Space Closure Using Frictionless Mechanics

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Abstract: Extraction space closure represents a fundamental stage in a considerable number of orthodontic treatments. With extraction as a method of gaining space, space closure becomes subsequently important. To obtain the desired result of closing spaces within the arch it was essential to control the amount of anterior retraction and molar protraction. There were different space closure measures advocated in the edgewise technique based on anchorage situations. The principles for retraction currently used can be described as either "frictional" system in which the canine, through application of a force, is expected to slide distally along and is guided by a continuous arch wire or frictionless system with forces and couples built into the loops of an arch section. In this review article some of the commonly used loops for closing extraction spaces by frictionless mechanics are explained.

Keywords- *space closure, frictionless mechanics, loop mechanics.*

I. Introduction

Space closure mechanics can either be friction or frictionless. So, optimizing the mechanics in different space closure situation is desired and required, whether the friction or frictionless mechanics is used and the planning of either of them should be based on sound biomechanical principles. With a continuous arch wire, the friction between each individual bracket and the wire is difficult to predict. The second approach entails bending various types of loops into the wire and this method is friction-free and thus provides more precise anchorage control.

In frictionless mechanics, teeth are moved without the brackets sliding along the arch wire. Retraction is accomplished with loops or springs, which offer more controlled tooth movement than sliding mechanics. The force of a retraction spring is applied by pulling the distal end through the molar tube and cinching it back. The moment is determined by the wire configuration and by the presence of pre activation or of gable bends, which produce an activation moment. In general, the more wire gingival to the bracket, the more favorable the activation moment, and therefore the better the overall M/F ratio. The design of the spring influences not only the M/F ratio, but also the load/deflection rate. The addition of helices lowers the load/deflection rate without significantly affecting the M/F ratio. Similarly load/deflection rate can also be altered by changing the wire composition whereas M/F ratio is not influenced by the wire material.**[1]**

There are many frictionless methods of closing spaces, some of them are explained here.

En Masse Retraction using Headgear

The "one step" retraction of the anterior segment, in the treatment of first premolar extraction cases has been practiced in the Begg and Tip-Edge edgewise techniques for many years. In a modern edgewise technique, the "one step" retraction of the maxillary six anterior teeth was first presented by **Andrews**. His retraction method was developed by **Bennett and McLaughlin** and used routinely in their "Pre adjusted Appliance System." Despite the application of light forces, in this last technique, the use of extra oral forces plays an important role in reinforcing the anchorage .**Roth,** in his straight wire technique, has used the "Asher" type face-bow for retraction of maxillary anterior teeth, to help control suitable root inclination. However, patient cooperation is required while using this technique.[2]

The Broussard two force system[3]

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

Bimetric arch[4]

The external arch Bimetric System consists of modules of the Bimetric series which operate in an overlay fashion. The Bimetric Arches and Torquing Arches with their modules are designed to utilize the gingival .045" headgear tube, which frees the edgewise or light wire tube for its normal use. Anteriorly, they engage specially designed brackets which are bonded gingivally to the bands or brackets on the anterior teeth. This position is above and independent of other brackets and allows operation from a position of unique mechanical advantage. The brackets are designed for snap insertion of the arch and require no elastics or ligation. The Bimetric Round Arch modules are designed for ease of insertion and removal. They consist of .040" end sections, which provide rigidity and support the intermaxillary hooks; and an anterior arch bar of .022" Tru-Chrome for flexibility. The Tandem Yoke with retractor consists of a .045" round tube which slides with freedom on the .040" end section of the Bimetric Round Arch. The Tandem Yoke serves many functions. It may be used with .045" coil spring for distal movement of the molar with intermaxillary traction.

