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## Review Article

# A comprehensive review on loops in orthodontics

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### ABSTRACT

Extraction therapies are commonly done in patients with protrusion and/or crowding which demands a thorough understanding of biomechanics. Two basic types of space closing mechanics are friction/sliding and frictionless/loop 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 and may be associated with undesirable side effects such as uncontrolled tipping and deep bite. In frictionless mechanics, specially designed springs are used which provides the required moment to force ratio (M/F ratio) in three dimensions and they are more predictable and versatile. An electronic literature search was conducted via google scholar, PubMed, and dental associations' of different countries' website using the key word "Loops" and "Frictionless mechanics. Different configuration of loops have been used in orthodontic treatment and a comprehensive review of types of loops commonly used in retraction has been highlighted in this article.

**Key Messages:** Provide appropriate messages of about 35-50 words to be printed in centre box:

In frictionless mechanics, specially designed springs are used which provides the required moment to force ratio in three dimensions and they are more predictable and versatile. Different configuration of loops have been used and a comprehensive review of types of loops commonly used in retraction has been highlighted in this article.

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## 1. Introduction

Extraction therapies are frequently necessary in patients with protrusion or crowding. Once extraction is decided, antero-posterior position of incisor must be established and determination of the force system is to be done. Differential space closure is divided into Group A, Group B and Group C mechanics. Group A and C mechanics is more challenging than group B mechanics.<sup>1</sup>

Two basic types of space closing mechanics are friction/sliding and frictionless/loop mechanics. In frictionless mechanics, there is no guide wire and specially

designed springs are used. The spring provides required M/F ratio in three dimensions and as no force is lost due to friction they are more predictable and versatile.<sup>1</sup>

Loop mechanics has the same 3 phases during space closure as sliding, namely tipping followed by translation and then root movement. The difference in a properly designed appliance is greater activation range and a more constant force, moment and M/F ratio leading to a constant centre of rotation.<sup>1</sup> In this review article we have explained about the various loops used widely in orthodontics including ideal dimension, activation and studies conducted using the loops.

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## 2. Materials and Methods

An electronic literature search was conducted via google scholar, PubMed, and dental associations' of different countries' website using the key word "Loops" and "Frictionless mechanics."

### 2.1. Components of a loop

Loops consists of horizontal force system, vertical force system, alpha bend, beta bend and helical component. Each loop is constructed with one or more of the above components. Specific component of each loop has been mentioned under the respective loop.<sup>2</sup>

### 2.2. Classification of loops

1. Based on configuration
  - (a) Horizontal loops(e.g. boot loop)
  - (b) Vertical loops
  - (c) Combination(T Loop)
2. Based on purpose of the loop
  - (a) Leveling and Aligning
  - (b) Retractione
  - (c) Multipurpose
3. Based on presence of helix
  - (a) Loops without helix(e.g. vertical loop)
  - (b) Loops with helix(e.g. Helical bulbous loop)
4. Based on function
  - (a) Opening loops
  - (b) Closing loops

## 3. Biomechanical Properties of Loops

An ideal loop has a large range of action, large allowable working load and a low load deflection rate.<sup>2</sup> Parameters improving biomechanical properties are increasing height of the loop, additional wire at the apex of the loop and angulating loop base to apex which improves M/F ratio.<sup>3</sup> Off-centered placement of loop plays an important role in altering the moments generated at the alpha and the beta ends. Placement of loop towards anterior side would increase alpha moment and decrease beta moment. Differentials in M/F ratios can be very helpful in anchorage management. Thus, a higher beta moment leads to posterior anchorage augmentation. When inter-bracket distance is less, off-centering will affect the moment significantly, thus this distance is an important consideration for biomechanical properties of loop.<sup>4</sup>

## 4. Various Loops used in Contemporary Orthodontics

### 4.1. Vertical loop(Figure 1)

Vertical loop was in introduced by Robert Strang in 1933. It is constructed with 0.016" SS wire and has a height of 6mm. Vertical loops can be closing or opening loops and can be used for opening or closing spaces and rotating teeth.<sup>1</sup> Modifications of vertical loops are<sup>5</sup>

1. Double vertical loop used for labial/lingual movement and rotation correction
2. S loop- similar to vertical loop without undermining occlusal /gingival thrust
3. Omega loop which gives bodily thrust to the last tooth in the arch
4. Horizontal loop used for bite opening and easier bracket engagement
5. Double horizontal loop used for tipping and root movement
6. Horizontal T loop
7. Box loop, a combination of horizontal and vertical lever
8. Torquing loop produces labial or lingual torque

Burstone described the force system of vertical loop in retraction mechanics. Vertical height of 6mm is a typical clinical application as it delivers a force deflection rate of 437g/mm and moment to force ratio to 2.2mm. Moment to force ratio of 2.2mm is too low for uncontrolled tipping.

Moment to force ratio can be increased by increasing the height of the loop. Helix can be added to increase this height, however more than 3 helical turns were not useful. M/F ratio increases linearly as the helix is more apically placed thus further reducing force deflection rate.<sup>6</sup>

In Beggs mechanotherapy, anterior tooth alignment is accomplished with archwires incorporated with vertical loops. The loops increase the wire span between the teeth and produce a gentler pressure during movement. The looped arch is constructed with a round cuspid hook which rests on the mesial aspect of the cuspid bracket on either side. The loops are then activated to produce overcorrection of rotations, labio-lingual or mesio-distal movement.

### 4.2. Bull loop(Figure 2)

The Bull loop was given by Harry L. Bull in 1951. A sectional steel arch wire made of 0.0215" x 0.025" was used to retract the anteriors. A closed loop in the region of the extraction site of the first bicuspid is activated to open the loop by a millimetre after tying the arches in. A tie-back loop is placed well ahead of the molar tube to activate the arch sufficiently. Dr. William Houghton modified the maxillary sectional arch by adding a small loop, distal to the closing loops for engaging the anterior end of the class II elastics.

