A COMPARATIVE STUDY ON T-LOOP ACTIVATION BETWEEN THE CONVENTIONAL "PULL AND CINCH" METHOD AND A NOVEL CALIBRATED ACTIVATION SYSTEM

By

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I hereby declare that this dissertation entitled "***A comparative study on T-loop activation between the conventional "pull and cinch" method and a novel calibrated activation system***." is a bonafide and genuine research work carried out by me under the guidance of ***Dr Binnoy Kurian***, Professor and HOD, Department of Orthodontics and Dentofacial Orthopaedics, St. Gregorios Dental College, Chelad, Kothamangalam.

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ABSTRACT

Background and Objectives: Space closure during retraction can be accomplished by various strategies in orthodontics. The Loop mechanics enables very efficient usage of space closure, devoid of friction. Loop fabrication and activation requires skill and a thorough understanding of the basic principles of biomechanics. Bilateral activation of T-loops by the conventional "pull-and-cinch" method may result in varying levels of activation, leading to unequal force distribution. The objective of the study is to have a quantifiable method which can deliver same amount of forces during subsequent activations and to improve the ergonomics of activation.

Methods: Two typodonts bonded with straight wire appliance, simulating first premolar extraction cases were sorted into two groups: control and experimental. Continuous T-loops were fabricated and inserted into the molar tubes. The control group had molar tubes welded on the molar band, activated by pull-and-cinch method and the experimental group had molar bands welded with the novel tube-and-screw assembly, activated by turning the calibrated screw. Ten experienced orthodontists were made to activate the loops 10 times, sample size(n) in both the groups. A digital force gauge attached to the archwire measured the retraction forces. The forces in both the groups were then recorded and the results compared.

Results: T-loop archwires activated by the novel "tube-and-screw" assembly showed consistent and optimal force magnitudes for retraction upon each 1mm of bilateral activation when compared to the control group, which delivered varying as well as higher force magnitudes.

Interpretation and Conclusion: The novel assembly delivered consistent amount of forces upon subsequent activations. Hence the novel "tube-and-screw" assembly can be considered as a useful adjunct for orthodontic loop activation.

Keywords: T-loop, Digital force gauge, Tube-and-screw assembly

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INTRODUCTION

INTRODUCTION

During orthodontic treatment, extraction is a common option in case of space requirement. Once the teeth are extracted, planned closure of the space remains a challenging issue. Fixed appliances are necessary to transmit forces of required magnitude as well as moments to the teeth for controlled tooth movement. Extraction sites are closed either by pulling or pushing the teeth along a heavy basal arch wire or by segmenting the arch and then approximating the segments by frictionless mechanics with the help of springs etc. Orthodontic brackets serve as handles for applying a force or moment to a tooth or group of teeth.[1] The resultant forces must be continuous and the center of rotation (C_{rot}) of the tooth must be constant in order to release biologically favourable forces that does not continually keep modifying the stress areas of the periodontal ligament.[2]

The tooth movement is determined by the application of force system at the center of resistance (C_{res}) of the tooth and group of teeth. For a single tooth, typically, this C_{res} is located 10 mm apically from the bracket. This distance forms a lever arm, which, together with the force, forms the moment of a force ($F \times d = M$). This force system at the C_{res} from a single force acting at the bracket produces uncontrolled tipping, that is, the crown moves in the direction of the force while the root tip moves in the opposite direction, with a C_{rot} just slightly apical to the C_{res}.[3] In the literature, there lacks studies on the adequate magnitude of the loads that must be applied for space closure.[2]

Proper space closure mechanics is necessary for planning treatment objectives and to achieve desired outcomes.[4] Retraction mechanics, categorised as the therapeutic procedures carried out to close spaces, is an essential part of orthodontic treatment which requires a clear understanding of orthodontic biomechanics. In the pre-adjusted edgewise technique both sliding and frictionless loop mechanics are involved for space closure.[5]

