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ANTERIOR AND CANINE RETRACTION:

BIOMECHANIC CONSIDERATIONS

Part One

Original article
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Introduction

Over the years orthodontists have increasingly shown more interest in the problem of retracting permanent cuspids. This dental movement is necessary in space closure of the arch for resolving different orthodontic problems. Very often, the extraction of first bicuspids is necessary in cases where there is severe crowding due to a discrepancy in tooth size and jaw size.

First bicuspid extraction followed by cuspid retraction is also indicated in cases of dento-alveolar sagittal anomalies such as excessive dental protrusion of the upper and/or lower teeth. Still in the case of basal sagittal malocclusions, such as a prognathic maxilla with a molar Class II relationship or a prognathic mandible with a Class III relationship, the extraction of bicuspids (the maxillary ones in the first case and the mandibular ones in the latter case) could be a suitable compromise solution followed by retraction of the anterior segment.

The continuous evolution of direct bonding has illuminated the understanding of the factors, which are necessary to effect dental movements with minimum tissue damage and discomfort to the patient.

The purpose of these articles is to analyze from a biomechanic perspective the distal movement of the cuspid with fixed appliances.

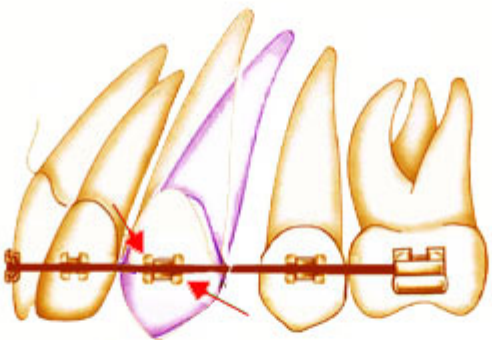
Sliding mechanics vs. Closing loop mechanics

The friction method (sliding mechanics) is based on the cuspid bracket sliding on a sectional wire from cuspid to second molar. The distalizing force comes from an elastic or from a closed coil connecting the cuspid to the first permanent molar. The second bicuspid, first molar and eventually the second molar, tied together with a steel ligature usually supply the anchorage. The second permanent molar can be included in the anchorage unit when maximum anchorage is required to prevent mesial movement of the posterior

segment during space closure.

Auxiliary anchorage can be supplied in the form of a transpalatal arch (TPA) at the first molars or extraoral anchorage can be used when it is necessary get space closure exclusively from retracting cuspids. The friction system is distinguished by the fact that a certain degree of friction exists between the wire and the bracket. The level of friction depends on multiple factors, including the type of orthodontic brackets and wire used. Stainless steel brackets slide with relative ease on steel wires. In contrast, wires that contain a certain percentage of titanium (such as beta-titanium or nickel-titanium wires) present a rougher surface compared to steel wires and therefore produce more friction in retraction. Ceramic brackets present an even rougher surface and therefore more friction when compared to metal brackets. From a biomechanical point of view all of these factors cause a high degree of unpredictability in sliding mechanics.

In order to move a tooth along an arc it is necessary to apply a force of such magnitude to overcome friction and thus start the movement of the tooth. The major difficulty is that of evaluating just how high this force should be. If the force is too excessive, the posterior segment can inadvertently move anteriorly (1). With regards to the degree of elasticity of the thread used during sliding mechanics, two types of problems could arise:

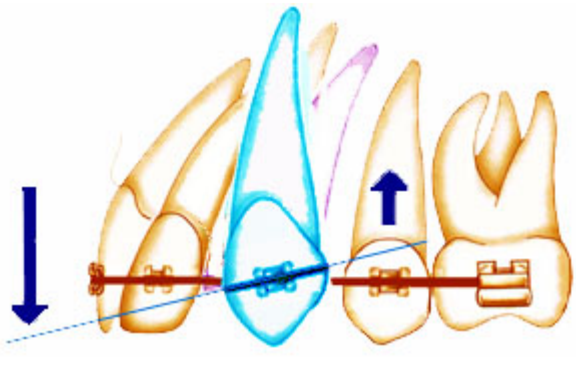


a) if the thread is rigid and the force is applied horizontally to the tooth, uncontrolled movement will occur due to excessive friction between the tooth and slot (Fig. 1).

Micro shifts of the tooth during mastication allow better movement as shown experimentally.

b) If a more elastic wire is used it will flex after force application. The tooth can tip and at the same time the anterior segment is subjected to extrusive forces (Fig. 2). This bending of the wire develops a moment that determines the radicular uprighting of the cuspid.

In this case it is possible to achieve bodily retraction of the tooth. However, uncontrolled and undesirable effects accompany this.



