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Friction Mechanics – A Review

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Abstract

Space closure is one of the most challenging processes in Orthodontics. Tooth extraction, molar distalization, expansion of dental arches, interproximal reduction, among other things, have been part of the orthodontic armamentarium to correct malocclusion and allow dental space gain with which the orthodontist should deal[1]. The ability to close spaces, especially those resulting from tooth extraction, is an essential skill required during orthodontic treatment. Space closure mechanics without knowledge can result in failure to achieve an ideal occlusion.[2] Current knowledge in biomechanics, allied with the development of new material and techniques, made significant upgrading possible in space closure, which has simplified mechanics. This article discusses about the various friction mechanics involved in retraction of anterior teeth.

Introduction

The biomechanical basis of space closure enables clinicians to determine anchorage and treatment options, reach the prognosis of various alternatives, as well as decide specific adjustments that can improve the outcomes of care.

Extraction sites may be needed to achieve specific orthodontic goals of positioning the dentition within the craniofacial complex[1]

Six goals (Burstone, AJO 1982 Nov) should be considered for any universal method of space closure: anchorage control, axial inclination of the tooth, control of rotations, minimum patient cooperation, dentist convenience, and optimum biological response.[1]

Retraction can be done by two mechanics

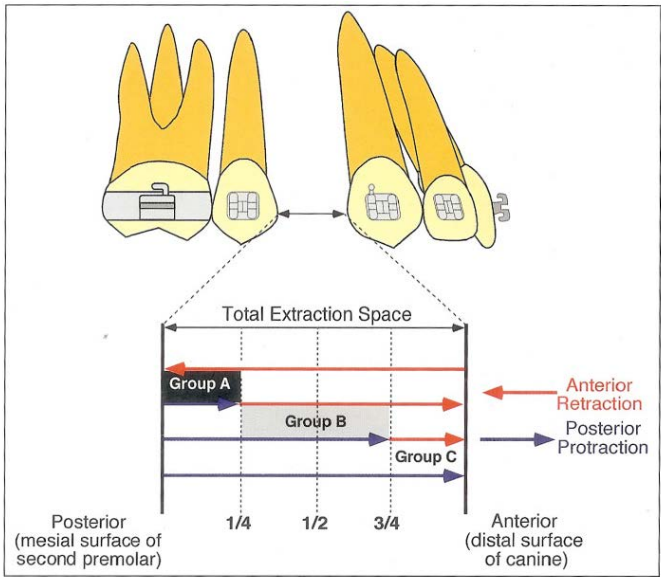
1. **Friction mechanics or sliding mechanics[3,4,5]**:

It involves the movement of either the arch wire through the bracket or the bracket through the arch wire which cases the tooth movement but the disadvantage is that it generates friction between the bracket and the wire.

2. **Frictionless mechanics or loop mechanics**:

It involves the movement of teeth (closure of spaces) by using loops. In loops mechanics there is no friction produced. In this, the position of the loop decides the tooth movement.

Anchorage Control



The basic techniques for anchorage control generally rely on 3 essential similarities:

(3) Extraoral forces on the anchorage unit (headgear),

(2) Intermaxillary elastics

(3) Tipping movements of the active teeth while simultaneously discouraging tipping of the anchorage teeth.[9]

Friction mechanics

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.

In friction or sliding mechanics, an elastic chain or thread is attached to the tooth and a continuous archwire is placed. The elastic chain is the force component of the retraction assembly, with wire-bracket interaction producing the moment component.[5]

The tooth experiences a moment of force in two planes of space, however, since the elastic chain is placed at the bracket level and not at the center of resistance.[16] One moment rotates the tooth mesial-out, and the other causes distal tipping of the crown(Fig 1).[5]