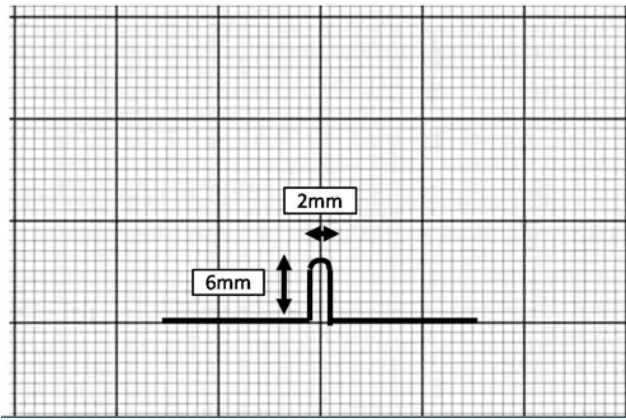


Fig. 1: Dimensions of vertical loop

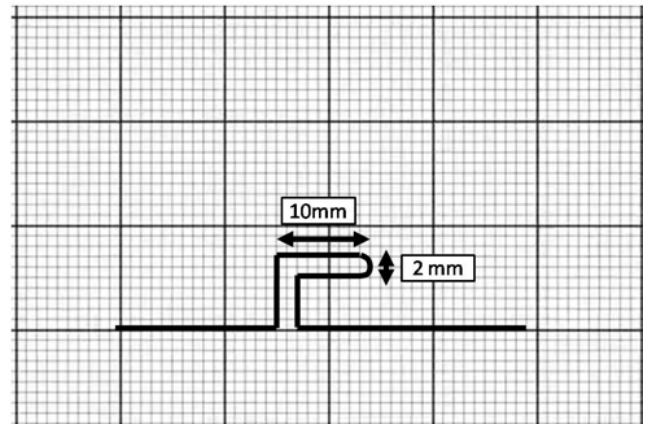


Fig. 3: Dimensions of horizontal/boot Loop

An advantage of the use of this loop when used for class II correction in conjunction with class II elastics is that they do not procline the mandibular anteriors since the closing loops restrain this effect.<sup>7</sup>

#### 4.3. Dimensions of the loop for each arch<sup>8</sup>

Upper bull loop – Height-7mm, wire distal to loop – 18mm, wire mesial to loop -22mm, Lower bull loop – Height-5mm, wire distal to loop – 20mm, wire mesial to loop -28mm

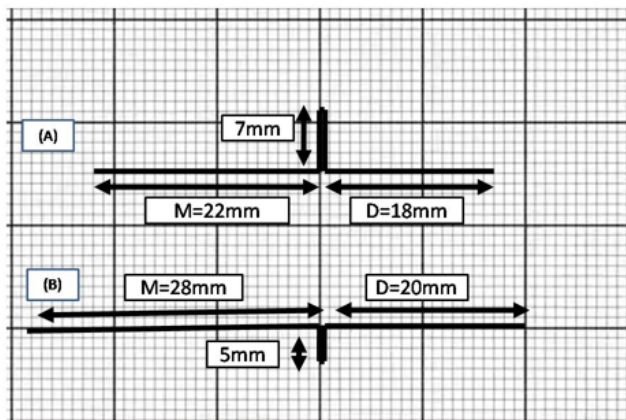


Fig. 2: Dimensions of Upper and Lower Bull Loop

#### 4.4. Horizontal loop / Boot loop (Figure 3)

Boot loop was described by Morris M. Stoner in 1960 and is formed by placing the active legs parallel to the arch wire. Incorporating a horizontal loop allows greater control over the direction of the force.<sup>5</sup>

The horizontal loop's principal value is its reduction of force in the vertical plane or occluso-gingival direction, permitting immediate bracket engagement in severely positioned teeth which the operator may want to elevate or depress. It is effective in bite opening. Immediate bracket

engagement is possible without excessive force on severely crowded teeth. It is possible to contour the horizontal loop to press against the gingival area to develop a torquing activity on the root; however, clinically has not been found to be very effective.<sup>5</sup>

Efficiency of the double Horizontal Loop is best when kept on an individual tooth either above or below the line of occlusion. It can be activated in an occluso-gingival and labio-lingual plane but not in the mesiodistal plane. One loop can be contoured to elevate and the other loop can be contoured to depress, tending to tip the tooth or move the roots.<sup>5</sup>

#### 4.5. Omega loop (Figure 4)

A variation of the open vertical loop was described by Morris M. Stoner in 1960. It was called so due to its resemblance to the Greek letter omega after which it is named. Its advantage over the open vertical loop lies in its lesser fracture tendency, owing to a more even stress distribution through the curvature of the loop rather than its concentration at the apex. It is commonly used for bodily movement of the root and as a molar stop.<sup>5</sup>

A modified omega loop was described to close a maxillary midline diastema by Gandhi et al. by placing two crimpable hooks on the arms of the loop diametrically opposite to each other. An E-chain stretched between the hooks provided the activating force to close the midline diastema.<sup>9</sup>

#### 4.6. Loop (Figure 5)

Loop was given by Dr Charles J Burstone 1962<sup>10</sup>

According to Burstone,<sup>10,11</sup>

1. TMA wire should be used in construction of T loop.
2. Additional wire should be placed as far apically as possible to increase the activation moment-to-force ratio.

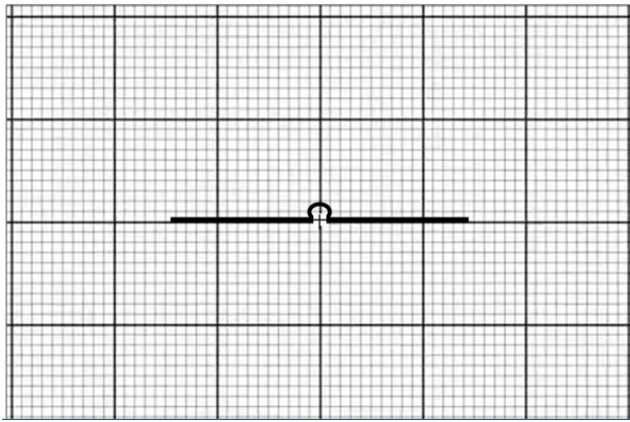


Fig. 4: Dimensions of Omega Loop

3. The loop centricity in the alpha and beta positions affects the rate of change of the moment-to-force ratio.

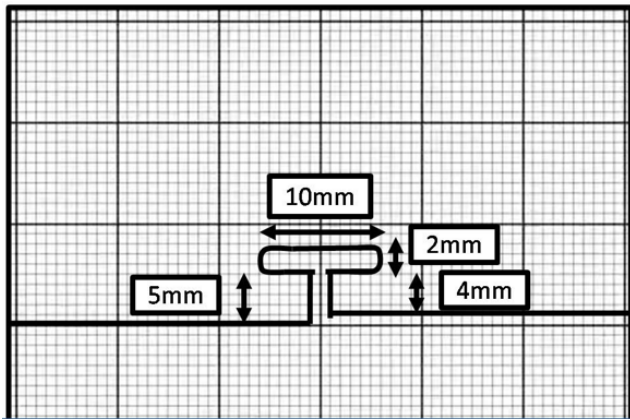


Fig. 5: Dimensions of segmental T Loop

The large inter-attachment distance between the auxiliary tube on the first molar and the vertical tube of the canine allows sufficient room for the large activations required. In addition, it adds to the accuracy of determining the force system, since small errors in the shape or geometry of the spring will not radically change the forces produced.

