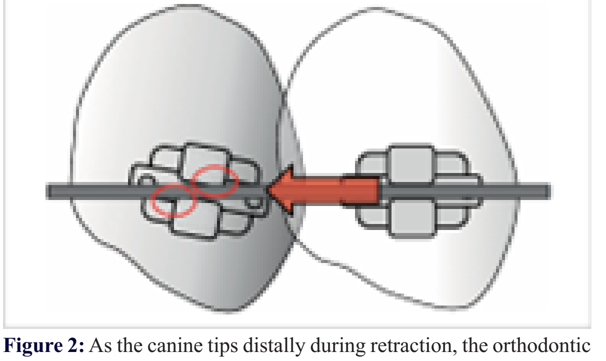

Figure 2: As the canine tips distally during retraction, the orthodontic wire binds against the edge of the bracket slot, increasing friction.

As binding delays tooth movement in the active unit, the reactive unit starts to move, causing anchorage loss.[14,15] 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 (Fig 3).[16]

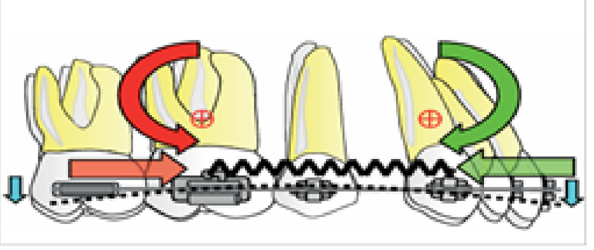

Fig 3: Force system generated by a closed coil spring applying force bellow the center of resistance of the segments. Due to linear distance between the force application and center of resistance, moments occur, and the dumping effect with vertical forces will take part of the space closure.

The orthodontist can add power arms in the anterior segment to provide better vertical control of the anterior segment. When power arms are lengthened, rotation of the entire dentition decreases.[16]

DIFFERENTIAL FORCE SYSTEMS:

In orthodontics, differential force systems are used to achieve anchorage control by applying unequal moment-to-force ratios (M/F ratios) to different units. This is done using orthodontic appliances that provide either unequal forces or unequal moments. For example, the Begg Technique uses light forces on anterior teeth to move them quickly without disturbing anchor teeth, while heavier forces are used to inhibit movement of anterior teeth and displace the posteriors.[17]

The concept of optimal force, which suggests that a specific magnitude of force produces the most efficient tooth movement, lacks empirical support when applied clinically over a meaningful period. They also question the differential force theory, which posits that teeth respond differently to forces based on their root surface area. The study found that forces well above the recommended 300 grams for canine retraction were often used in clinical practice without clear justification.[17-26]

Six Goals Considered For Any Universal Method Of Space Closure:

1.Differential space closure, the capability of anterior retraction, posterior protraction or a combination of both.[27]
2.Axial inclination control.
3. Control of rotation and arch width.
4. Optimum biologic response.
5. Minimum patient cooperation and
6. Operator's convenience.

Methods Of Space Closure:

Closing loop archwires
Sliding mechanics with heavy forces
Elastic chain
Sliding mechanics with light continuous forces (recommended).
Tiebacks
Hycon® device from Edenta

Closing loop archwires: Each rectangular steel wire typically had four loops - two omega loops and two closing (teardrop) loops - and had to be individually made for each patient.

Flexible, because of the loops, but applied a heavy space closure force in the extraction sites. There was therefore a need for extra tip, rotation control, and torque control during space closure with these mechanics, and this was achieved by placing individual bends in the wire for each tooth.[6]

Sliding mechanics with heavy (ex-edgewise) forces: Heavy space closure forces (for example using steel Pletcher springs on .018/ .025 steel wires) caused unwanted tip, rotation, and torque changes.

Elastic Chain : In a first premolar extraction case, over-stretched chain links in the extraction sites will cause rotation of adjacent teeth. Under-stretched chain links in the extraction sites will not produce any space closure. Elastic chain is useful for dealing with one or two minor spaces towards the end of treatment and light chain can be helpful in preventing spaces from opening late in the treatment, when finishing .014 wires are in place.