In sliding mechanics, friction interferes with the forces acting on the teeth and the operator loses control over the rate of tooth movement. In continuous arch wire mechanics, the friction between each bracket and the archwire is difficult to predict. A frictionless system never relies on sliding the archwire along the bracket base, but is designed to generate the forces and moments required for space closure by moving the teeth as a segment. As a result, for efficient tooth movement, desired force level values are much lesser than what is used in sliding mechanics due to the frictionless system. Frictionless/Loop mechanics involves diverse designs of orthodontic loops into the archwire.[6]

The forces and moments generated by springs used in orthodontics demands quantitative knowledge for understanding the tooth moment that occurs upon the application of force. For controlled treatment mechanics, controlled loading of spring is a requisite and also the factors influencing the forces and moments must be well known. The amount of anchorage loss for retraction, attraction, and protraction cases are based on the goals of treatment planning. Retraction cases require maximum anchorage considerations with minimal mesial tooth movement of anchor teeth. Attraction cases require symmetric space closure where the extraction spaces are closed equally by distalization of anterior teeth and mesialization of the posteriors. Protraction cases are those where the residual space is closed by mesialization of the posteriors with minimal anterior movements. All three different scenarios requires different yet effective biomechanics for residual space closure.[7]

The role of orthodontist lies in selecting the appropriate force system for effective control of tooth movement. The variables under the control of the clinician are the moment-to-force (M/F) ratio, the magnitude of the force and/or moment, and the consistent force application. The C_{rot} of a tooth or segment of teeth is determined by the M/F ratio, allowing translation, tipping or root movement. For ideal tooth movement optimal force magnitude should be applied which will rapidly move the teeth with minimized pain, discomfort and tissue damage. The maintenance of the desired force level throughout the orthodontic tooth movement is the basis of force consistency.[8] To specifically adjust the orthodontic appliance to obtain the desired tooth movement, each of these variables must be given due consideration.[9]

During orthodontic space closure, the force systems should be carefully calibrated and judiciously applied. For pure translation and frictionless space closure mechanics during retraction, loops can be effectively used for either continuous or segmented arches to deliver controlled forces.[10,11] The control of orthodontic tooth movement and effective implementation of biomechanics is solely based on the capability to quantify and manipulate the M/F ratio. Minute differences in M/F can result in different clinical outcomes. [12, 13]

The inability to have control over the orthodontic force systems during retraction can lead to undesirable tooth movement, which in turn reduces the overall treatment efficiency. The design of the loop also influences the load/deflection rate. The incorporation of helices reduces the load/deflection rate without affecting the M/F ratio. Additionally load/deflection rate can be altered by changing the material of the wire whereas M/F ratio is not influenced by this.[14]

Majority of the published studies are based on altering the M/F ratio and also the factors affecting it. There are limited studies regarding quantifying the force delivered by a continuous closing loop archwire. Numerous experimental or computational studies have been performed on the force systems. All the published studies based on altering the force systems have concluded that the orthodontic force is multifactorial and can be adjusted according to the uniqueness of every case.[15, 16]

Over the past few decades various number of techniques have been put forth to move teeth. Many of those were promoted without any in-depth understanding of the force systems delivered by the particular appliance design. Space closure mechanics are intricate and are influenced by a number of variables. Numerable appliances have been designed for space closure but very few have been studied in detail so that the clinician can fully control the mechanics in order to obtain the desired rate of tooth movement.

Among the loops, the most commonly used is the "T-loop", both in continuous and segmental arch mechanics. For retraction mechanics, T-loop is activated using the conventional “pull-and-cinch” method. Although this method of activation has its own advantages, the major drawback is the varying amount of force levels due to varying levels of activation as this method is based on the amount the distal leg of the T-loop pulled and cinched behind the molar tube. The amount of activation may vary from clinician to clinician and often may not be symmetrical as both sides. To overcome the short comings of the present technique, novel system has been invented using a tube-and-screw mechanism. This is system calibrated in such a way that a two-and-half turn of the screw activates the T-loop by 1mm. The objective of this research is to compare and evaluate the force magnitudes during activation in the two methods.

AIMS AND OBJECTIVES

AIMS AND OBJECTIVES

Aim

To compare the retraction forces exerted by a T-loop continuous arch wire, activated with the conventional “pull and cinch” activation method and a novel calibrated activation system.