Pre-activation bends placed in the loop has been shown in figure 6 and template for T-loop conformation was given by Hoeningl et al,<sup>12</sup> as shown in figure 7.<sup>13</sup>

The horizontal activation of the 'T' loop was studied by Koenig et al who found that a 'T' loop activated horizontally by 2 mm had a moment to force ratio which deviated from the reported experimental value by less than 2%.<sup>14</sup>

Vertical activation of the 'T', 'L', and rectangular loops studied by Vanderby et al.<sup>15</sup> showed a 'T' loop of 14 mm gingival-horizontal length and activated by 3 mm vertically had moments at the two ends of the loop which were found to be equal almost exactly to the experimental values.

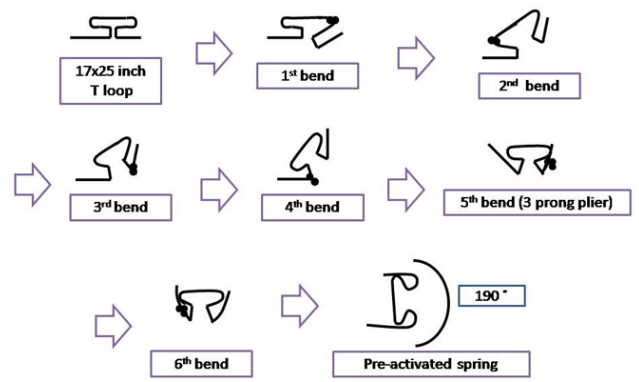


Fig. 6: T-loop preactivation bends



Fig. 7: Template for T-loop conformation

The vertical force was found to be higher than the mean experimental value, but within the two standard deviation range.

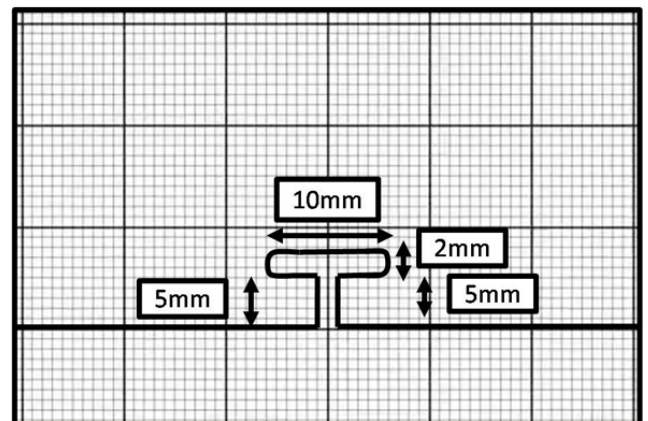
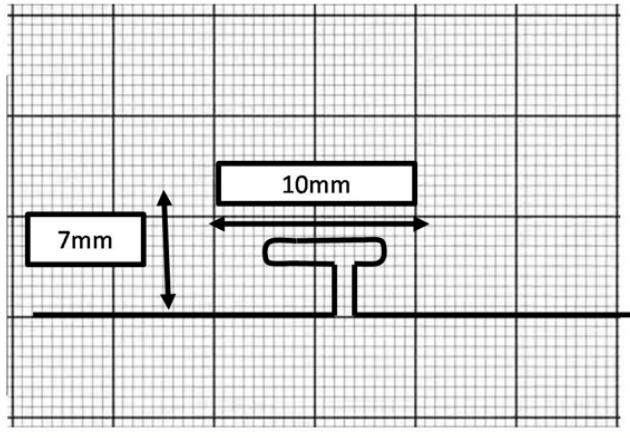


Fig. 8: Dimensions of T loop in continuous arch

T loop in continuous arch have vertical segment of equal lengths as shown in figure 8.<sup>16</sup>

#### 4.7. Asymmetric T loop (Figure 9)

Asymmetric T loop was described by James Hilger in 1992. This loop allows simultaneous bite opening and space closure. It is made of 0.016" X 0.022" TMA or 0.019" X 0.025" TMA wire with 5mm vertical step, 2mm anterior loop, 5mm posterior loop and exaggerated reverse curve of Spee.<sup>17</sup>



**Fig. 9:** Dimensions of asymmetrical T loop

Activation of asymmetric T loop is done by compressing short mesial loop and opening long distal loop.

#### 4.8. Double keyhole loop (DKL loop) (Figure 10)

John Parker of Alameda, California introduced Double keyhole loop (DKL) in Roth treatment mechanics. 0.019" X 0.025" rectangular SS archwires are used for fabrication of DKL. This loop resembles a champagne bottle which is a mixed vertical and horizontal loop.

DKL consists of two symmetrical loops bilaterally near canines that resemble key eyelets. Height of the loop is 7mm and the distance between two loops of the same side is approximately 8 mm.

Indispensable requisites for installation of DKL:

1. The anterior sector should be diastema free and consolidated with ligature wire to maintain close proximal contact.
2. Well aligned dental arches with previous arch wire sequence fully expressing torque on each tooth.
3. Dimension of DKL must be similar to previous rectangular arch wire to allow an easy insertion and perfect sliding of the arch in the slots of the braces.<sup>18–20</sup>

Activation of DKL:

1. Use of the arch as a spring  
This activation can be done in two ways:

- (a) Activation by distal traction of the arch

By pulling the archwire for opening the loops from behind the molar tube for activation. Activation of loops should not be more than 1 mm.