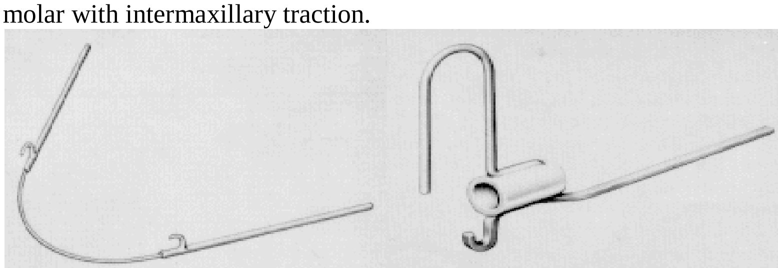


Figure 1. Bimetric Round Arch (inverted) and Tandem Yoke with retractor.

Bull loop[5]

Dr. Harry Bull's procedure for cuspid retraction was to bring these teeth back bodily by means of a sectional arch, which contains the Bull (closed vertical) loop and was formed with 0.021” X 0.025” steel wire. In an upper cuspid retraction sectional arch, the Bull loop is approximately 7 mm in height and, on an average, there is 18mm of wire distal to the loop and 22 mm of wire mesial to the loop. In a lower sectional, the Bull loop is 5 mm in height and, on the average; there is 20mm of wire distal to the loop and 28 mm of wire mesial to the loop.

Activation: The eyelet loop is held between the parallel beak-closing plier and the vertical arm is bent toward the horizontal to place a gingival bend of 45° to 60° in the cuspid arm. When a gingival bend is placed on the cuspid arm, a lighter force is obtained with greater deflection, thus bringing the cuspid back bodily. The wire is placed in the mouth with the vertical loop 2-3 mm mesial to the bicuspid bracket. The wire is now moved to the distal until the vertical loop is against the bicuspid bracket. Next, the wire is placed in the cuspid bracket and ligated with the pigtail to the distal, and the wire distal to the molar tube is bent gingivally to act as a stop to keep the sectional arch from going forward when the loop is activated.

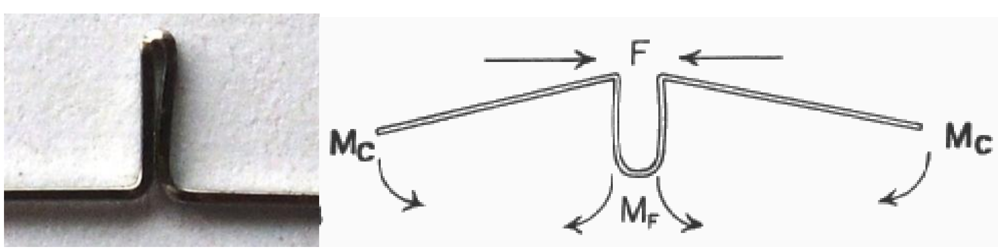


Figure 2. Forces and moments produced by an activated Bull loop system.

A bite opening and space closing archwire

Leonard Bernstein[6] in 1970 developed a bite opening and space closing archwire. The purpose was providing an upward and backward force in an arc– shaped motion to the maxillary central and lateral incisors with a retraction force at the same time. By keeping a distal closing force on these teeth, the upward and backward force producing bite opening seems to be enhanced. A 2 to 3mm helix is bent distal to the lateral incisors. Closing loops are superimposed on these helices on the buccal aspect. The down leg of the closing loop is turned horizontally as it crosses the archwire. A Bayonet bend is placed distal to the loop to compensate for the wire thickness and that the cuspids will be not be placed too far buccally.

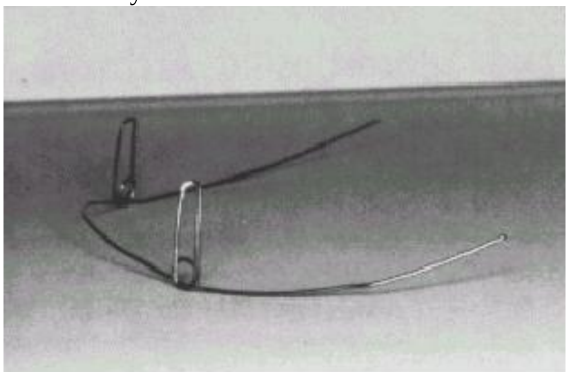


Figure 3. Leonard Bernstein's bite opening and space closing archwire.