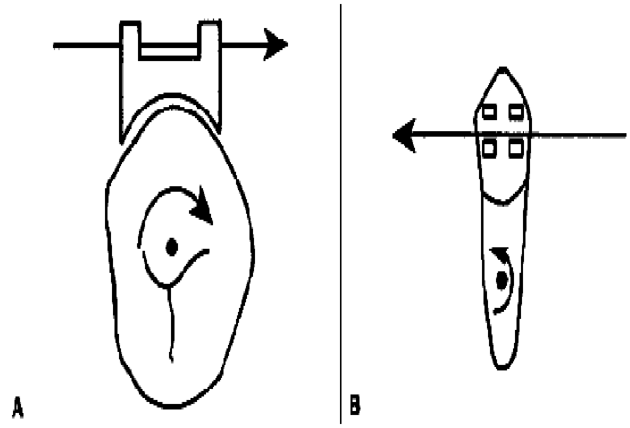


Fig. 1: Moments of force produced by elastic chain placed at bracket level and not at center of resistance. A. Crown rotation. B. Crown tipping.

The mesial-out moment is an undesirable side effect, but the distal crown moment contributes to the retraction. Eventually this distal tipping causes binding of the archwire, which produces a moment of a couple that results in distal root torque.[1]

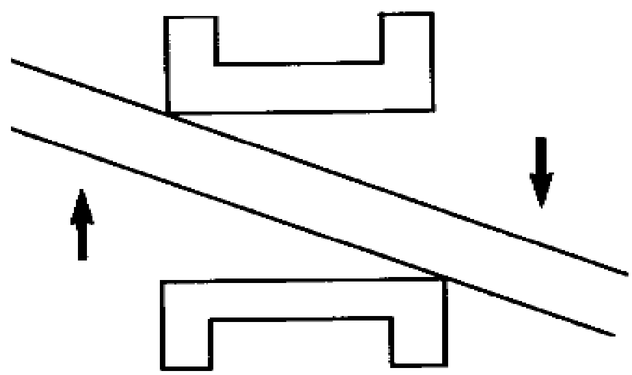


Fig. 2: Couple produced by archwire, binding results in distal root torque.

The magnitude of the torquing moment depends on the size, shape, and material of the wire and the width of the bracket. The larger the load/deflection rate of the wire, the greater the force resulting from its deflection and the greater the moment produced. The wider the bracket, the greater the moment.[5]

As the tooth uprights, the moment decreases until the wire no longer binds. Then the crown slides along the archwire until distal crown tipping again causes binding (ratcheting type of movement) and is called the "stickslip phenomenon". The process is repeated until the tooth is retracted or the elastic force is dissipated. The moment-to-force ratio of the retraction assembly is at its lowest point during the first few days after placement of the elastic chain, because the magnitude of force is then at its highest level.[15]

Advantages of friction mechanics [21]

1. An advantage is that complicated wire configurations are not needed, making initial wire placement less time consuming. This can enhance patient comfort and permit more delegation to assistants.
2. Better rotational control and arch dimensional maintenance.

Bennett and Mclauglin (JCO 90) advocates that, most efficient method of closing spaces is sliding mechanics with a standard appliance prescription, closing 0.5-1.5 of space per month with gentle forces.[22]

Disadvantages of Friction Mechanics

1. Anything that adds friction slows the movement of teeth along the arch wire. Hence, the lack of efficiency compared to frictionless mechanics should be accounted.[21]
2. More tipping and extrusion when compared to frictionless[(21)]Methods of force application in sliding mechanics

Elastics and elastomeric chains

Elastomeric chains are made from synthetic rubber polymers that are capable of large elastic deformation due to their pattern of folded or kinked molecular chains at rest, which when extended, unfold in an ordered linear fashion.[3]

Exposure to ozone and UV light breaks down the unsaturated double bonds and results in decrease in tensile strength and flexibility. So anti oxidants and anti ozonates are added to retard these effects.[23]

Advantages[24]

- Inexpensive and easily applied
- Better patient comfort
- Less chair time

Disadvantages

- In the oral cavity, water and saliva breakdown the internal bonds and in addition, the elastics swell and stain due to the filling of voids by fluid and bacterial debris.[25]
- Rapid force decay

Force degradation of elastics and elastomeric chains

Anderson and Bishara (AO 1970) compared latex elastics and plastic Alastiks.