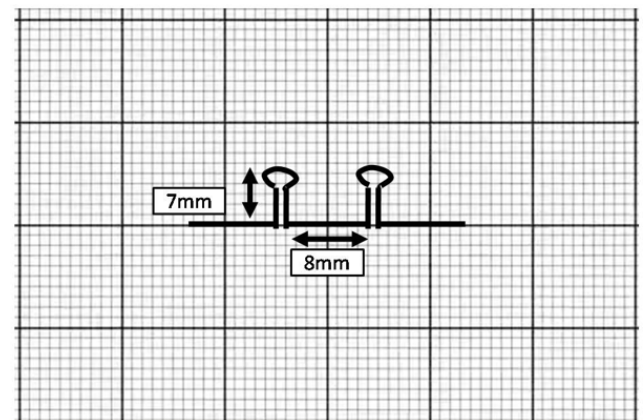
- (b) Activation with retro-ligature

A ligature wire tied in between hook of the molar buccal tube and the distal loop of the DKL arch wire to activate this arch is another way.

2. Used as an anchorage for auxiliary elements

In posterior sector migration (anchorage loss) type of special cases DKL arch was used as an anchorage for auxiliary elements.

Modification of DKL arch has been used for retraction without torque.<sup>18</sup>



**Fig. 10:** Dimensions of double keyhole loop

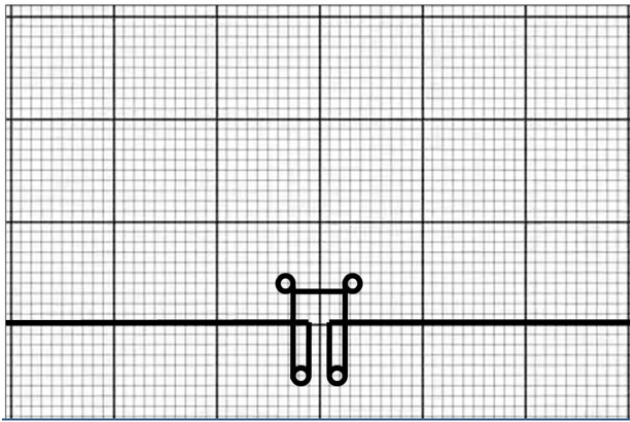
#### 4.9. Rickett's Canine retraction spring (Figure 11)

Rickett's canine retraction spring was described by Robert Rickett in 1976.<sup>21</sup> The maxillary canine retractor is a double vertical helical T closing loop with extended crossed arms. It is usually fabricated from 0.016"x0.022" SS wire of 70 mm length. It produces a canine retraction force of 50 gm for an activation of about a millimetre. An activation of 3-4 mm is required for individual canine retraction.<sup>21,22</sup>

In the mandible, the design of the spring is more compact. It is made of 0.016 x 0.016" blue Elgiloy and produces a force of 75 gm for a millimetre of activation. 2-3 mm of activation is required for producing the necessary force.<sup>21,22</sup>

#### 4.10. Opus loop (Figure 12)

Opus loop was given by Raymond E. Siatkowski in 1977 in study which was a systematic approach to closing loop design for use in continuous arch wires. The design process uses Castigliano's theorem to derive equations for moment-to-forceratio (M/F) in terms of loop geometry.<sup>2</sup>

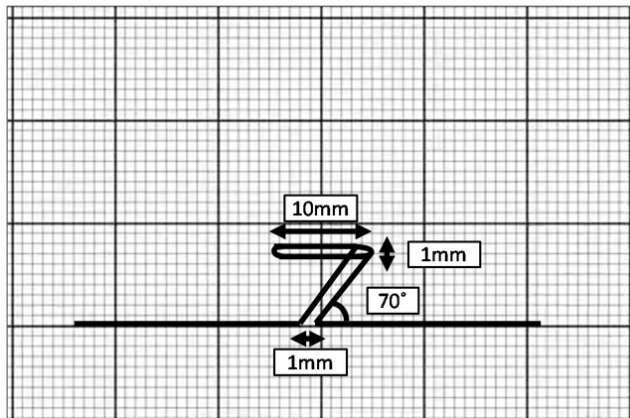


**Fig. 11:** Dimensions of Rickett's retraction spring

Opus loop is capable of delivering M/F within the range of 8.0-9.1 mm.

Dimensions: 10 mm height, 10 mm length and 0.5 mm radius. It is constructed with 0.016 × 0.022 inch SS wire, 0.018 × 0.025 inch SS wire or 0.017 × 0.025 inch TMA wire.<sup>23</sup>

Variations of Opus loops are Opus 90 and Opus 70.



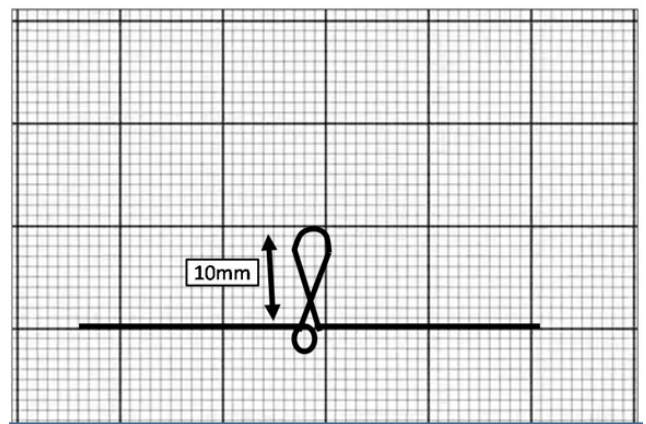
**Fig. 12:** Dimensions of OPUS loop

#### 4.11. PG retraction spring (Figure 13)

PG retraction spring was introduced in 1985 by Poul Gjessing. The resultant spring design, made from 0.016 × 0.022 inch stainless steel wire and finalized by using a trial-and-error procedure applied to the bench testing set-up. The predominant active element is the ovoid doublehelix loop extending 10 mm apically. The spring is constructed to resist rotational and tipping tendencies during retraction and not to correct rotations and/or extreme deviations in inclination of the canine. Therefore, leveling of the buccal segments must be terminated prior to insertion of the spring. Activation to 140 to 160 grams is obtained

by pulling distal to the molar tube until the two sections of the double helix are separated 1 mm and is repeated every 4 weeks. Minor rotations of the canine, which may take place during retraction in case of anatomic deviations in root anatomy, are easily corrected with lingual elastics subsequent to retraction.<sup>24</sup>

Halazonetis in his study placed pre-activation bends of 15° and 12° on the anterior and posterior legs, respectively. This was followed by activation of loop by 1, 2 and 3 mm. A load deflection of 64 gram force/mm of activation was calculated, which is higher than the 45 gram force/mm reported experimentally. The moment-to-force ratio is high for anterior segment which was ranging from 7 mm to 10.5 mm at 3 mm and 1 mm activation respectively. These values are not as high as those reported by Gjessing.<sup>11</sup>