Compound loops [7]

In Bio-progressive therapy, **Bench RW, Gugino CF, Hilgers JJ** designed various compound loops by combining a series of wire lengths and loop designs. Here, by increasing the amount of wire, the force is reduced and the duration of activation is increased.

Double keyhole loop

This was introduced by **John Parker**. The double keyhole loop is 0.019"X 0.025" dimension, built out of round edge rectangular wire. The anterior teeth are generally retracted en masse as a group of six. The double keyhole loops control the canine rotation during extraction site closure and make handy elastic hooks for the arrangement of elastics that may become necessary.

Vertical loop[8]

Vertical loop is one of the most commonly used mechanisms for retraction. It is simple in design and is usually fabricated of 0.016" stainless steel wire which is 6 mm high. . It is centered between the canine and second premolar brackets. Since common activations of a vertical loop are approximately 1mm, it is seen that force values for a 0.016 inch round loop are very large, however addition of helix to loop decreases the load deflection rate.A standard vertical loop gives greater control over displacing an apex of the canine mesially than a single force applied to a canine by a wire or elastic. However the moment to force ratio is so low that it is not capable of producing translation or even controlled tipping with a center of rotation at the apex.

Placement of a gable bend in the horizontal legs of the vertical loop would increase the M/F ratio. A large M/F ratio would translate the canine distally. As the horizontal length of the loop changes while keeping the interbracket distance and angulations constant M/F changes drastically. Thus the angulated vertical loop is capable of producing any type tooth movement.

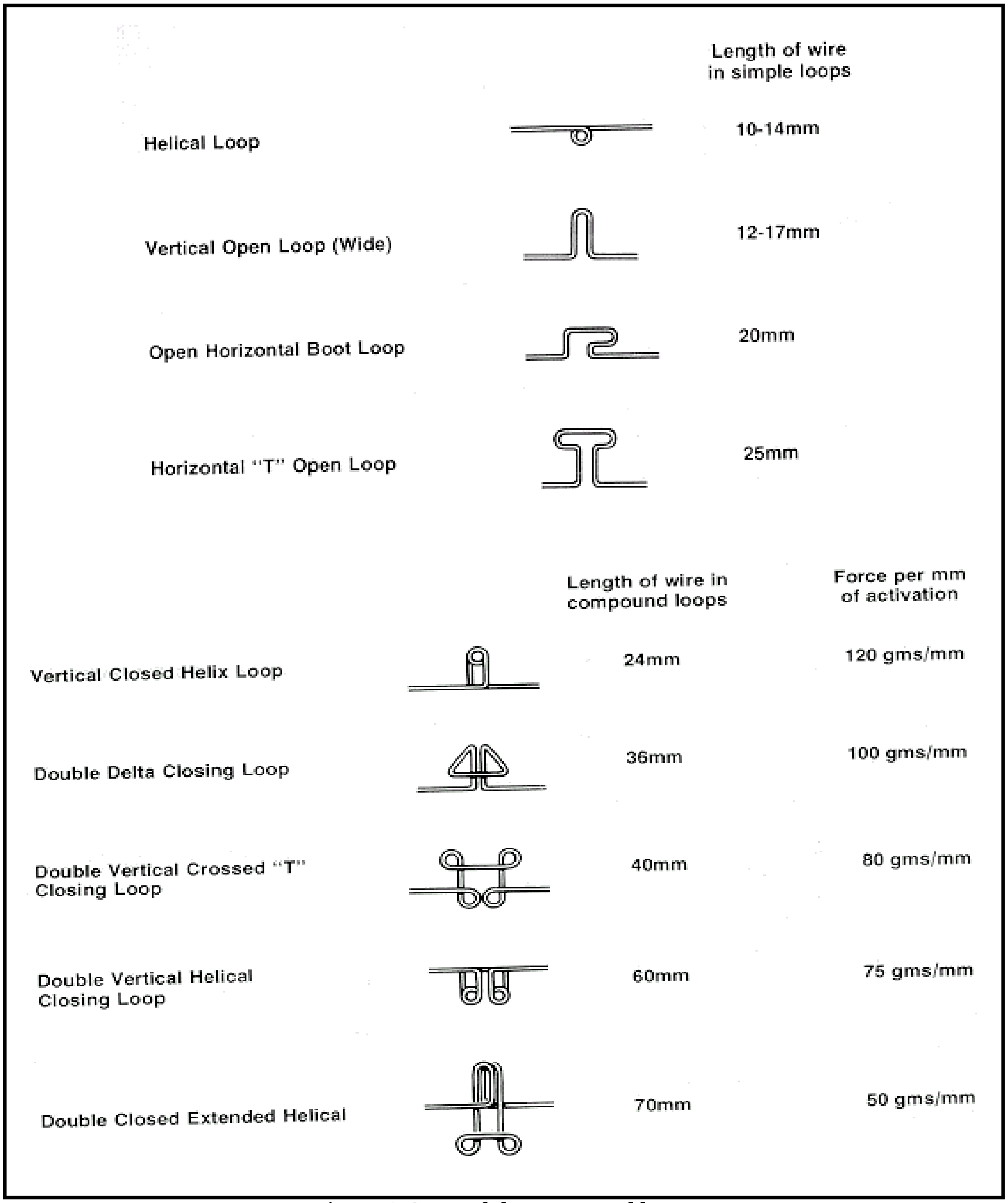
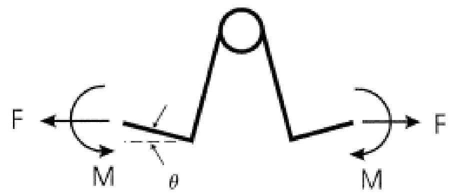