The latter suffered 74% force loss whereas latex suffered 42%. Based on this study the authors recommended an initial stretch of the chain to four times the desired force level to compensate for this force loss.[23]

Comparing rubber and plastic elastics, the authors found that the average decay was lesser for rubber elastics (10%) than plastic Alastiks (12%).

Ferriter et al (AJO 1990) investigated the effect of pH and found that elastomeric chains subjected to more basic solution exhibited greater force decay over the 4 week test period.[24]

Prestretching of elastics

Rapidly extending the elastomeric chains resulted in greater initial force levels but more force loss after a week.[24] Prestretching the elastomeric materials in air prior to engaging onto the brackets invivo resulted in a smaller percentage of force decay **(Young and Sandrik, AO 1979)**

Elastic tie backs

McLaughlin and Bennett (JCO 1990) advocated sliding mechanics with light forces using an 0.019 x 0.025" working archwire in an 0.022 "slot system.

Hooks of 0.024 " stainless steel or 0.028 " brass are soldered to the upper and lower archwires . The average distances between hooks— 38mm in the upper arch and 15mm in the lower arch— suit the clinical requirements of more than half our patients, so we have had wires prefabricated to this size. Additional sizes of 35mm and 41mm (upper) and 24mm and 28mm (lower) cover most of the remaining cases.[22]

The force required for space closure is delivered by elastic "tiebacks." An elastic module stretched by 2-3mm (to twice its normal length) usually delivers 0.5-1.5mm of space closure per month.[22]

Passive tie backs: before space closure the tie backs are left in place without stretching for 1 month for toque changes and final leveling.

Active tie backs: On stretching the tie backs deliver 16 to 100 gm of force if pre stretched and 200 to 300 gm of force if used directly. It can be given with a mesial or distal module placement.[22]

Trampoline effect: The elastomeric modules continue to deliver forces for space closure even if left for months due to the trampoline effect during mastication.

Active Tie backs using NiTi coil springs:

- For large spaces
- Infrequent adjustment opportunities
- Optimum force of 116 gm with light NiTi closed coil springs
- More consistent space closure than elastomeric modules[59]

Group movement and sliding mechanics are combined for gentle, controlled space closure, so that about 0.5mm of incisor retraction and 0.5mm of mesial molar movement can be seen each month. The tiebacks are replaced every four to six weeks.[28]

Intercanine Coil

This is an effective means of starting cuspid retraction and opening spaces for bands between crowded incisors[25]

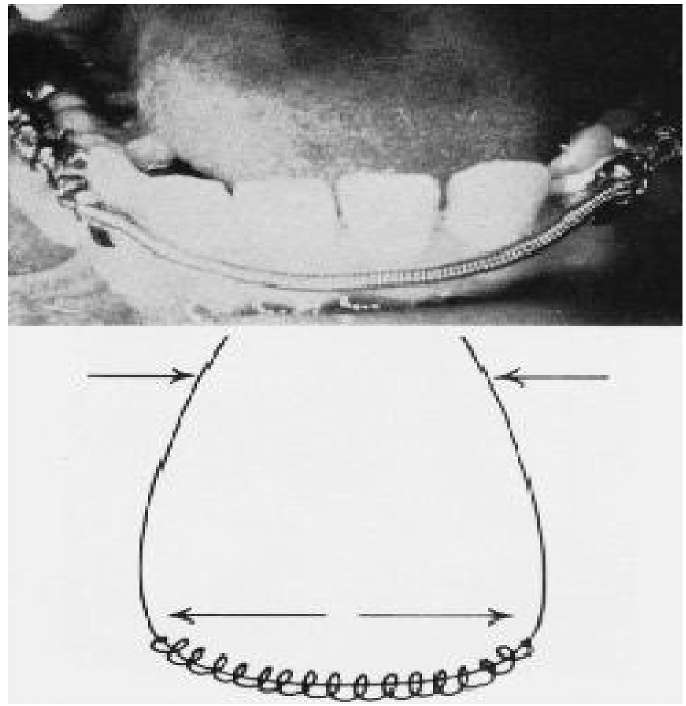


Fig. 3

There are three side effects to be compensated for:

- Since the cuspids are located at the corners of the mouth, they are pushed laterally as well as distally.
- This buccal distortion of the archwire at the corners creates a lingual distortion of the arch ends which may cause the molars to torque lingually.
- If the ends of the archwire are cinched, the molars will also be pulled mesially since the length of the archwire is shortened by this bending at the corners.[25]

When an intercanine coil is used, these unfavorable side reactions must be anticipated, and compensation for them must be incorporated into the archwire.[25]

Modular Coil Spring

Jack Perlow (JCO 1974) devised the modular spring based on the idea of Dr. Abe Lees.

The modular coil spring is a pull coil spring which can be used on the labial and/or lingual for space closure. On the lingual, buttons are used to which to tie the spring with ligature wire.

This spring can be used equally well for rotations and for anti-rotations. The anti-rotation application can be used to control anchorage by preventing adverse molar rotation with the use of any horizontal space closing device.[12]

One end of the spring is tied to the lingual button of the molar and the other end is tied through to the labial archwire, mesial to the bicuspid.[12]

Advantages: Continuous and gentle force application

Disadvantages: More chances of colleting debris and excess coil activation can cause arch wire distortion.

Variables that affect the force levels produced by the coil springs include

- Alloy : Co-Cr load deflection rates averaged 5% greater than stainless steel[25] found that closed coil springs of stainless steel showed a linear relationship between load and deflection. The NiTi springs showed superelastic effect with a constant force for large deflection.[25]
- Wire size: It had the greatest effect upon the spring rate and larger wire size resisted displacement.[27]
- Lumen size: Lighter forces with larger lumen size, and springs with larger lumen sizes and smaller wire size are indicated for orthodontic use [27].
- Pitch angle of the coil : As the pitch angle increases the number of coils per unit length decreases. The smaller the number of coil in the spring, the more the space between the coils and greater the activation that can be achieved.[12]

Contraction Coil Spring

The contraction coil spring was first demonstrated by Nagamoto in 1947. There are two types of continuous contraction coil springs, the simple contraction coil spring and the double contraction coil spring.

The contraction coil spring is made of hard .008" stainless steel wire wrapped around an .030" round wire. The .008" wire should be wound to form a coil of about seven turns. These springs are available prefabricated.[26]

The contraction coil springs are placed in the gingival slot of the bracket. The portion of the wire near the distal end of the spring should be annealed to prevent breakage when wrapping it at the distal section of the main archwire during activation[26].

Arch placement: The coils should be near the distal of the bracket of the teeth that will be retracted.

Cuspid retraction with a Vertical Spur

Lawrence DiPietro (JCO 1974) demonstrated the use of the vertical spur providing a simple, efficient, controlled method of retracting cuspids The Vertical Spur.

The vertical spur is made by bending a length of 0.018 x 0 .025” wire into the shape of a staff. A piece of 0.016 round wire is welded to this as a crossbar to create a stop.For proper positioning, the crossbar should always be on the labial side of the spur. The spur and crossbar assemblies can be prefabricated in lefts and rights.[29]

The Technique: To use the vertical spur, it is necessary to have a siamese edgewise bracket with a vertical slot (0.020 x 0.030”) on the cuspid bands.

The vertical spur is inserted into the gingival end of the vertical slot of the cuspid bracket. No retention of the spur is necessary other than a slight bend at the incisal end of the spur. The crossbar acts as a stop and prevents the vertical spur from slipping below its optimum height.