Objectives

1. To quantify the retraction forces generated by the T-loop when activated 1mm by the conventional “pull and cinch” method.

2. To quantify the retraction forces generated by the T-loop when activated 1mm by using the novel tube-and-screw calibrated activation system.

3. To compare the retraction forces exerted by the T-loop continuous arch wire when activated by the conventional “pull and cinch” method and the novel calibrated activation system.

BACKGROUND &

REVIEW OF LITERATURE

BACKGROUND OF STUDY

Space closure in orthodontics during retraction can be accomplished by various strategies. Elastics, coil springs etc. are the means to obtain the required force to close extraction spaces. These techniques have limitations, particularly issues with friction at the wire-bracket slot interface, high load/deflection rates, and a scarcity of anchorage management. With Loop mechanics, space closure has proven to be very effective as it takes advantage of frictionless mechanics. Although this being a common method used by the orthodontists, loop fabrication and activation requires skill, and a deep understanding of the biomechanics involved.

Bilateral activation of T-loops by the conventional "pull-and-cinch" method may result in varying levels of loop activation leading to unequal force distribution on subsequent visits. The forces may not be symmetrical and may result in unwanted teeth movements, if not delivered uniformly on both sides. Increased force magnitude is another disadvantage if known and calibrated forces are not applied for retraction. In case of trismus or reduced mouth opening, cases where second molars are banded etc., loop activation tends to be a laborious task.

To overcome these disadvantages, the best option is to have a quantifiable system which can deliver a known, uniform force magnitude during activations. The method should also be simple to use, should reduce chair side time and be easily accessible to the clinician.

REVIEW OF LITERATURE

Burstone (1962)[17] in his study concluded that, during orthodontic space closure, the maximum optimal response, in both histological and clinical perspective, is more prone to occur when precisely calibrated force systems are used. Loops incorporated in either continuous or segmented mechanics can be designed to deliver known forces so that pure translation and frictionless space closure occurs during retraction. The segmented arch technique, as developed by Burstone, makes use of T-loops for space closure. The loop design consideration is intended to provide optimum mechanical systems during space closure. Segmentation of the arch into two separate units i.e. anterior and posterior portions create a two-tooth system, allowing it to become a statically determinate system. The increased inter bracket distance (between canine and first molar) enables long activations which reduces the load deflection rate and lastly the use of segments permit prefabrication of orthodontic springs which can be calibrated to quantify the force magnitude on activation.

Boester and Johnston (1974)[18] performed a clinical investigation of the concepts of differential and optimal force magnitude in canine retraction. The experimental design included the application of force on four different levels to each quadrant of ten orthodontic patients undergoing all the four first premolar extraction. Assigning the retraction force to quadrant was random within each patient in the groups. Canine retraction was performed with Ricketts' 0.016" x 0.016" sectional retraction springs. Rate of retraction/tooth movement was measured intraorally on a weekly basis for a period of ten weeks. The results suggested that a low force level produced remarkably minimal tooth movement than the other three higher force levels but there was no statistical difference between the higher force levels when compared. The data obtained from the study did not support the differential force concept of anchorage control and highlighted that relative anchorage loss was independent of the force used.

Burstone and Koenig (1976)[19] analysed force systems from vertical loops. The results showed that the higher the vertical loop, larger the moment and smaller the force delivered from the spring. Higher vertical loops had increased ranges of activation without any permanent deformation. On increasing the horizontal dimension of the loop, the M/F ratio decreased thereby reducing the forces and the moments, but the M/F ratio was not as greatly affected by horizontal changes when compared to the changes caused in increasing the vertical dimension.