Figure 4. Some of the compound loops.



$$\frac{M}{F} = \frac{H^2 + HR\pi N + 2R^2}{2H + N\pi R} - \frac{\theta E b h^3}{12F(2H + N\pi R)}$$

Figure 5. Moment-to-force ratio (M/F) equation for a vertical closing loop with helix.

Mushroom loop[9]

The M-Loop produces lower and more continuous forces compared to simpler designs due to apical addition of the wire in the archival configuration which decreases the load-deflection rate. Additionaly, the archival shape has the added advantage of increasing the applied moment when the spring is activated.[38] The decreased force and increased moment, when activated, increases the M/F ratio and allows for greater root control and anchorage. Moreover the CNA beta-titanium recommended for use in the M-loop has a much lower stiffness than stainless steel and promotes a more constant force delivery.

Wire dimensions are 0.017” X 0.025” CNA, although, for adults requiring lower force values, 0.016” X 0.022” may be preferred. Once engaged, the loop may be activated up to 5 mm. This activation will deliver enough force to simultaneously retract all the anterior teeth en masse with little impact on posterior anchorage. Reactivation is necessary approximately every 6-8 weeks.

Figure 6. Mushroom loop archwire with preactivation bends given.

Figure 7. Maxillary .017" ✕ .025" Beta III CNA mushroom loops for retraction of maxillary anterior teeth.

T-Loop[10]

The 0.017 X 0.025-inch TMA T-loop, used for reciprocal space closure and described by **Burstone**, generates relatively high horizontal forces of approximately 350 gm. The TMA attraction spring has been designed to eliminate many of the problems inherent in the use of a vertical loop. The key to its design is the attempt to make the moment-to-force ratio more constant. This is accomplished by lowering the load-deflection rate of the spring and by the use of the T loop design, which increases the activation moment by placing wire more apically. There is six point preactivation of T-Loop with each of 30˚, making a total of 180˚ activation. The preactivation bends are actually overbent so that after the trial activation, about 180˚ of moment preactivation is left. Because the canine is retracted with the spring on its labial surface, there is a distal in, mesial out rotation tendency, therefore to avoid that antirotation bends are also placed on the spring.