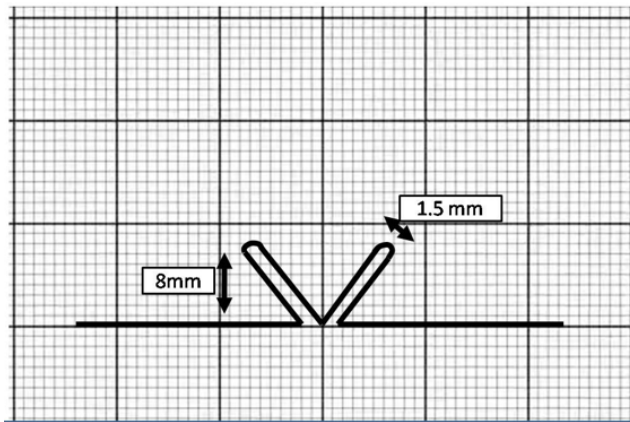
**Fig. 13:** Dimensions of PG spring

#### 4.12. Loop (Figure 14)

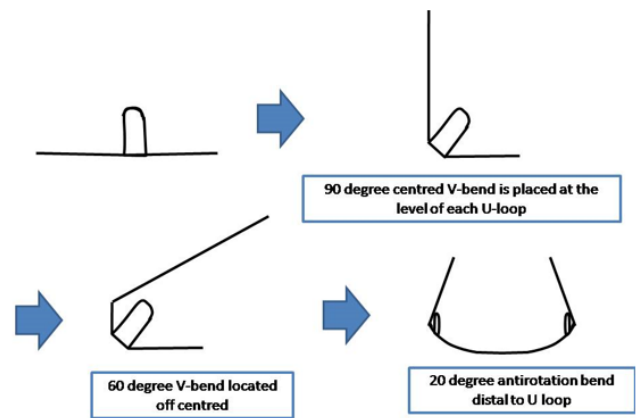
In 1995 Dr. Varun Kalra introduced “K-Loop” appliance for molar distalization in Class II malocclusion, which he claimed to have been developed in accordance to certain biomechanical principles as outlined by Dr. Charles Burstone and has the ability to move the maxillary molars distally with total bodily control which is of great clinical significance. The appliance consists of a K-loop to provide the forces and moments and a Nance button for anchorage. It is made of 0.017” × 0.025” TMA wire with each loop 8mm long and 1.5mm wide. Wire is marked mesial to the molar tube distal of premolar bracket, bend is placed 1 mm distal to distal mark and 1 mm mesial to mesial mark. Stop should be well-defined and about 1.5mm long. It is placed with 2mm activation.<sup>25</sup>

#### 4.13. K-SIR arch

The K-SIR arch which stands for Kalra – Simultaneous Intrusion and Retraction was developed by Dr. Varun Kalra. It is a modification of the segmental arch technique as



**Fig. 14:** Dimensions of K loop



**Fig. 15:** Activation of K-sir loop

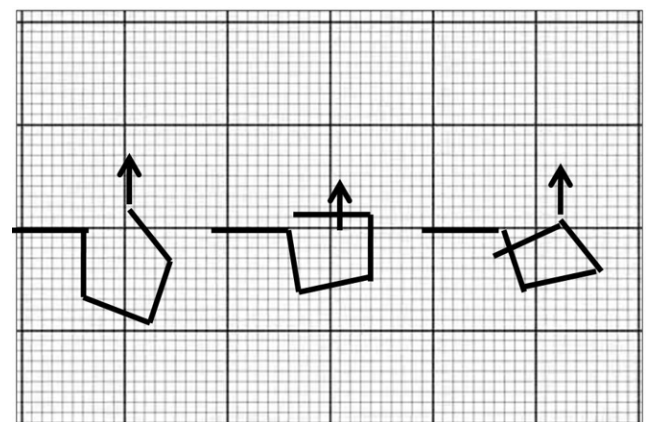
applied to continuous arches. Closed U-loops of 7mm height and 2mm width is fabricated with 0.019" x 0.025" TMA archwire at the sites of extraction. A 90 degree centred V-bend is placed at the level of each U-loop and a 60 degree V-bend located off centred with the shorter arm near the molar tube producing an increased clockwise moment on the 1<sup>st</sup> molar thereby augmenting posterior anchorage. A 20 degree anti-rotation bend is used to counter the mesiolingual rotation of the buccal segments.<sup>26</sup>

Trial activation reduces the stress build up in the loop and also decreases the severity of the V-bends. It exerts an extrusive moment on the molar which needs to be adequately controlled. This is overcome by the forces of occlusion and mastication. Activation bends are shown in figure 16.<sup>26</sup>

Its advantages include simplicity in design and fabrication, comfort to the patient and less chances of tissue impingement. As it carries out en-masse retraction it abbreviates orthodontic treatment time compared to conventional edgewise mechanics. Also, this prevents the appearance of an unsightly space distal to the laterals which is seen in individual canine retraction.<sup>26</sup>

#### 4.14. Rectangular loop (Figure 16)

The rectangular loop described by Drs. Vittorio Cassiafesta and BirteMelsen is a versatile loop which can be used for first, second and third order corrections. Being inserted and held at both ends, it encompasses the statically indeterminate force system. TMA wire is the wire of choice in fabricating a R-loop since wires of varying dimensions can be welded together. Typically, 0.018"/0.017" x 0.025" wires are used for the correction of rotated and tipped teeth since they have a large working range. This loop is the most effective in correcting single tooth discrepancies in all planes of space. A good control of the desirable tooth movement along with transference of the undesirable effects to the anchorage unit is noted. A particular advantage of this



**Fig. 16:** Activation of K-sir loop

loop is that round ripping can be minimized with a force system with better accuracy and efficiency.<sup>27</sup>

#### 4.15. Mushroom loop (Figure 17)

Pre-fabricated mushroom loop arch-wires were introduced by Drs. Flavio Uribe and Ravindra Nanda in 2003. This looped arch-wire produces an ideal moment to force ratio for translation. Moreover, neither is there any interference of the loop with the gingival tissue nor does it distort readily thereby improving the delivery of orthodontic load. 0.017" x 0.025"  $\beta$ -III Connecticut new arch-wire is used at distances which have been standardized between 26-46 mm with a 2 mm increment. This measurement in millimetre denotes the distances between the distal surfaces of the lateral incisors.<sup>28</sup>

