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Review Article

Friction and Frictionless Mechanics

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ABSTRACT:
Space closure requires the clinician's ability to predict force system and control tooth movement after due consideration of the periodontal tissues. Orthodontic tooth movement during space closure is achieved through friction mechanics and frictionless mechanics. The selection of appropriate mechanics requires a thorough understanding of the clinical scenario and biomechanical principles.

Keywords: Friction, frictionless mechanics, space closure, loops.

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INTRODUCTION:
Space closure is one of the most challenging processes in Orthodontics and requires a solid comprehension of biomechanics in order to avoid undesirable side effects. The ability to close spaces, especially those resulting from tooth extraction, is an essential skill required during orthodontic treatment. Orthodontic tooth movement during space closure is achieved through two types of mechanics:

Sliding mechanics (friction mechanics)
Segmental or Sectional mechanics (frictionless mechanics) [8]

FRICTION IN ORTHODONTICS
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. When one surface slide over the other, two force components are created:

- Frictional Force (FF), tangent to the Contacting Surface and
- Normal Force (N), perpendicular to the FF and to the contacting surface[7]

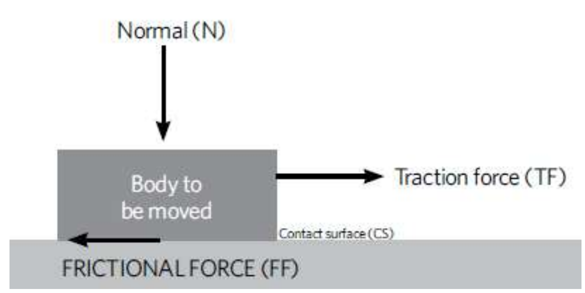

Figure 1: Static and kinetic friction

There are two types of friction considered in orthodontics: Static and Kinetic.
The static frictional force is the smallest force needed to start the motion of solid surfaces that were previously at rest with each other, whereas the kinetic frictional force

is the force that resists the sliding motion of one solid object over another at a constant speed. Practically, the kinetic friction is inapplicable for orthodontic tooth movement since the continuous movement of the teeth along the archwire does not occur. In orthodontic tooth movement, friction results from the interaction between the orthodontic archwire and the sides of an orthodontic bracket or the ligature.[11]

Because the force of friction impedes tooth movement, it should be controlled during all stages of orthodontic treatment, especially the space closure stage. If the friction resistance is high, slow progress and unnecessary elongation of the treatment time might result.[7]

FRICTION MECHANICS

By definition, in sliding mechanics force is applied between two teeth or segments of teeth such that they move or slide on a straight wire inserted in the respective brackets of the two segments so that a significant amount of friction is generated between the wire and the bracket surfaces.[6]

Wire selection: Space closure with sliding mechanics requires a wire which produces less friction between the brackets. 0.016" x 0.022" stainless steel wire in an 0.018" slot and a 0.019" x 0.025" stainless steel wire in 0.022" slot are ideal for sliding mechanics.[5]

METHODS OF FORCE APPLICATION

1) Elastomeric chains

Elastomeric chains are commonly used in orthodontics for intra arch tooth movements. The elastic chain is the force component of the retraction assembly and the wire-bracket interaction produces a moment component. Polyurethane chain elastics are commonly used in orthodontics. Placement and removal requires less chair side time for the clinician and minimal patient cooperation. The main disadvantage of elastic chain is that they deteriorate rapidly in the oral environment and consequently do not produce continuous forces necessary for tooth movement. Elastic chain is not recommended for closure of large spaces.[4]

2) Elastic tiebacks

Richard P Mclaughlin and John C Bennett attached single elastic modules to anterior archwire hooks with ligature wires extended forward from the molars. These elastic tiebacks, when activated by 2 to 3 mm, generate about 100 to 150 gm of force.

a) Passive tiebacks
b) Active tiebacks

Passive tiebacks: It refers to the use of stainless steel ligatures that is attached to the molar posteriorly and canine anteriorly. Before starting space closure, it is recommended that the rectangular 0.019" x 0.025" steel wires be left in place for at least a month with passive tiebacks to allow time for torque changes to occur on individual teeth and for final leveling of the arches so that sliding mechanics can proceed smoothly when active tiebacks are placed.