Optimum height is achieved by placing the hook portion of the spur as far apically as possible without causing tissue impingement.[29]

An 0.018 round continuous archwire is placed with the incisors tied in or the distal ends of the archwire tied back or bent back. The distal element of the cuspid siamese bracket is secured with a heavy Alastik or an 0.010 ligature wire. This prevents distolingual rotation during retraction .[23]

An elastic module or Powerchain is extended from the distal end of the archwire and/or buccal tube to the hook of the vertical spur. The force of these modules can be measured and controlled. They are changed every 3½ to 4½ weeks.[29]

Advantages of the Vertical Spur

- Cuspids are retracted in an upright fashion. Usually there is no need for root correlation after retraction.
- There is a minimal amount of taxation of molar anchorage. Forces can be controlled and are highly predictable.
- Using prefabricated vertical spurs, setting up cuspid retraction requires little chair time.
- Retraction in this fashion allows the use of a continuous arch which will help prevent lingual "dumping." It will also allow the orthodontist to correct rotations, level and align the arches while he is retracting cuspids, thus decreasing treatment time.[29]

Disadvantages of the Vertical Spur

- Hygiene around the vertical spurs can be a problem, especially in the mouths of poor brushers.
- Tissue irritation can occur if improper insertion does not give the spur and elastic sufficient tissue clearance.[29]

Haskell Spencer Day Spring

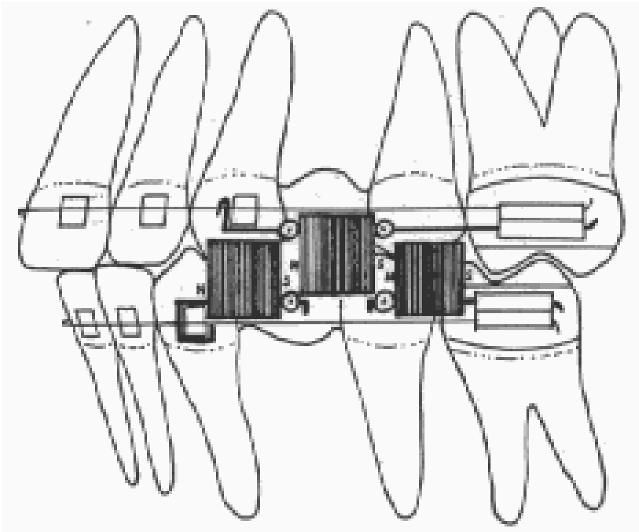
Haskell, Spencer and Day (AJO 1990) devised the auxiliary spring appliance is designed to prevent unwanted tipping and rotations of teeth during its translational movement along a main 0.016 x 0.022-inch archwire. The system consists of specially designed 0.017 x 0.022-inch heat-treated Elgiloy springs, which are inserted into buccal and gingival tubes that are part of the molar and canine brackets. Only the special canine brackets need to be substituted in existing edgewise prescriptions in cases where the first molar brackets include gingival auxiliary tubes.[30]

The helix, in conjunction with the gables placed in the posterior (ß) legs of the spring provides the required couple which counters the moment produced by the closure force and allows translation of the canine or molar during space closure. The main spring helices are placed in the area of the extraction site.

The preadjusted springs are first placed in the mesial part of the auxiliary molar tube and then inserted into the mesial part of the canine tube. The excess wire at the distal side of the auxiliary molar tube is activated 2 mm by a pulling and cinching action on the wire at the end of the spring. Spaces between the teeth may be closed en masse or by separate canine-retraction methods, depending on the requirement of the clinician.[30]

Magnets

Magnets offer the advantage of providing intermaxillary force of sufficient intensity and duration independent of patient cooperation.Theoretically, another advantage in using magnetic force systems in the treatment of malocclusions is better vector control.[31]



Three-magnet configuration used to simultaneously move all four canines distally.[31]

Enmasse Retraction of Anterior Teeth With Headgear

Canine retraction with J hook headgear (Ayala Perez et al, AJO 1980)

The high-pull headgear produced the least tipping tendency, being closer to a bodily movemment effect. Further, stresses were transmitted to deeper structures of the simulated facial bones; these regions were the frontozygomatic, zygomaticomaxillary, and zygomaticotemporal sutures.[32]

Advantages are

(I) Anterior headgear may have the advantage of retracting anterior teeth with minimum strain on posterior anchorage.