Figure 8. Segmented T loop with 6 activation bends for canine retraction.

Asymmetrical T loop

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

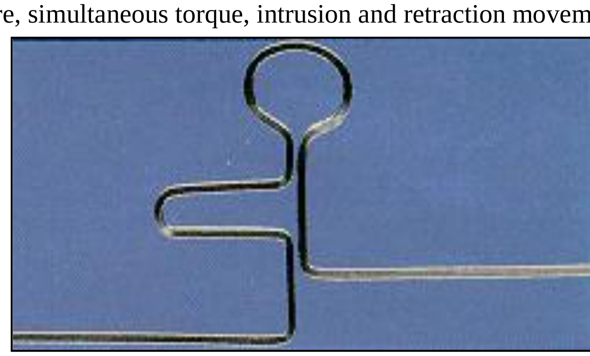


Figure 9. Broussard combination closing and bite opening loop with step between anterior and posterior segments.

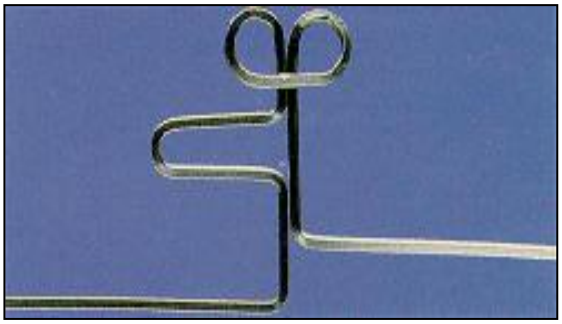


Figure 10. Hilgers modification with reduced loop size for patient comfort and crossed "T" for greater mechanical efficiency.

Hilgers JJ and Farzin FN[11] modified the vertical component in the Broussard loop into a crossed ‘T’, allowing a smaller loop size and greater mechanical efficiency sine the vertical portion is closed on activation.

Modified ‘T’ loop arch wire

Modified ‘T’ loop archwire was devised by **Tayer BH**[12] in 1981. In some cases, there is a need for additional maxillary intrusion (bite opening), space closure and torque toward the end of active treatment. The modified T-loop archwire achieves all these corrections.

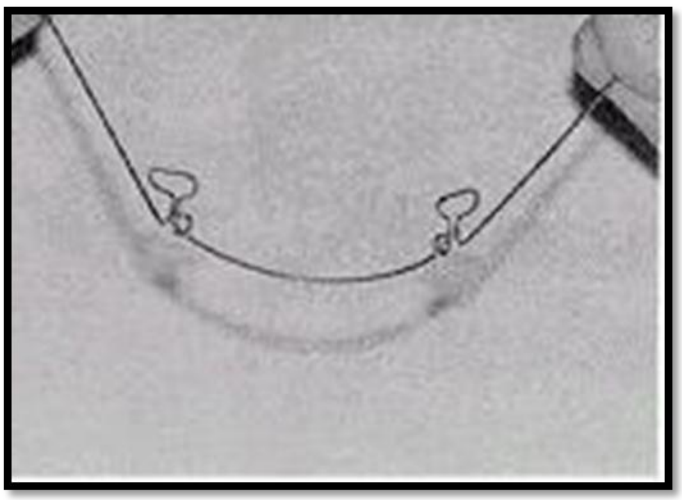


Figure 10. Modified T loop arch wire.

