‘Loops in Orthodontics’—A Review
CH Nareen Chakravarthy¹*, Perumalla Kiran Kumar²

ABSTRACT
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. A review of frictionless mechanics in general and most commonly used loops in retraction has been highlighted in this article.

Keywords: Space closure, Friction, Frictionless mechanics, Bracket and archwire

INTRODUCTION
Frictionless mechanics have evolved from simple vertical loops to present more complex loop⁴,7,13,29,30 design to achieve better moment/force ratio and constant delivery of force. Materials used for frictionless retraction have also evolved from stiff stainless steel (SS) wires to the more flexible beta titanium wires introduced by Burstone,⁶ and to the newer materials like connecticut archwires (CNA) wires²³,2⁴ which are supposed to reduce the force levels and thus making the treatment more effective and efficient.

The literature contains many extensive descriptions of the in vitro static force systems produced by different orthodontic springs⁹,11,14 and wire activations,¹⁵ and the comparison between different springs. Although these models are supported by logical rationale in mechanics, a clinical study comparing different loops will determine whether biomechanics of different loops work as shown and acclaimed by their authors clinically.

One of the major advantages of frictionless mechanics is that a known force system is delivered to teeth because there is no dissipation of force due to friction. The three primary characteristics of a retraction spring are (1) the moment/force ratio which determines the centre of rotation of tooth during its movement, (2) the greatest force at yield that can be delivered from a retraction spring without permanent deformations, and (3) force to deflection rate⁷. The most important characteristic is the moment/force ratio since this determines whether tooth movement takes place by translation tipping⁷,4. Literature shows us that the moment / force ratio is altered by the vertical height of the loops,⁷ horizontal length of loop,⁷ positioning of the loops,¹,2,7,2₀ extent of activation,⁴,5,7,1₇ properties and thickness of wire⁶,1₂ used.

DISCUSSION
Varying the moment on the posterior and anterior teeth serves as another option towards creating differential M/F ratios. The application of differential moments

¹Reader, A J Institute of Dental Sciences, Mangalore, Karnataka.
²Reader Mamata College of Dental Sciences. Khammam, Andhra Pradesh.
*Corresponding author email: enareench@yahoo.com
between teeth is recognised as an effective means for achieving desired tooth movement and anchorage control[16,20,21]. These moments are termed alpha and beta moments for the anterior and posterior teeth, respectively. The moments or couples created by the brackets/wire-spring combination generate moment to the anchorage teeth, whereas a lower moment acts on the anterior teeth. For example, in maximum anchorage cases, the high M/F ratio on the posterior teeth will produce translation (M/F = 10/1) or root movement (M/F = 12/1), whereas the low M/F ratio on anterior teeth ratio controlled tipping (M/F = 7/1). As there will be greater crown movement with tipping relative to a tooth undergoing translation, this shows how tipping movements can result in greater movements of teeth from a clinical perspective[21].

The important criteria to be considered for the use of closing loops are given as follows:

1. Loop position
2. Loop pre-activation
3. Loop design[24]

1. Loop position

To understand the effects of loop positioning, the forces that occur when a closing loop is activated should be considered. Kuhlberg and Burstone[20] concluded that a centred T-loop produces equal and opposite moments with negligible vertical forces. Off-centre positioning of a T-loop produces differential moments. The moment magnitude is greatest at the teeth nearest to the loop and smallest at the distant teeth as asymmetrical positioning leads to unequal length in anterior and posterior segments. The greater stiffness of shorter section of wire creates greater moments relative to the longer section. Since the type of tooth movement is determined by the moment/force ratio at bracket, differential tooth movement is encouraged with asymmetrically placed loops[7,30]. By asymmetric positioning of the loop, moment differential remains approximately constant as the spring deactivates and the space closes, which ensures that the moment-to-force ratio acting on the anchorage unit(s) will always be greater, reducing the likelihood of anchorage loss. These results are consistent with the effect of the placement of V-bend activations in archwires for obtaining differential moments[8].

The freedom of desired location of the loop in continuous archwire is restricted by the adjacent teeth. Profitt[27] advocated the preferred location of the loops to be at the spot that would be the centre of embrasure when the space is closed for a ‘fail safe’ closing. This approximates to 5 mm distal to centre of canine tooth. The mushroom loop is also placed distal to canine, by bypassing the premolars and engaging the molar auxiliary tube[24,25] or premolars can be engaged and the loop placed in the extraction space. In this study as the continuous arch was used, loop was placed distal to canine centred in the extraction space, and the premolars were engaged.