The frictionless method (closing loop mechanics) for retraction of cuspids uses closing loops that connect the cuspid directly with the posterior segment. Generally closing loop mechanics is more complex due to the construction of the closing loop springs and their clinical management.

However, currently, most types of closing loop arches are readily available preformed. When compared to sliding mechanics, closing loop mechanics have the following advantages:

- absence of friction between the bracket and the wire
- the force levels are easier to evaluate clinically
- the moment/force ratio of the cuspid and the posterior segment is predictable and controllable during retraction

According to Burstone (3), a spring with closing loops for retracting cuspids can be described by three principal characteristics:

1. Moment to force ratio (M/F) applied at the bracket whose value determines the position of the center of rotation during the orthodontic movement;

2. Load/deflection ratio (F/D) of the spring (the level of force caused by the spring per activation;

3. maximum strength (F_{max}) that the spring is able to release without permanent deformation.

Ideally these three factors should be able to determine respectively:

1. control of the center of rotation;

2. maintenance of ideal force levels during orthodontic tooth movement;

3. use of ideal levels of strength for orthodontic tooth movement.

Control of the center of rotation

The center of rotation should be kept as constant as possible during cuspid retraction. The maintenance of a constant M/Fratio during the retraction of the cuspid is perhaps the most important characteristic from a biological point of view. In fact, the M/F ratio, and therefore the center of rotation determined from the spring, directly influences the distribution of compression and tension at the periodontal level and therefore the consequent degree and type of cellular reaction. The ideal M/F ratio at the cuspid bracket should be such that it produces pure translation of the tooth (center of rotation at infinite). From a biological point of view this translation results in a more uniform distribution of force in the periodontal ligament. Tipping movements result from the center of rotation being at the apex. This type of movement puts maximum stress on the bony marginal crest and minimum stress at the root apex. The bodily movement of the cuspid during retraction avoids additional uprighting, which becomes necessary if the tooth tips.

Based on a study by Weine (4), which used more than 9000 subjects, the average M/F ratio which resulted in translation of the cuspid was 11.

According to Burstone (3) this value should be approximately 10. These are reference values since different factors can influence the M/F ratio: positioning of the bracket, length of the root, level of the bony marginal crest, and axial inclination of the tooth. These factors, therefore, must be taken into consideration for individual cases.

The anchorage unit in closing loop mechanics generally consists of the second premolar, the first permanent molar, and, if needed, the second permanent molar. According to Burstone (3), "T" closing loops can be used to retract cuspids. A rectangular sectional steel wire such as .018" x .025" or .021" x .025" is passively tied in with steel ligatures and closing loops (Gjessing loop, Ricketts spring) are used.

The right and left segments can be connected by means of a transpalatal arch (TPA made of .035" steel wire) to form a stronger anchorage unit. The inclusion of the second permanent molar in the anchorage unit is dependent on just how much anchorage is required. For example, if it is desirable to close all the extraction space exclusively by means of cuspid retraction, maximum anchorage is required (Type A anchorage according to Burstone) and it will be necessary include the permanent second molars. In a case where the extraction space must be closed equally by cuspid retraction and by slipping posterior anchorage (Type B anchorage according to Burstone) the second molars don’t need to be included.

Type A and B anchorage have varying M/F ratios. A M/F ratio of 8 usually causes bodily anterior movement of the posterior anchorage unit and is particularly favorable in the case of B anchorage. To obtain Type A anchorage, the M/F ratio at the level of the posterior anchorage unit should be raised up to 10-12 (center of rotation in proximity to the occlusal surface) to counteract the anterior movement of the crown.

Maintenance of ideal force levels during orthodontic tooth movement.

The force/deflection ratio (F/D) of a spring correlates with its ability to mainain constant force levels during retraction. By definition the F/D ratio expresses the force generated by activation of the spring.

A spring used for cuspid retraction should possess a low F/D ratio to guarantee constant force during orthodontic movement and therefore a favorable periodontal response. Furthermore, a spring with a low F/D ratio allows better control of force levels during activation. For example, with a typical vertical steel spring in a standard edgewise appliance, a F/D of 1000 grams per millimeter is fairly high. An error of one millimeter during the activation translates into an error of 1000 grams in the force level. Conversely, with a spring that has a a low F/D ratio of 10 grams/ millimeter, an error of one millimeter during activation results in an error of only 10 grams (3).

Use of optimal levels of force during orthodontic tooth movement

The optimal force used for cuspid retraction should generate a favorable periodontal response with consequent rapid tooth movement and minimal discomfort to the patient (5). The optimal force for cuspid retraction has not been scientifically evaluated and it is based exclusively on clinical experience. It varies according to different authors (6-10) from 75 grams to 260 grams for the bodily movement of the cuspid.