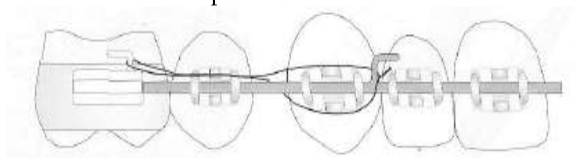

Figure 2: Passive tiebacks

Active tiebacks: Active tiebacks using elastomeric modules are preferred for space closure in most cases even though nickel titanium springs have been shown to be more reliable.

i. Type one active tieback (distal module)

The 0.019" x 0.025"rectangular steel wire is placed with modules or ligature wires on all brackets. The elastomeric module is attached to the first molar or second molar hook and 0.010" ligature is used with one arm beneath the archwire connecting the module on the molar with the canine.

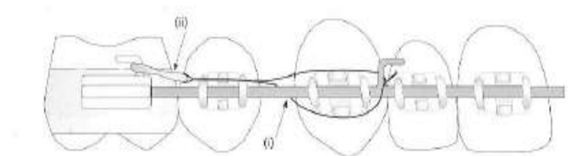

Figure 3: Type 1 active tieback

ii. Type two active tieback (mesial module)

This follows the same principle as the type one but the elastomeric module is attached to the soldered hook on the archwire between the lateral incisor and canine and the 0.019" x 0.025" rectangular steel wire in place with modules or ligature wires on all brackets except the premolar brackets. A 0.010" wire ligature is attached to the first molar hook with several twists in the wire and attached to the elastomeric module placed on the archwire hook.[5]

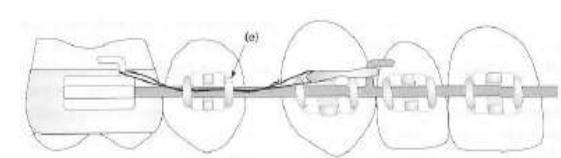

Figure 4: Type 2 active tieback

3) Vertical spur for cuspid retraction

In 1974, Lawrence E Dipietro retracted cuspids in bicuspid extraction cases using a vertical spur. This provides a simple, efficient, controlled method of retracting cuspids. It is made by bending a length of 0.018" x 0.025"wire into the shape of a hook. A piece of 0.016"round wire is welded to this as cross bar to create a stop. A power chain is extended from the distal end of the archwire or the buccal tube to the hook of the vertical spur.[3]

4) Coil spring

Albert Signorella in March 1968 classified coil springs as open or closed. He also classified them according to their use. An open coil spring maybe utilized as an intercanine coil, push coil, pull coil, open rotation coil etc. A closed coil may be called as a closed rotation coil, contraction coil or a pletcher T spring. The various materials that have been used for making springs are:

- Co-Cr Ni alloy
- NiTi
- Stainless steel[6]

5) Headgear

Headgears provide an excellent extra oral anchorage for either en-masse space closure or separate canine retraction.

6) Magnets

Magnets provide a means of force system in clinical orthodontics for various tooth movements. Samarium Cobalt and Aluminium-Nickel-Cobalt magnets are the commonly used ones. In 1987, Kawata et al soldered Samarium Cobalt magnets plated with nickel and chromium to Edgewise brackets for delivering mesio-distal magnetic forces. In extraction cases, canines were retracted conventionally until enough force were exerted on canines by the magnetic brackets on the second premolars.[12]

7) Hycon device

Richard McLaughlin, Anmol Kalha, and Winfried Schuetz used the 'Hycon Device' as an alternative method of space closure, for cases where space closure is problematic because of excessive friction, increased bone density, or narrowing of the alveolar process in the extraction site. The device consists of a centimeter segment of 0.021" x 0.025" 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. Ligature wire is loosely connected to the head of the screw. The ligature wire is then extended forwards and tied to the archwire hook. The patient is instructed to turn the bolt for space closure by using a small screw driver.[5]