2. Loop pre-activation

Although loop position is critical in delivering proper force system,[4,7,20] 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[23]. Both the loops in this study were given alpha and beta activation of 20° and 40°, respectively so as to create increased moment on the anchor teeth to preserve anchorage and allow anterior segment to be retracted with adequate root control. When the gable bends are placed, the vertical legs of loop tends to cross while engaging, thereby increasing the magnitude of force[7]. Thus, both the loops were pre-activated for 3 mm outside the mouth and then placed to maintain the neutral position. The loops were activated to 6 mm for complete activation and left for two months for full expression of the activation to deliver enough force for an en masse retraction. In patients with Group A anchorage arches, space closure occurs as an en masse controlled tipping followed by en masse root movement[4]. This is achieved as the loop gets deactivated with space closed which leads to increase in moment to force ratio.

3. Loop design

Positioning and pre-activation are important factors for space closure but the final key is the 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 comfortable for patient. The standard vertical loop, even with the modifications outlined, is limited in its ability to produce M/F ratios that approach those necessary for translation or even controlled tipping. Further, this design is also limited in total activation and the spring is relatively easy to deform permanently during installation; as a result, its mechanical characteristics are altered considerably. The effects of changing several parameters, including that of height, radius, and inter bracket distance, were evaluated experimentally and numerically by Burstone and Koenig[4]. 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 diameter of bends, or, by adding helices.

**General Concepts of Frictionless Mechanics**
The general concepts of frictionless mechanics are discussed as follows:

1. In frictionless mechanics, the teeth are moved without the brackets sliding along the archwire. Retraction is accomplished with loop or springs.
2. The force of a retraction spring is applied by pulling the distal end through the molar tube and cinching back.
3. The moment is determined by the wire configuration and by the presence of pre-activation or of gable bends, which produce an activation moment.
4. In general, the more wire gingival to the bracket, the more favourable the activation moment and therefore better the overall M/F ratio.

**Advantages of Frictionless Mechanics**
The advantages of frictionless mechanics are as follows:

1. Precise control over the anterior and posterior anchorage.
2. The tooth will move only to the limit to which the loop is activated.
3. Differential tooth movement is possible.

### Types of Loops

<table>
<thead>
<tr>
<th>Types of Loops</th>
<th>Type of Retraction</th>
<th>Type of Slot Main/Auxillary</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rickets Maxillary and Mandibular Cuspid Retraction Spring</td>
<td>Individual</td>
<td>Main</td>
<td>Retraction of canine</td>
</tr>
<tr>
<td>Poul Gjessing Canine Retraction Spring</td>
<td>Individual</td>
<td>Main</td>
<td>Retraction of canine</td>
</tr>
<tr>
<td>Tear Drop Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Vertical Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Open Loop–Vertical Loop Without Helix</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Open Loop–Vertical Loop With Helix</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Bull Loop</td>
<td>Individual</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Diamond Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Key hole Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Opus Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Triangular Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>Double Delta Closing Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Retraction of anteriors</td>
</tr>
<tr>
<td>K-SIR Loop</td>
<td>Enmasse</td>
<td>Main</td>
<td>Simultaneous intrusion and retraction of anteriors</td>
</tr>
<tr>
<td>Burstone T-Loop (Segmental)</td>
<td>Individual</td>
<td>Enmasse</td>
<td>Auxillary Retraction of anteriors</td>
</tr>
<tr>
<td>Burstone T-Loop (Continuous)</td>
<td>Enmasse</td>
<td>Main</td>
<td>Simultaneous intrusion and retraction of anteriors</td>
</tr>
</tbody>
</table>
Retraction loops or springs offer more controlled tooth movement than friction.

**Disadvantages of Frictionless Mechanics**
The disadvantages of frictionless mechanics are as follows:

1. A good understanding of the mechanics is required when using retraction loops or springs, because minor error in mechanics can result in major errors in tooth movement.
2. More wire-bending skill and chair time are required than with sliding mechanics.
3. Retraction loop may be uncomfortable to some patient, especially with less vestibular depth.
4. Retraction loops produce an undesirable mesial out moment when individual teeth are retracted.

**Correction of the Side Effects**
The correction of the side effects is stated in the following:

1. (a) Tipping of the anterior and posterior teeth into the extraction space
   (b) Increase the alpha and beta moments
2. (a) Flaring of the anterior teeth
   (b) Reduce the alpha moment or increase the distal activation
3. (a) Mesial in rotation of the buccal segments
   (b) Mesial out rotation of the palatal arch, archwire or lingual arch
4. (a) Excessive lingual tipping of the anterior teeth
   (b) Increase the alpha moment

**Rickett’s Maxillary Cuspid Retraction Spring**
The maxillary cuspid retraction spring is a double vertical helical extended crossed T closing loop spring which contains 70 mm of the wire made of 0.016” × 0.022” SS wire. It produces only 50 gm per mm of activation, because of the additional wire used in its design and all loops are being contracted during its activation. 3–4 mm of activation is sufficient for upper cuspid retraction (Fig. 1a).