The maximum elastic force (F_{max}) which the spring exerts must be higher than the force applied during activation. A high F_{max} prevents permanent deformation of the spring during accidental overloads such as with mastication or following an aggressive activation (3).

Biomechanics of closing loop springs

Burstone and Koenig investigated the basic configuration of a closing loop spring in 1976 (11). It consists of .016" steel wire bent into a vertical loop of varying length. The closing loop spring lies halfway between the cuspid and the second premolar and is then activated with varying strengths (Fig 3).

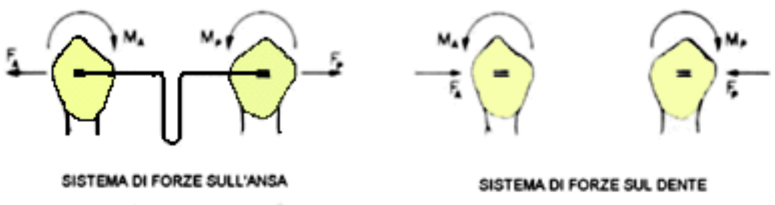


Figure 3 (from Burstone and Koenig, 1976)
(reprinted by permission)

A moment/force ratio is created at the bracket (constant for a specific base configuration and independent from the quantity of activation).
The load/deflection ratio (F/D), however, always remains high with consequent unfavorable effects from a clinical standpoint relating to the difficulty of calibrating the optimal strength for the activation and very rapid decline in forces during de-activation.

With regards to the height of the vertical loop, increasing it causes a lowering of the F/D ratio and increasing the M/F ratio. If the M/F ratio remains within a given range, however, undesirable tipping movements can be avoided.

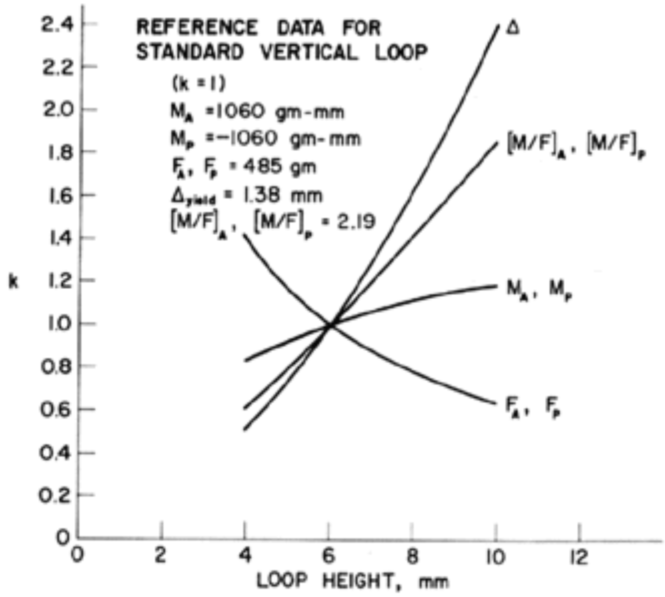


Figure 4 (from Burstone and Koenig, 1976)
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Varying the diameter of the vertical loop has minimal influence on the system. An increase in the diameter increases the M/F ratio and decreases the F/D ratio (Fig. 5).

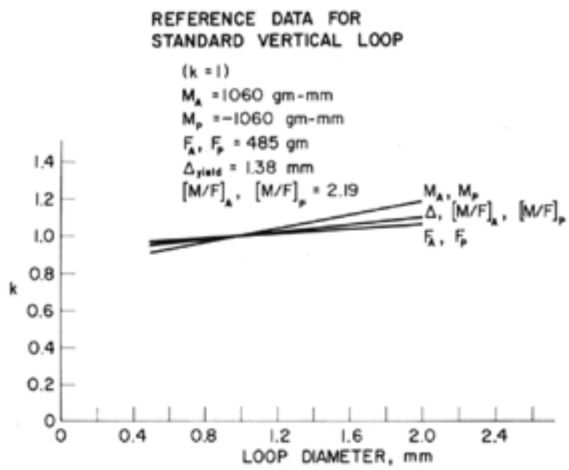

Figure 5 (from Burstone and Koenig, 1976)
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Increasing the inter-bracket distance (between the brackets of the cuspid and of the second bicuspid) causes an increase in the M/F ratio (less effect, however, than increasing the height of the loop) and also increases the F/D ratio (Fig. 6).