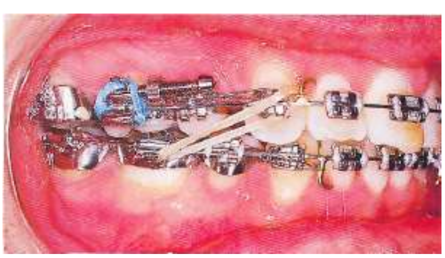

Figure 6: Hycon device

Reducing friction in sliding mechanics

Reduction of friction can mainly be achieved either by decreasing the friction coefficient of the bracket or wire materials or by decreasing the force of ligation acting on the wire. The golden standard material to perform sliding mechanics is the combination of stainless steel brackets and wires. In recent years, several bracket manufacturers have been producing "reduced-friction" (or "friction-free") brackets. Studies have shown that self-ligating bracket system produced a significantly weaker frictional force than conventional brackets. Other bracket systems that have been introduced with low friction properties include Synergy, Nu edge and Discovery brackets.[9]

FRICTIONLESS MECHANICS

In frictionless mechanics, teeth are moved without the brackets sliding along the arch wire. Retraction is accomplished with loops or springs, which offer more controlled tooth movement than sliding mechanics. The force of a retraction spring is applied by pulling the distal end through the molar tube and cinching it back.[10] The important criteria to be considered for the use of closing loops are given as follows:

- Loop position
- Loop pre-activation and
- Loop design

Loop position: Off-center positioning of a T loop produces differential moments. It has been shown that the loop position can increase or decrease the amount of posterior anchorage loss. If the closing loop is placed off centered between the anterior and posterior units, the shorter section creates greater moments, encouraging root tipping (increasing anchorage), while the longer section creates smaller moments, encouraging translation.

Loop pre-activation: Studies have suggested the moments occurring through activation alone are insufficient to produce an adequate force system necessary for root control. Thus, gable bends are given to increase the root control, avoiding 'dumping' of teeth into the extraction space. Therefore, desired alpha and beta moments are placed anterior and posterior to T-loop vertical legs. Recommended beta activation for A, B and C anchorages are 40°, 30° and 20° respectively.

Loop design: Ideal loop design should meet certain criteria most notably a large activation, low and constant force delivery with low load deflection rate and should be comfortable for the patient.[10] Reduction in the force level and increase in moment required for root control can be achieved by increasing the horizontal length of the loop, the height of loop and angulations of bends, or, by adding helices.[1]

There are many frictionless methods of closing spaces; some of them are explained here:

1) The Broussard two force system

The Broussard Two-Force Technique is predicated upon the philosophy that one passive force, the main arch wire, will establish and maintain the harmony, symmetry and arch coordination while the auxiliary springs will provide the second, active force. These auxiliary springs, under the guidance and control of the main arch wire, are used to move a tooth or a group of teeth.

2) Bimetric arch

The external arch Bimetric System consists of modules of the Bimetric series which operate in an overlay fashion. The Bimetric Arches and Torquing Arches with their modules are designed to utilize the gingival .045" headgear tube. Anteriorly, they engage specially designed brackets which are bonded gingivally to the bands or brackets on the anterior teeth.

3) Bull loop

Dr. Harry Bull's procedure for cuspid retraction was to bring these teeth back bodily by means of a sectional arch, which contains the Bull (closed vertical) loop and was formed with 0.021" X 0.025" steel wire. In an upper cuspid retraction sectional arch, the Bull loop is approximately 7 mm in height and, on an average, there is 18 mm of wire distal to the loop and 22 mm of wire mesial to the loop. In a lower sectional, the Bull loop is 5 mm in height and on the average, there is 20 mm of wire distal to the loop and 28 mm of wire mesial to the loop. The loop is activated by holding the eyelet loop between the parallel beak-closing plier and the vertical arm is bent toward the horizontal to place a gingival bend of 45° to 60° in the cuspid arm.