Pre-activation of 3mm separation between the legs is done anteriorly along with anchorage reinforcement as necessary. Reactivation of the loop is not done until a closure of 3mm of space closure thus ensuring a constant moment to force ratio is maintained. The same wire is left

in place for an additional two visits to ensure correction of axial root inclination by utilizing the residual moments.<sup>28</sup>

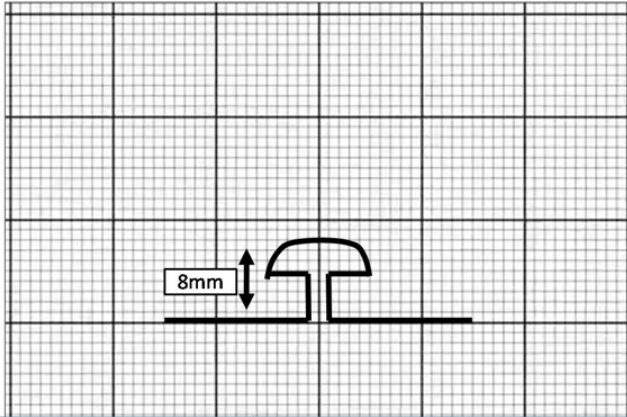


Fig. 17: Dimensions of mushroom loop

4.16. Snail loop (Figure 18)

Snail loop was introduced by Dr. Pavankumar Vibhute in 2004. Snail loop is spiral shaped and designed for en masse space closure of the anterior teeth.<sup>29</sup>

The snail loop is fashioned from 0.017" x 0.025" stainless steel wire by bending a simple omega loop into a spiral shape, which provides the forces and moments. The outer portion of the snail loop is 8mm high and 6mm wide and the inner portion is 6mm high and 3mm wide.<sup>29</sup>

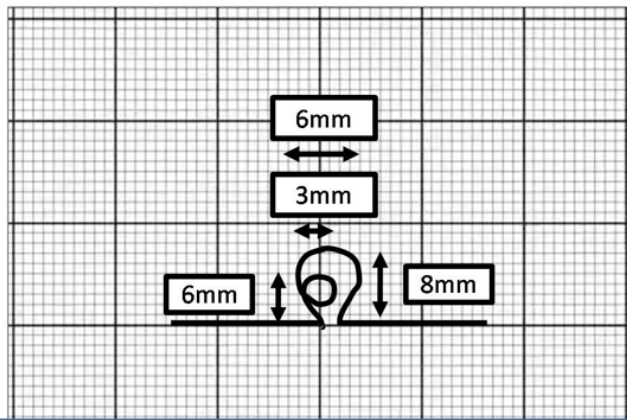


Fig. 18: Dimensions of snail loop

4.17. Double delta loop (Figure 19)

The double delta loop serves to close spaces. It is also frequently used for the leveling and integration of the arches.<sup>21</sup>

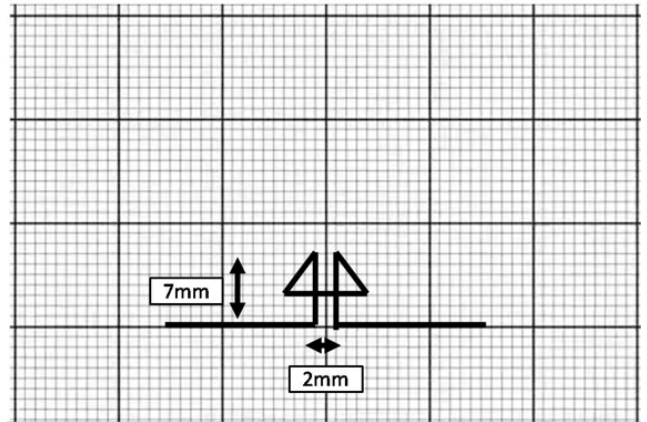


Fig. 19: Dimensions of double delta loop

4.18. Tear drop loop (Figure 20)

The ideal force applied to achieve movement of the mandibular incisors is approximately 2.60 N.<sup>11,30,31</sup>

The springs that best approached this value were the teardrop springs of 6 mm height activated by 0.5 mm, which provided 2.51 N force and the teardrop loop of 8 mm height which was activated 1.0 mm provided a 2.77 N force. The teardrop loops with heights of 7 had values less than 2.60 N, heights of 8 mm had values less than 1.89 and when activated 0.5 mm had values 1.37 N. 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.

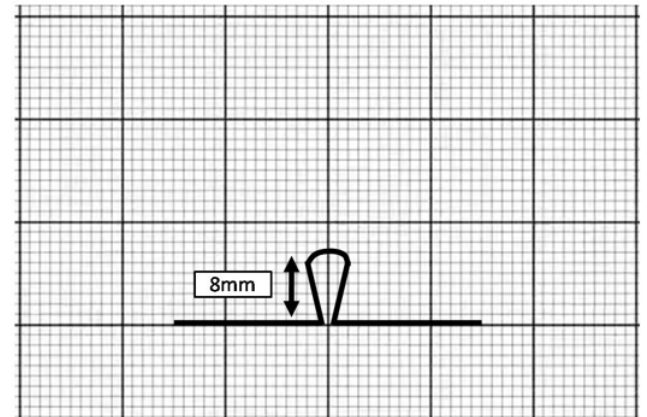
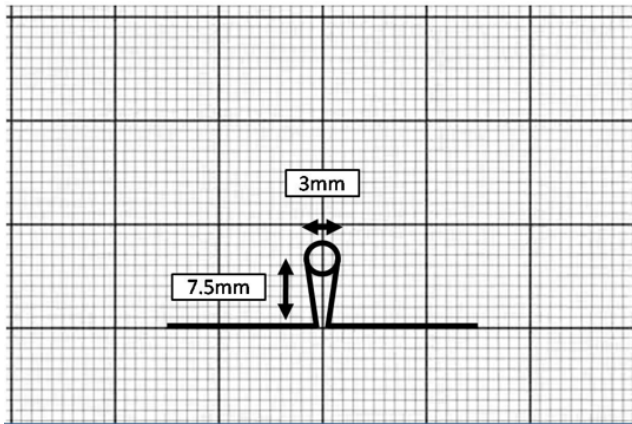