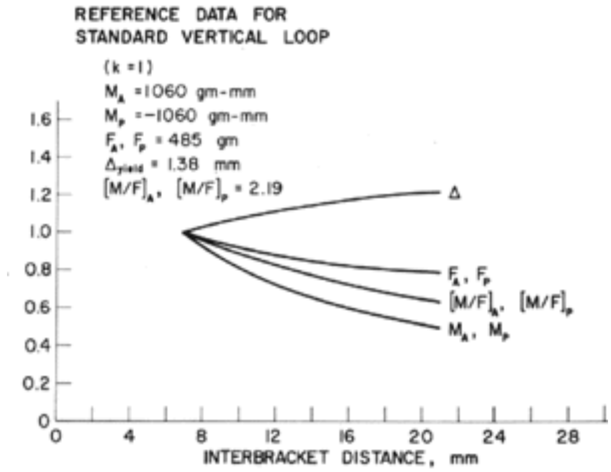

Figure 6 (from Burstone and Koenig, 1976)

The anteroposterior position of the vertical loop can influence the system in the following manner: (Fig. 7)

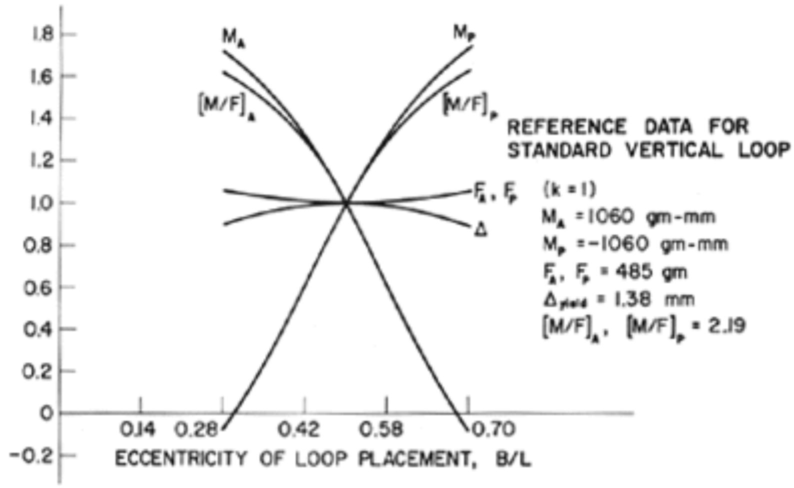

Figure 7. An increase in the B/L ratio corresponds to a displacement of the loop toward the cuspid (from Burstone and Koenig, 1976) (reprinted by permission)

If the spring is too close to the cuspid, the moment increases dramatically and there is also a small increase in the horizontal force, resulting in a favorable increase of the M/F ratio. As the moments at the cuspid and the second bicuspid are not equal, the system balances with the development of vertical forces. This causes extrusion of the cuspid and intrusion of the second bicuspid. An eccentric position of the vertical loop also causes an increase in the F/D ratio.

The possible positioning of a helix in a vertical loop decreases the F/D ratio but it doesn't affect the M/F ratio.

A meaningful increase of the M/F ratio, which will allow traslation, can be achieved with just a vertical loop by pre-activating it. By pre-activation we

mean a bend toward the top of the two horizontal arms of the loop. To permit the insertion of the loop into the slots, it is necessary to apply two moments. An activation of a spring that produces only moments in the absence of horizontal forces is a neutral activation. The moment produced in a neutral activation is called a residual moment because it is also present when the spring has been completely de-activated. The result of a neutral activation is that the vertical arms of the loop are crossed: this phenomenon must be adhered to for correct evaluation of the magnitude of horizontal activation (Fig. 8). The position that the spring takes after a neutral activation is called a neutral position.