(2) The adjustability of the outer bow in relation to the premaxilla's center of resistance, provides effective desired movements.

(3) Intrusion and torque control are achieved in the course of anterior segment retraction.[32]

Discussion

Extraction space closure is an integral part of orthodontic treatment which demands a thorough understanding of the biomechanics. In the pre-adjusted edgewise technique, retraction is achieved either with friction (sliding) or frictionless mechanics. In the former, the wire and position of the bracket are important factors in tooth movement but the simplicity of friction mechanics is offset by the binding between bracket and archwire. This slows tooth movement, compromises the delivery of desired force levels, causes anchor loss and may be associated with undesirable side effect such as uncontrolled tipping and deep bite. Frictionless mechanics are more effective at reducing tipping and extrusion while the Frictional binding and the swing effect are the main problems associated with sliding mechanics. In order to overcome this, frictionless system is opted, which includes a loop as the source of the applied force.[3,4] Again frictionless system also has its demerits. It fails to produce better results in practice because of the complexity of loop forming and sometimes it is not comfortable to the patient. In addition, minor errors in loop can result in major differences in tooth movement. Biggest advantage of retraction with closing loop mechanics is that force level can be predicted which helps for the desired tooth movement. Load deflection rate is considered as a principle characteristic to describe a spring for closing loop mechanics. Friction mechanics is considered superior over frictionless system in terms of rotational control and dimensional maintenance of the arch. 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. Frictional binding and swing effect are the main problems associated with sliding mechanics. Though frictionless mechanics has advantages over the friction mechanics , most orthodontists prefer to use friction mechanics because of the technical complexity of frictionless mechanics Depending upon the condition and severity of malocclusion and treatment techniques employed, a number of methods are used for the retraction of canine either by fixed or removable orthodontic appliances. The extraction spaces can be closed using either friction mechanics or frictionless mechanics. Canine retraction also has certain undesirable effects which has to be taken care of like after leveling canine retraction, side effects, such a reverse curve of Spee, can be generated. Uprighting of canines can produce mesial crown movement and create space between canines and premolars. Tie-back or power chain elastics can be used while uprighting of canines is performed. Also, a canine bypass is used to prevent side eff ects on adjacent teeth. meaningful only if the clinician can practically produce the force system. The mechanisms that have been described are predictable for a number of reasons.[3,4]

Undesired or inefficient tooth movement during orthodontic treatment results from individual variations in biologic response and the improper use of forces. Application of the rules of biomechanics allows one of these sources of variation to be reduced or eliminated. The ability to measure and control couple-to-force ratios at the bracket is a key to predictable and controlled tooth movement.

It is better to influence on the goals of space closure and the do the treatment accordingly At least six goals should be considered for any universal method of space closure as follows: Differential space closure. The capability of anterior retraction, posterior protraction or a combination of both should be possible. Minimum patient cooperation. This is achieved by eliminating the usage of head gears and elastics. Axial inclination control. Control of rotations and arch width. Optimum biologic response. This includes rapid tooth movement with a minimum lowering of the pain threshold. Tissue damage, particularly root resorption, should also be at a minimum. Operative convenience. The mechanism should be relatively simple to use, requiring only a few adjustments for the complication of space closure.

Depending upon the condition and severity of malocclusion and treatment techniques employed, a number of methods are used for the retraction of canine either by fixed or removable orthodontic appliances. No single technique suits every situation because each technique has its limitation. Thus the individual clinician must choose the method preference to treat malocclusion which requires tipping or bodily movement or rotation of teeth with minimal time, to produce an aesthetic and functional and near ideal occlusion as much as possible[3,4]

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