Fig. 20: Dimensions of tear drop loop

4.19. Bulbous helical loop (Figure 21)

A helical bulbous loop of height 7.5mm is fabricated at the end of mandibular anchorage preparation of 0.020" x 0.025" arch wire flush against the 2order bends. The helix is wound to the lingual during fabrication. The helical loops are opened by 1mm prior to their insertion which distalizes



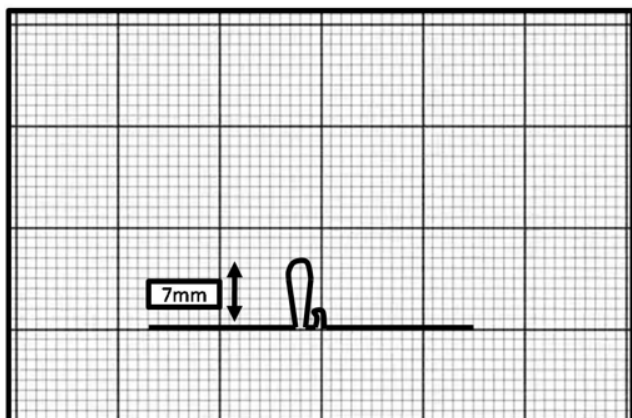


**Fig. 21:** Dimensions of bulbous helical loop

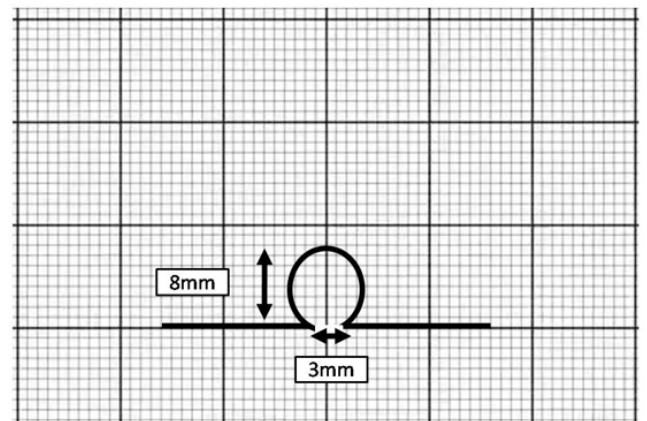
the 2about molar disalization.

#### 4.20. Shoe horn loop (Figure 22)

Shoe horn loop has been described in Tweed Merrifield appliance. The height of the loop is 8mm. It consists of a long and a short vertical loop.<sup>32</sup>



**Fig. 22:** Dimensions of shoe horn loop



**Fig. 23:** Dimensions of cherry loop

#### 4.21. Cherry Loop(Figure 23)

Cherry loop was given by Peretta Redento in 2002. It is constructed with 0.017"x 0.025" SS. A large diameter round loop of 8mm width is bent using Rouland plier. Height of the loop is 8-9mm and opens 3-4mm at occlusal end to avoid stress and deformation. Cherry loop is used in molar protraction where it is placed one half distance. The loop is activated in 2 phases, 1.<sup>33</sup>

Studies on loops have been described in Table 1.

**Table 1:** Loops related articles

Articles	Study design	Aim	Sample	Type of appl	Type of mech	Result
Geramy et al International Orthodontics 2018 <sup>34</sup>	Experimental method using a “Santam” universal testing machine and finite element method	To compare the results of FEM and experimental methods in determining moment, force and M/F of four loops and to find the level of concordance between them.		Open vertical loop, closed vertical loop with helix, T loop and L loop	Retraction	The force and moment values increase when the activation range and angular bend increase, and M/F increases when the activation range decreases and angular bend increases. Experimental results and FEM predictions were concordant while determining the mechanical characteristics of the loops
Geramy A. Angle Orthod. 2002. <sup>35</sup>	Finite element method	To optimize the loop modification step by step in unilateral overjet		Helical, vertical, closed u loop 2 loop 1 loop 1 loop + helix 2 loop + activation	Retraction in unilateral overjet case	Best result by placing vertical, helical and closed on unilateral overjet and vertical loop in normal side
Krishnan et al Angle Orthod 2012 <sup>36</sup>	Electron scanning microscopy	Evaluation of physical vapour deposition coated archwire		Beta Ti uncoated U loop Vs Beta Ti with Titanium aluminium nitride (TiAlN) coated helical loop Vs Beta Ti with tungsten carbide/Carbon(WC/C) coated reverse U loop		Beta Ti with tungsten carbide/Carbon(WC/C) wires can be recommended due to low frictional properties and low load deflection rate
Kamisetty J Clin Diagn Res. 2014 <sup>37</sup>	Finite Element Method	Determine moment, M/F ratio		Tear drop(19x25ss) Vs t-loop (19x25ss) vs vertical loop (19x25ss)	Retraction	Tear drop loop preferred over the other two retraction loop

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Table 1 continued

Odegard et al Am J Orthod and Dentofac Orthop. 1996 <sup>38</sup>	Torsional forces measured in a custom made device.	To evaluate the torsional flexibility and stiffness of the wires with different loop designs and cross- sections.	Half helical contraction loop, bull loop, T-loop, keyhole loop and tear drop loop	A custom-made used in the study mounted a stationary bracket on a pedestal, through which the wire to be twisted passes and the various parameters were evaluated.	Torsional flexibility increased from 26% to 63% depending on loop design. Reverse closing loop caused greatest increased in flexibility whereas bull loop changed the torsional stiffness the least. T-loop is the loop of choice When vertical flexibility is needed along with reduced torsional stiffness.
Haris et al J Contemp Dent Pract. 2018 <sup>39</sup>	Finite element model	To evaluate the force, moments and M/F ratio in 4 loops with different pre- activation bends at 1,2, 4 mm activation.	T-loop, K-SIR, omega loop, Tear drop loop	Retraction	Without pre-activation bends, highest force values found in omega, least in T-loop. With pre-activation bends highest force seen in tear drop loop, least in T-loop. M/F ratio in the $\alpha$ -segment similar in all loops. T loop with preactivation bend showed the most favourable properties. M/F ratio LC90>highest M/F ratio L90>170 Opus90>opus70 LC90>LC70
Techalertpaisarn et al Am J Orthod Dentofacial Orthop. 2013 <sup>40</sup>	Finite Element Method	Investigation of mechanical properties	OPUS (opus 90, opus 70) Vs L loop (L90, L70, LC90, LC70) Vs T loop		
Rao et al Journal of Indian Orthodontic Society 2013 <sup>41</sup>	Finite Element Method	Determine MF ratio, F $\Delta$ rate and force	3snail (o,10 2snail (o,10 3snail (o,10 3snail (o,10 OPUS LOOP 17X25TMA TEAR DROP LOOP 17X25TMA		17x25 TMA and 19x25 TMA with 20 activation snail loop delivers M/F ratio for bodily movt and acceptable F $\Delta$ rate