Lingual lever arm technique[13]

A single force at the bracket slot level produces uncontrolled tipping— a rotation around the center of resistance. To achieve direct translation, a single force directed at the center of resistance is needed. **Kucher G, Weiland FJ and Bantleon HP** described a refinement of the lingual lever arm for producing pure bodily tooth movement. The leverarm is adapted to the palatal vault and bonded to the lingual surface of the tooth to be moved (usually a cuspid or premolar) at the same height as the bracket on the buccal side. Two elastic chains or superelastic closed coil springs (Sentalloy Blue) are used as a power source; one is stretched buccally between the cuspid or premolar bracket and the molar tube at crown level, and the other is stretched palatally from the lever arm to an extension soldered on a transpalatal bar.

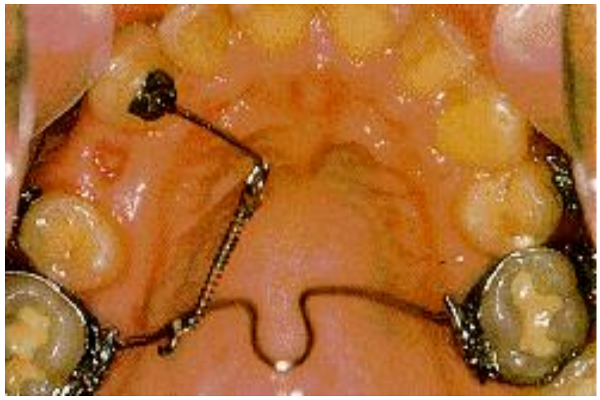


Figure 11. Lever arm adapted to palatal vault and bonded to lingual surface of cuspid. Extension soldered to palatal bar, and activation achieved with buccal and lingual superelastic coil springs.

Tear drop shaped loops

In 1983, **Alexander RG**[14] used these Teardrop shaped loops in his vari-simplex discipline. The loops are placed distal to the maxillary lateral incisor bracket. Before placing the archwire in the mouth, the portion of the archwire distal to the closing loops is reduced approximately 0.001" in the anodic polisher, so that part of the wire can slide through the brackets easily during activation.

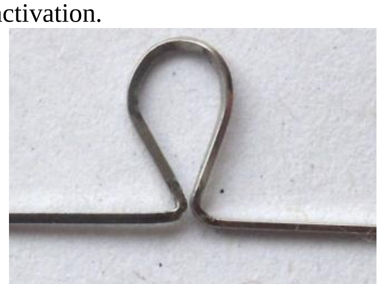
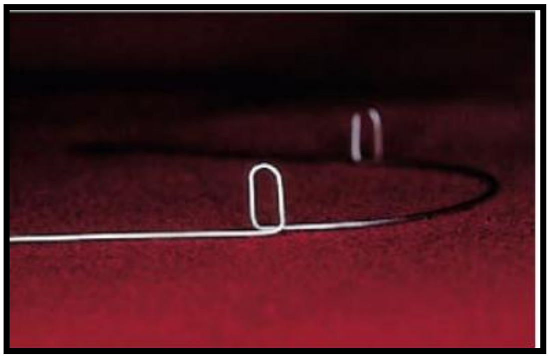


Figure 12. Tear Drop Loop

The K-SIR Arch[15]

Simultaneous Intrusion and Retraction of the Anterior Teeth designed by **Varun Kalra.** The main indication for the K-SIR archwire is for the retraction of anterior teeth in a first-premolar extraction patient who has a deep overbite and excessive overjet, and who requires both intrusion of the anterior teeth and maximum molar anchorage. A major advantage of the K-SIR appliance, compared to archwires that provide similar mechanics, is its simplicity of design, with a minimal amount of wire in the loop configuration. The 0.019"X 0.025" TMA provides sufficient strength to resist distortion, as well as enough stiffness to generate the required moments. At the same time, the design of the archwire and the material properties of TMA combine to produce relatively low forces, a low load-deflection rate, and a range of activation.