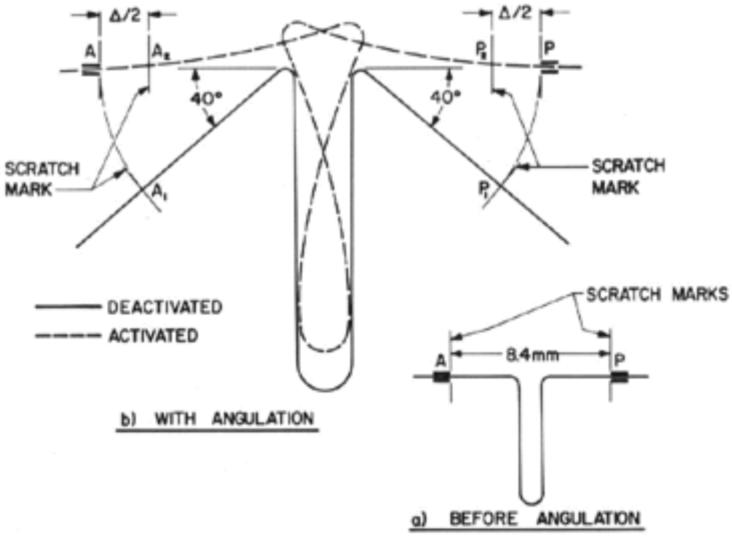

Figure 8: A vertical loop of 40 degrees has been inserted in the bracket slots by applying a couple of moments. A shortening of the loop can be observed. After a neutral activation, the base of the loop should be one millimeter away from each corresponding slot. The orthodontist must be able to observe this to avoid application of excessive force and deforming the loop (Burstone and Koenig, 1976).

With pre-activation, therefore, it is theoretically possible to obtain any given M/F ratio. However, in a spring with a vertical loop this ratio does not remain constant during de-activation. It rapidly increases since the horizontal force decreases faster than the moment (Fig. 9).

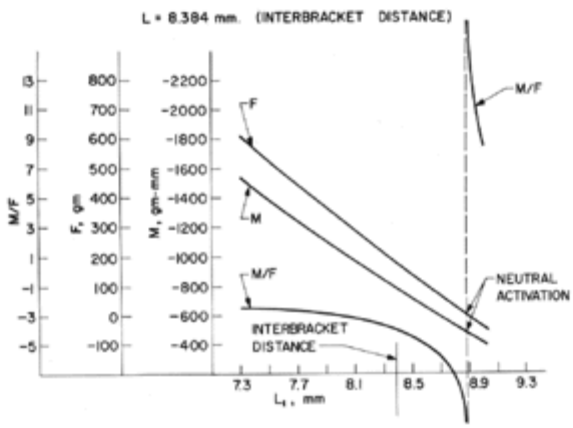

Figure 9 (from Burstone and Koenig, 1976)
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After 0.3 millimeters of de-activation the M/F ratio changes from a value which causes uncontrolled crown tipping to a value which causes root tipping through translation (Fig. 9).

As an alternative to the configuration of the vertical loop, Burstone and Koenig (11) proposed a "T" loop. This variation results in an increased M/F ratio during activation. The M/F ratio is never higher than the height of the loop (up to a maximum of 8 mm and therefore M/F=8) (Fig. 10).

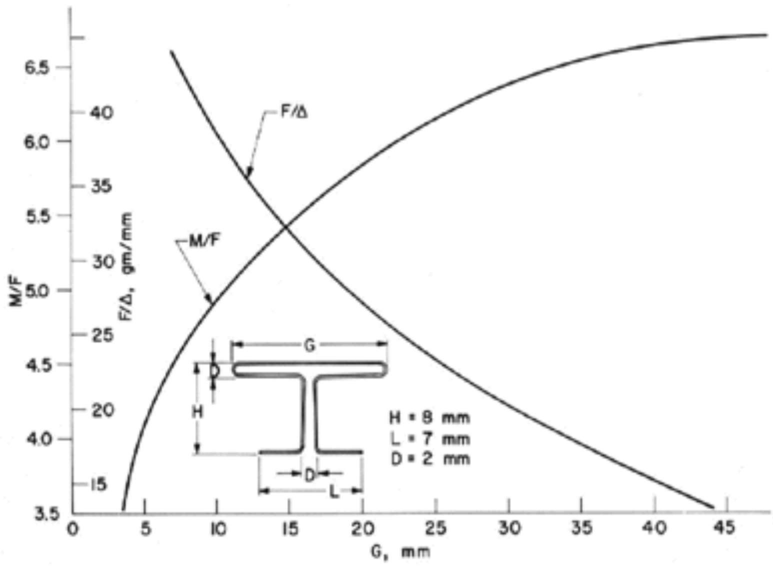

Figure 10 (from Burstone and Koenig, 1976)
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A big advantage of the "T" loop is the dramatic reduction in the F/D ratio as a result of an increase of the amount of wire in the horizontal portion of the loop.

Conclusions

From the review of the literature involving the biomechanic characteristics of retracting cuspid by means of fixed appliances, we conclude that there are definite drawbacks to sliding mechanics. These are mostly to do with the fact that it is difficult to appraise the necessary level of force for an optimal periodontal response. Closing loop mechanics have been elaborated on in an attempt to answer the fundamental requisite of orthodontic movement: the possibility of predicting and checking the moment/force ratio at the cuspid and at the anchorage unit during retraction and the possibility of measuring and maintaining constant retraction forces.

[Test Question (Self Evaluation)]

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