**Rickett’s Mandibular Cuspid Retraction**
The large extended maxillary retractor loop would however be difficult to use in the lower arch due to the fact that it would extend into the chewing area. The mandibular cuspid retractor is a compound spring, a double vertical helical closing loop. It contains 60 mm of 16 × 16 blue elgiloy and produces approximately 75 gm of force per mm of activation. A range of variation exists due to loop size and character of wire. Therefore, 2–3 mm of activation is required to produce the desired force (Fig. 1b).

**The Poul Gjessing Canine Retraction Spring**
The spring consists of a double ovoid helix of 10 mm height gingivally and with a smaller occlusally placed helix of 2 mm diameter, and is available commercially in the preformed version, constructed in 0.016 × 0.022 inch² SS wire and produces 160 gm of force for every 1 mm 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. Pre-activation bends of 15° and 12° were placed on the anterior and posterior legs, respectively (Fig. 2).

**Simultaneous Intrusion and Retraction of the Anterior Teeth by K-SIR Loop**
The Kalra Simultaneous Intrusion and Retraction (K-SIR) archwire is a modification of the segmented loop mechanics of Burstone and Nanda. It is a continuous 0.019 × 0.025 inch² TMA archwire with closed 7 × 2 mm² U-loops at the extraction sites (Fig. 3).

**Activation**
A trial activation of the archwire is performed outside the mouth. This trial activation releases the stress built up from bending the wire and thus reduces the severity of the V-bends. After the trial activation, the neutral position of the each loop is determined with the legs extended horizontally. In neutral position, the U-loop will be about 3.5 mm wide. 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 interbracket distance between the two ends of attachment. This allows the clinician to utilize the mechanics of the off-centre V-bend.

The K-SIR archwire exerts about 125 gm of intrusive
force on the anterior segment. There will initially cause controlled tipping of the teeth into the extraction sites. As the loops deactivate and the force decreases, the moment-to-force ratio will increase to cause first bodily and then root movement of the teeth. The archwire should therefore not be reactivated at short intervals, but only every six to eight weeks until all space has been closed.

It is to be noted that activation in the mouth is 3 mm every 6–8 weeks.

**Burstone T-Loop Retraction Spring**
The T-loop was first introduced by Charles H. Burstone at the University of Connecticut in 1982. It can be fabricated from 0.017” × 0.025” inch² TMA or 0.16” × 0.022” inch² SS wires. It was specially designed for canine retraction in segmented arch technique and enmasse or separate incisor retraction. It has a horizontal loop of 10 mm length and 2 mm diameter. Mesial leg is of 5 mm height and distal leg is of 4 mm height. Anti rotation bends of 120° is given between the legs during pre-activation. T-loop activated horizontally by 4 mm. (Fig. 4).

**Tear Drop Loop**
The ideal force applied to achieve movement of the mandibular incisors is approximately 2.60 N[14–16]. The springs that best approached this value were the teardrop springs of 6 mm height activated 0.5 mm, which provided 2.51 N force, and the teardrop loop of 8 mm height activated 1.0 mm, which provided a 2.77 N force. The teardrop loops with heights of 7 and 8 mm activated 0.5 mm had values less than 2.60 N: 1.89 and 1.37 N, respectively. The teardrop loops with heights of 7 and 8 mm activated 1.0, 1.5, and 2.0 mm had higher forces than the ideal values for mandibular incisor movement (Fig. 5).
For the maxillary incisors, the ideal force level is 3.10 N[14–16]. When activated 1.0 mm, the teardrop loops with heights of 7 and 8 mm induced forces that were close to the ideal levels: 3.43 and 2.77 N, respectively. Activations greater than 1.0 mm showed forces that were higher than the ideal value for all springs tested.

The torsion angle incorporated after activation, the torque observed ranged from 0.2° to 1.4°. The 7-mm teardrop loop had the highest values on all the activations tested: 0.5°, 0.9°, 1.2° and 1.4° for activations of 0.5, 1.0, 1.5 and 2.0 mm, respectively. The spring that incorporated less torque was the 6-mm teardrop, which had values of 0.2°, 0.7°, 1.0° and 1.3° for activations of 0.5, 1.0, 1.5 and 2.0 mm, respectively.

**Other Types of Loops**

Other types of loops include key hole loop, Omega loop, box loop, boot loop, double delta, vertical loop.

**CONCLUSION**

At least six goals should be considered for any universal method of space closure[4] as follows:

1. Differential space closure. The capability of anterior retraction, posterior protraction or a combination of both should be possible.
2. Minimum patient cooperation. This is achieved by eliminating the usage of head gears and elastics.
3. Axial inclination control.
4. Control of rotations and arch width.
5. 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.
6. Operative convenience. The mechanism should be relatively simple to use, requiring only a few adjustments for the complication of space closure.

**REFERENCES**

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