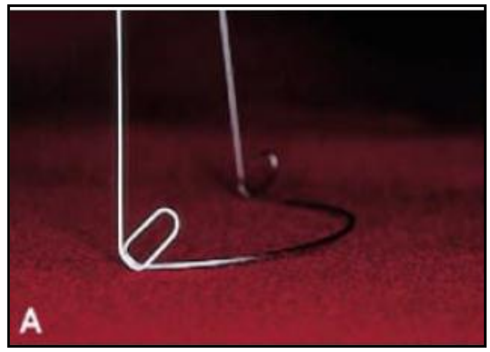


Figure 13. K-SIR archwire: 0.019" X 0.025" TMA archwire with closed U-loops 7 mm long and 2 mm wide with 90° bends placed in archwire at level of U-loops.

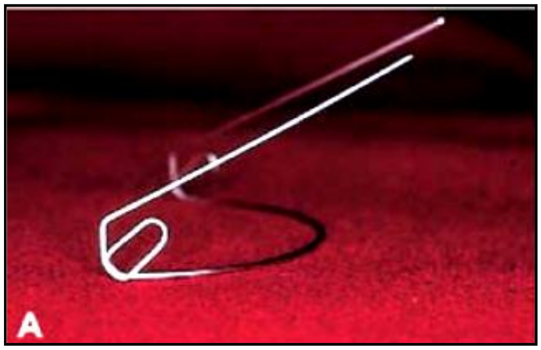


Figure 14. Archwire with off-center 60° V-bend placed about 2mm distal to U-loop.

Opus loop[16,17]

In 1997, Siatkowski RL[52] put forth a design process using castigliano's theorem to derive equations for M/F ration in terms of loop geometry. The equations are used to optimize designs by optimizing M/F to produce tooth movement via translation. This loop was designed to deliver inherent moment-to –force [M/F] sufficient for en mass space closure via translation for teeth of average dimensions. As the loop M/F is high, no activation bends or bends in the formed loop need to be added before insertion.

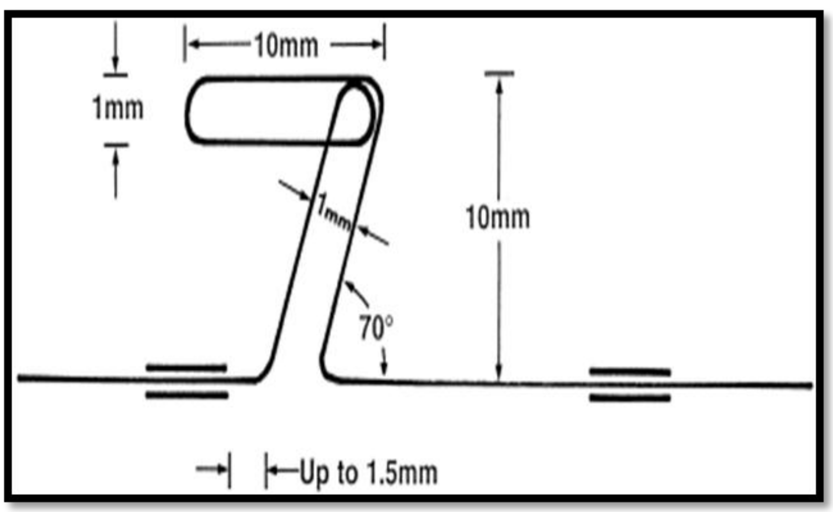


Figure 15. Dimensions of the standard Opus loop.The Opus loop arch was designed and optimized to produce M/F ratios of 8 to 9, the range necessary to translate groups of teeth of average dimension.

The Universal Retraction Spring

In 1985, **Gjessing P**[18] designed a canine retraction spring. It was constructed from 0.016 X 0.22inch stainless steel wire, the principal element being a double ovoid loop 10mm in height. A 'sweep' bend was incorporated to avoid untoward side effects at the second premolar.

Figure 16. Intraoral views of PG retractor at commencement of canine retraction.