Sliding mechanics with light forces:
In 1990, a method of controlled space closure was described using sliding mechanics
1. Archwires. Rectangular 019/025 steel wires ('working wires') are recommended with the .022 slot
2. Soldered hooks; The authors continue to prefer 0.7 soldered brass hooks.
3. Passive tiebacks. Before starting space closure, it is recommended that the rectangular steel .019/.025 wires be left in place for at least 1 month with passive tiebacks
4. Active tiebacks using elastomeric modules
5. Active tiebacks using a nickel-titanium coil spring

Arch Wires:

Rectangular 0.019X0.025" SS wires are recommended with the 0.022" slot, because this size of wire gives good overbite control while allowing free sliding through the buccal segments.

Soldered Hooks:

0.7mm soldered brass hooks are preferred. Soft stainless steel 0.6mm soldered hooks can be a useful alternative. The most common hook positions are 36mm or 38mm for upper and 26mm for lower measured along the line of the arch.

Passive Tie Backs:

Before starting space closure, the rectangular steel 0.019X0.025" wires should be left in place for at least 1 month with passive tie backs. This allows time for torque changes to occur on individual teeth and for final levelling of the arches, so that sliding mechanics can proceed smoothly when active tiebacks are placed.

Active tiebacks using elastomeric modules: These are simple, economical and reliable and easier to place. Active tiebacks using elastomeric modules are preferred for space closure in most of the cases, even though nickel-titanium springs have been shown to be more reliable and effective.

Type one active tiebacks (distal module): The 0.019X0.025" rectangular steel archwire is placed, with modules or wire ligatures on all brackets. The elastomeric module is attached to the first or second molar hook. A 0.010" ligature is used, with one arm beneath the archwire. This makes the active tieback more stable, and helps to keep the ligature wire away from the gingival tissues.

Type two active tiebacks (mesial module):
The elastomeric module is attached to the soldered hook on the archwire.

The 0.019X0.025" rectangular steel archwire is placed with elastomeric modules or wire ligatures on all brackets, except the premolar brackets.

A normal module is placed on the premolar brackets to cover the tieback wire and the archwire.

Active tiebacks using a nickel-titanium coil spring: Nickel-titanium springs can be used, if large spaces are to be closed or if there are infrequent adjustment opportunities.

HYCON DEVICE:

The device consists of a centimeter segment of 21 x 25 rectangular wire, to which is soldered a 7 mm screw device. The rectangular segment is placed in the double or triple tube on the molar, and bent over distally. The screw is provided with a large head, to which a ligature wire can be loosely connected. The ligature wire is then extended forwards and tied to the archwire hook.[28]

Inhibitors To Sliding Mechanics:

Inadequate leveling resulting in archwire binding.
Posterior torque (torquing and sliding cannot occur simultaneously).
Blockage of the distal end of the main archwire by a ligature wire.
Damaged or crushed brackets that bind the main archwire.

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Soft tissue resistance (soft tissue build-up in extraction sites).

Cortical plate resistance (narrowing of alveolar bone in extraction sites).

Advantages:

Minimal wire bending time.[6]
More efficient sliding of archwires through posterior bracket slots.
No running out of space for activation.

Disadvantages:

Confusion concerning ideal force levels (since this was a new and untested system, there were no established guidelines concerning the amount of force to be used during space closure).[6]

Tendency to over activate elastic and spring forces which caused initial tipping and then inadequate rebound time for tooth uprighring (elastic and spring forces, while dissipating after initial activation, continued to create a tipping effect and did not allow for needed tooth uprighting).

CONCLUSION:

Resistance to sliding in orthodontics is multifactorial and significantly impacts the efficiency of tooth movement. It is directly influenced by the materials used, such as the type of archwire, bracket design, and method of ligation. While friction is often undesirable—hindering controlled movement and risking anchorage loss—it can be beneficial in certain clinical situations, such as anchorage reinforcement or torque control.

Despite advancements in materials and appliance systems aimed at reducing friction and binding, these forces are not entirely eliminated. Sliding mechanics continues to be the most widely used method for canine and anterior retraction due to its simplicity and clinical convenience.

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