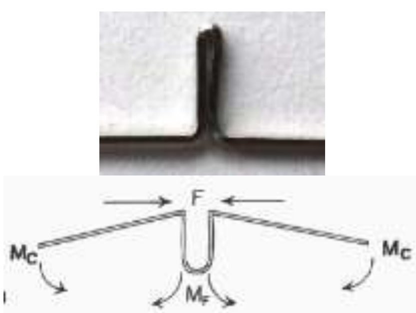

Figure 7: Bull loop

4) Compound loops

In Bio-progressive therapy, Bench RW, Gugino CF, Hilgers JJ designed various compound loops by combining a series of wire lengths and loop designs. Here, by increasing the amount of wire, the force is reduced and the duration of activation is increased. It includes the helical loop, open boot loop, double delta closing loop etc.

5) Double keyhole loop

This was introduced by John Parker. The double keyhole loop is 0.019" x 0.025" dimension, built out of round edge rectangular wire. The anterior teeth are generally retracted en masse as a group of six.

Figure 8: Double keyhole loop

6) Vertical loop

Vertical loop is one of the most commonly used mechanisms for retraction. It is simple in design and is usually fabricated of 0.016" stainless steel wire which is 6 mm high centered between the canine and second premolar brackets. Addition of helix to loop decreases the load deflection rate and placement of a gable bend in the horizontal legs of the vertical loop would increase the M/F ratio.

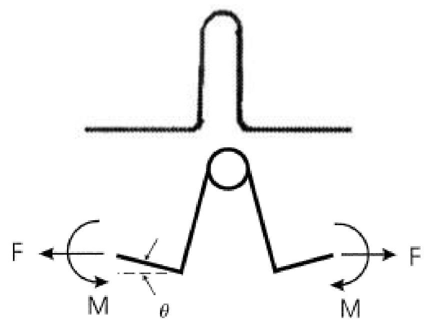

Figure 9: Vertical loop

7) Mushroom loop

The M-Loop produces lower and more continuous forces compared to simpler designs due to apical addition of the wire in the archival configuration which decreases the load-deflection rate. Wire dimensions are 0.017" X 0.025" CNA, although, for adults requiring lower force values, 0.016" X 0.022" may be preferred. Once engaged, the loop may be activated up to 5 mm.

Figure 10: Mushroom loop

8) Tear drop loop

In 1983, Alexander RG used these Teardrop shaped loops in his vari-simplex discipline. The loops are placed distal to the maxillary lateral incisor bracket. Before placing the archwire in the mouth, the portion of the archwire distal to the closing loops is reduced approximately 0.001" in the anodic polisher, so that part of the wire can slide through the brackets easily during activation. Stainless steel tear drop loops are the most common design due to their ease of fabrication; however, they deliver very high forces with only 1 mm of activation.

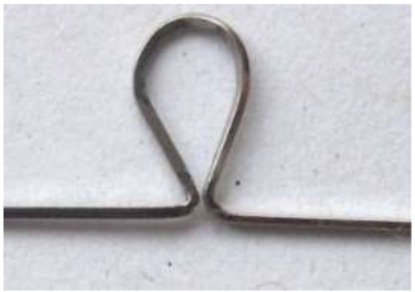

Figure 11: Tear drop loop

9) T-Loop

The 0.017" X 0.025" TMA T-loop, used for reciprocal space closure and described by Burstone, generates relatively high horizontal forces of approximately 350 gm. The TMA attraction spring has been designed to eliminate many of the problems inherent in the use of a vertical loop. The key to its design is the attempt to make the moment-to-force ratio more constant. T-loops were developed by applying engineering principles to increase M/F ratios and optimize their design. Because of anatomical limitations, it is not possible to sufficiently increase the loop to obtain the desired M/F ratio. Thus, it is necessary to add larger moments to the loop, obtained by means of pre-activation.