The PG retraction system was designed to facilitate segmented treatment of extraction cases. The basic element of this system –available in right and left versions is a prefabricated, highly standardized stainless steel spring that is adjustable to fit both 0.018" and 0.022" edgewise appliances. This is usually for the controlled retraction of either canines. It is done by pulling distal to the molar tube until the two sections of the double helix are separated by 1mm. This produces an optimum force of 140gm to 160gms.

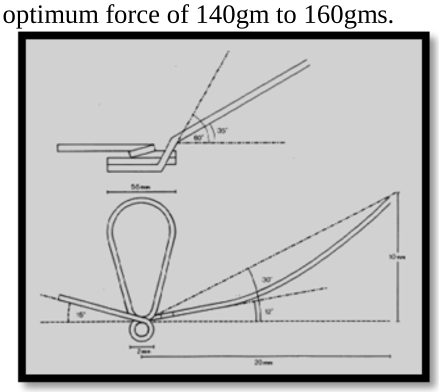


Figure 17. Spring design.

Retrusion Utility Arch

The usefulness of a retrusion utility arch in retracting and intruding incisors is obvious in cases of upper incisor flaring. However, this type of mechanics is also helpful in retracting the four anterior teeth as a unit, particularly in the maxilla. The retrusion utility arch can close interproximal spaces while intruding and aligning the upper anterior teeth and correcting midline discrepancies. The retrusion arch originates in the auxiliary tube on the molar, and 5-8 mm of wire should protrude anteriorly before a posterior vertical step of 3-4 mm is placed. The vestibular segment extends anteriorly to the interproximal region between the lateral incisor and the canine. The wire is pulled 2-3 mm posteriorly and then bent upward at a 90° angle. Care must be taken that this protruding end of the utility arch does not impinge on the gingiva or cheek. Second, an occlusally directed gable bend in the vestibular segment can be used to produce intrusion.

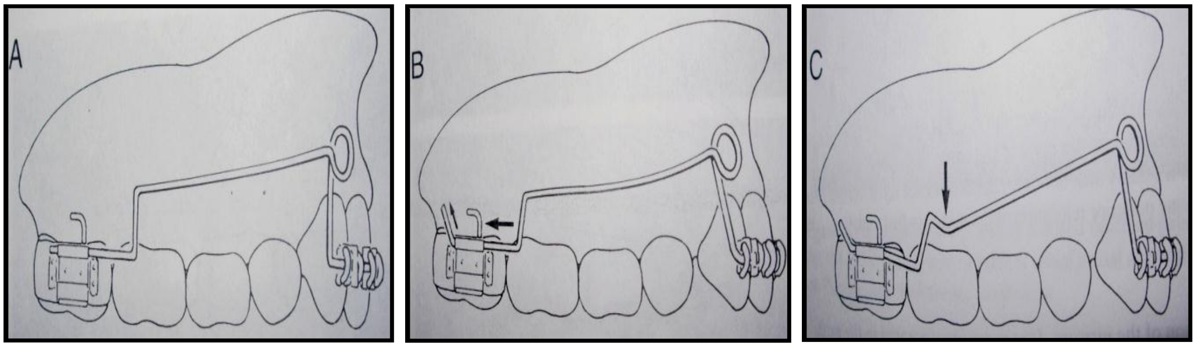


Figure 18. Sagittal view of maxillary retraction utility arch. A.Before activation. B. Activation for retraction by pulling distal end and bending it gingivally. C. An occlusally directed gable bend has been placed in the vestibular segment to produce incisor intrusion.

Conclusion

Extraction therapy is followed by the closure of spaces. Though some amount of space is spent to alleviate the crowding, the remaining space opens a new window in orthodontics. Controlled retraction, usually in extraction cases, requires the creation of a bio mechanical system to deliver a pre determined force and a relatively constant moment /force ratio in order to avoid side effects. Orthodontic space closure must be individually tailor based on the diagnosis and treatment plan. The selection of any treatment, whether a technique, stage, spring or appliance design should be based on the desired tooth movement.

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