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Table 1 continued

Safavi et al Aust Orthod J. 2006 <sup>42</sup>	Finite Element Method	Force, moment, M/F ratio with/without preactivation bends		T loop (16x25 ss) Vs L loop (16x25 ss) Vs Vert helical loop (16x25 ss) Closed coil spring Vs Open coil spring Vs PG spring Vs T loop 18x25 Jap niti T-loop Vs 17x25 TMA T loop Heated to 510°C for 9minutes	Holographic interferometry	Preactivation bend increases MF ratio at 1mm Dramatic decrease in M/F ratio at 0.1mm deactivation  T loop preferred in retraction with minimal tipping PG spring preferred when higher force magnitude is desired.
Kumar et al Angle Orthod 2008 <sup>43</sup>	Invitro study	Compare the magnitude and direction of initial canine displacement				
Lim et al Angle Orthod 2008 <sup>44</sup>	Invitro study	Effect of temperature on Force, moment, M/F ratio			Loop testing Apparatus with force transducer	Temperature has significant effect on force and moment of Niti loop whereas M/F ratio remained constant  Temperature has minimal influence on TMA T loop
Chacko et al Prog Orthod. 2018 <sup>45</sup>	Finite Element Method	Force, moment, M/F ratio at 1mm activation in lingual ortho		Closed helical Vs T loop	Retraction	Closed helical loop with activation has increased force and moment . T-loop with activation has more moment to force ratio.
Keng et al Eur J Orthod 2012 <sup>46</sup>	Pros RCT (Split mouth design)	Rate of space closure and tooth angulations	12 - 6M, 6F (13-20 yrs)	Preactivated Niti T Loop Vs Preactivated TMA T Loop	Canine retraction	No significant difference between them Niti loop has greater ability of retain and return

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Table 1 continued

de Castro et al Korean J Orthod. 2015 <sup>47</sup>		Effect of T loop preactivation on M/F, Force and Load deflection rate	100 T loops Grp 1 – 50 SS T loop Grp 2 – 50 TMA T loop	0°, 20°, 40° occlusal distribution T loop preactivation Vs 20° gingival distribution T loop preactivation Vs 40° occluso-gingival distribution T loop preactivation T loop Vs Powerarm to canine bracket (enmasse) Vs Powerarm to archwire (enmasse)	Orthomeasure apparatus	M/F ratio decrease on activating preactivated loop Whereas increase on activating loops without preactivation Highest M/F ratio when bend placed gingivally
Jiang et al Angle Orthod 2020 <sup>48</sup>	Finite Element Method	To assess the mechanical environment during lower retraction			Retraction in lower segment	T loop is more predictable Powerarm produce rotational and archwire distortion
Shashidhar et al J Clin Diagn Res. 2016 <sup>49</sup>	Pros comp study (Lateral ceph)	Compare the skeletal and dentoalveolar effect	Grp 1 -9F, 6M (16±2.6 yrs) Grp 2 7F, 8M (15.4±4.7)	K loop (17x25 TMA) Vs pendulum	Distalization	K-Loop molar distalizing appliance has similar skeletal and dentoalveolar effects as that of pendulum appliance, with the advantages of simple yet efficient to control the moment-force ratio to produce all types of tooth movements and also requires minimal patient co-operation K LOOP + Pendulum has no significant skeletal or soft tissue change when compared to cervical pull headgear
Polat-Ozsoy et al Angle Orthod 2008 <sup>50</sup>	Pros comp study (Lateral ceph)	Soft tissue change associated with 2 different distalisation method	Grp 1 – 7F, 8M (15±3.4 yrs) Grp 2- 10F, 5M (14.2±2.9)	K LOOP + Pendulum Vs Cervical pull headgear	Distalisation	

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Table 1 continued

Acar et al Eur J Orthod 2010 <sup>51</sup>	Pros comp study (Lateral ceph)	Dentoalveolar change associated with 2 different distalisation method	Grp 1 – 7F, 8M (15±3.4 yrs) Grp 2- 10F, 5M (14.2±2.9)	K LOOP + Pendulum Vs Cervical pull headgear	Distalisation	The major advantages of the pendulum appliance K-loop combination were prevention of anchorage loss on the anterior teeth and significantly less distal tipping at the maxillary molars. However, the amount of distal tipping of the molar teeth was still greater than with CHG.
Ferreira et al Dental Press J Orthod. 2020 <sup>52</sup>	Finite element analysis	Numerical simulation of Von Mises stresses on mushroom arch wires		Mushroom loop		A maximum tension of 1158 MPa was noted in the whole loop at 5 mm activation except a small area near the top of the loop where a maximum tension of 1324 MPa was recorded. Mushroom loops produce tension levels in an elastic range and an activation of up to 5mm is safe.
Rodrigues COBEM 2015. <sup>53</sup>	Finite element models	To analyze the influence of orthodontic delta springs with and without upper helix on tipping, translation.		Delta spring 0.016 x 0.022 inches TiMo alloy wire was used. Delta springs with helix were activated up to 12.0 mm and springs without helix up to 8.0 mm.	Retraction	Springs with helix provide lower forces than those found in springs without helix. No tooth movement in the occlusal plane was found for the M/F ratios studied. Delta springs without helix showed higher reaction forces than those with helix.

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*Table 1 continued*

Jadhav et al JIOS 2019 <sup>54</sup>	Finite element models	To evaluate and compare the force and LDR generated by different unit displacement through 1- 4mm of springs that vary in design and wire material.	Double delta closing loop, double vertical T crossed closing loop, double vertical helical closing loop, Ricketts Maxillary retractor	Force and LDR increased with incremental loops of $\beta$ -titanium and those of 0.017" x 0.025" had lesser force and LDR than those of SS and 0.019" x 0.025" dimension. Double delta showed highest force values amongst the loops studied.
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## 5. Conclusion

Six goals to be considered for any universal method of space closure include:

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 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.<sup>10</sup>

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None.

## 7. Conflict of Interest

None.


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