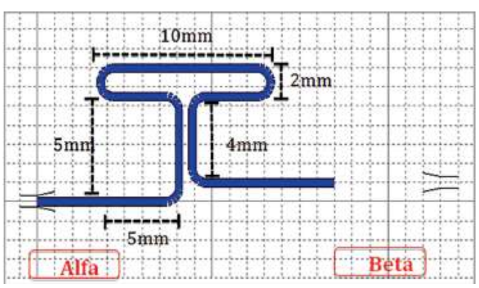

Figure 12: T loop

In addition to the gable, the T- loop can be preactivated by curvature or concentrated bends. The curvature bends promote a better internal distribution of stress during bends, since the bending moment is distributed throughout the thread. The concentrated bends are angled bends, but do not occur exactly between the horizontal and vertical legs of the loop. As the gable bends, they present a risk of permanent deformation due to stress relaxation, compromising the microstructure of the thread due to small breaks.

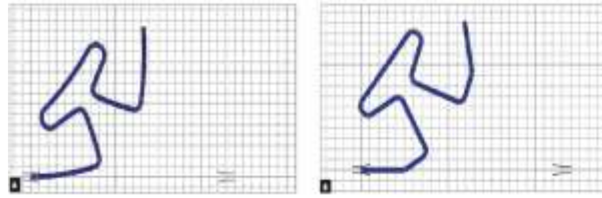

Figure 13: Curvature and concentrated bends

10) Asymmetrical T - loop

Broussard system uses a combination closing and bite opening loop that creates a step between the anterior and posterior segments. Here, simultaneous torque, intrusion and retraction movements are achieved.

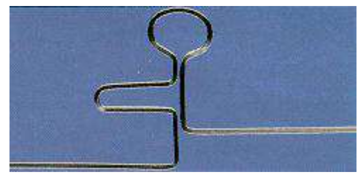

Figure 14: Asymmetrical T loop

11) Modified 'T'- loop arch wire

Modified 'T'- loop archwire was devised by Tayer BHin 1981. In some cases, there is a need for additional maxillary intrusion (bite opening), space closure and torque toward the end of active treatment. The modified T-loop archwire achieves all these corrections.

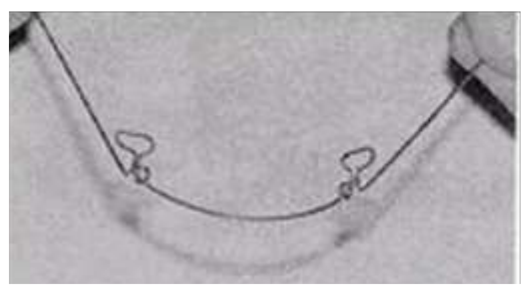

Figure 15: Modified T loop

12) Lingual lever arm technique

Kucher G, Weiland FJ and Bantleon HP described a refinement of the lingual lever arm for producing pure bodily tooth movement. The lever arm is adapted to the palatal vault and bonded to the lingual surface of the tooth to be moved (usually a cuspid or premolar) at the same height as the bracket on the buccal side. Two elastic chains or super-elastic closed coil springs (Sentalloy Blue) are used as a power source; one is stretched buccally between the cuspid or premolar bracket and the molar tube at crown level, and the other is stretched palatally from the lever arm to an extension soldered on a transpalatal bar.

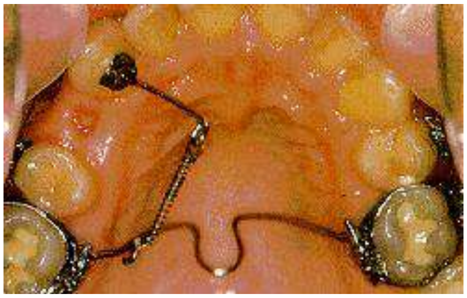

Figure 16: Lingual lever arm

13) The K-SIR Arch

The Kalra Simultaneous Intrusion and Retraction (K-SIR) archwire was designed by Varun Kalra is a modification of the segmented loop mechanics of Burstone and Nanda. It is a continuous 0.019" × 0.025" TMA archwire with closed 7 × 2 mm^2 U-loops at the extraction sites. The main indication for the K-SIR arch wire is for the retraction of anterior teeth in a first-premolar extraction patient who has a deep overbite and excessive overjet and who requires both intrusion of the anterior teeth and maximum molar anchorage. The archwire is inserted into the auxiliary tubes of the first molars and engaged in the six anterior brackets. It is activated about 3 mm so that the mesial and distal legs of the loops are barely apart. The second premolars are bypassed to increase the inter-bracket distance.

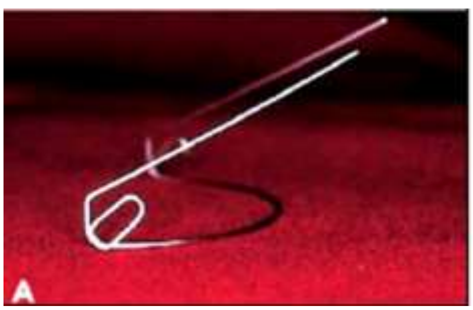

Figure 17: K sir arch

14) Opus loop

This loop was designed to deliver inherent moment to force ratio sufficient for en mass space closure via translation for teeth of average dimensions.

As the loop M/F is high, no activation bends or bends in the formed loop need to be added before insertion.

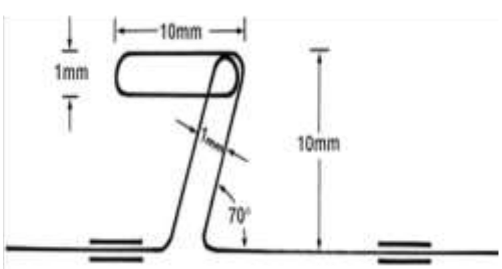

Figure 18: Opus loop

15) The Universal Retraction Spring

In 1985, Gjessing P designed a canine retraction spring. It was constructed from 0.016" X 0.022" stainless steel wire, the principal element being a double ovoid loop 10 mm in height. The spring consists of a double ovoid helix of 10 mm height gingivally and with a smaller occlusally placed helix of 2 mm diameter. It is constructed in 0.016" × 0.022" SS wire and produces 160 gm of force for every 1mm of activation. Mesial extension of the spring is 15° to the horizontal plane. Distal extension of the spring is 12° to the horizontal plane with an anti-rotation bend of 30° in the distal extension.

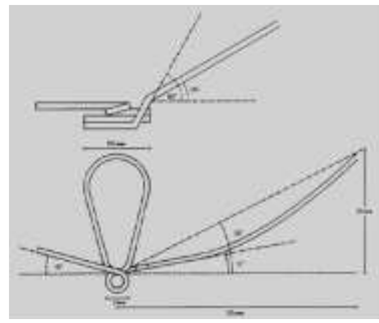

Figure 19: Universal retraction spring

16) Retrusion Utility Arch

The retrusion utility arch can close interproximal spaces while intruding and aligning the upper anterior teeth and correcting midline discrepancies. The retrusion arch originates in the auxiliary tube on the molar, and 5-8 mm of wire should protrude anteriorly before a posterior vertical step of 3-4 mm is placed. The vestibular segment extends anteriorly to the interproximal region between the lateral incisor and the canine. The wire is pulled 2-3 mm posteriorly and then bent upward at a 90° angle.[2]

Figure 20: Retrusion utility arch

CONCLUSION:

Friction and frictionless mechanics have their own merits and demerits. There is no such thing as the best method of space closure. Some situations will require some techniques over the others. The selection of any treatment, whether a technique, stage, spring or appliance design should always be based on the desired tooth movement. Thus orthodontic space closure should be an individually tailored procedure based on the diagnosis and treatment plan.

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