Sowerby R et al (1977)[20] in their article highlights about the Bauschinger effect. This effect points out those conditions in which the strength of a metal reduces when direction of the strain is changed. This phenomenon is found in most polycrystalline metals generally. In other words, if we fabricate two different T-loop designs in which one closure loop is activated and if all bends are bent in the same direction, that loop provides more resistance to permanent deformation than compared to the loop in which all bends are bent in the opposite direction. In short, wire should be bent in the same direction during the entire processes of fabrication and activation. In certain designs, the orthodontist should overbend the wire, followed by bending it in a reverse direction of the bending in order to reach the final shape. The direction of the last bend is correct and provides favourable residual stress during activation. This particular overbend will provide resistance to any permanent deformation, thereby increasing the range of activation of the loop.

Kusy and Whitley (1977)[21] reviewed the difference in friction between different wire-bracket configurations and materials used for it fabrication. They stated that a well-designed closing loop led to a more continuous type of tooth movement and also promotes greater rates of tooth displacement. The spring characteristics of the closing loops are most importantly determined by factors such as material of the wire used for fabrication, cross section of the archwire, inter bracket distance, configuration and position of the loop used. Apart from all these factors, M/F ratio is probably the main characteristic of a retraction archwire.

Burstone (1982)[22] refined the "T-loop" spring for use in the segmented arch technique. Variations in the force system between the anterior and posterior segments created differential space closure. For producing the desired force systems needed for the individual needs of each case specific predetermined geometries were developed. These were designed for narrow ranges of use and is dependent upon the type of tooth movement as well as the inter bracket distance. The springs were constructed from beta-titanium wire which is known to have improved material quality when compared to the conventional stainless-steel wires. Preactivation spring geometry and the loop placement or centricity between the attachments are the two important considerations in the design and use of T loops. The angulations of both the mesial and distal arms of the T loop are varied to obtain the appropriate alpha and beta moments respectively. Large interbracket distance helps to reduce deviations from the desired force system due to errors in the loop shape during fabrication. Placing the loop centered between the retraction space is important, especially during reciprocal attraction cases. He recommended that the loop be centrally placed in cases where the anterior and posterior teeth have to be moved equally. If the posterior teeth are to be held or anchored in place, the loop is placed closer to the anterior teeth and also when the anterior teeth are to be augmented, the loop is placed posteriorly.

Smith and Burstone (1984)[23] proposed that orthodontic movement of teeth is achieved by application of forces on teeth through orthodontic brackets, wires springs and elastics. The force system determines the type of tooth movement which can be translational or bodily movement, rotational, or a combination of each. Pure bodily movement or translation occurs when the applied force passes through the center of resistance of the tooth. The C_{res} is corresponding to a center of gravity or a center of mass and when a force applied at the center of resistance it will produce no rotation but bodily movement. The C_{res} for a given tooth depends on various factors such as the length of the root, surface area of the root, and alveolar bone height. Forces which do not pass through the C_{res} generates a moment thereby causing rotation. The magnitude of this moment produced is equal to the force applied multiplied by the perpendicular distance of line of action of that force to the center of resistance. Purely rotational movement can be accomplished by a couple only, which is basically two forces of equal magnitude with parallel noncolinear lines of action and opposite directions. The type of tooth movement can be controlled by the orthodontist by proper application of the forces and moments produced by the orthodontic appliance.

Quinn and Yoshikawa (1985)[24] reviewed four literatures regarding the relationship of applied force magnitude and the rate of tooth movement and on comparing the results of the six clinical studies and it was found that the data supported the hypothesis that the relationship of the rate of tooth movement and stress magnitude is linear up to a particular point, after which an increase in stress leads to no significant increase in the rate of tooth movement. This clearly states that particular mechanical solutions can be set up to augment the anchorage during canine retraction i.e., involving the second molars into the anchorage unit and maximizing stress magnitudes for the canine to tally with maximal rates of tooth movement. The study concluded that orthodontic appliances with a reduced load-deflection rate and relatively constant M/F ratios is the key for the most efficient tooth movement.

Sachdeva (1985)[25] experimentally studied the force systems produced by T loops fabricated using TMA (Titanium Molybdenum alloy) wires and examined the effect of inter bracket distance, loop placement, and design on the force systems produced by "T loop" space closure springs. Different springs were fabricated for different tooth movements such as retraction, attraction, and protraction. These loops were then compared over four inter bracket distances and the effects of placement on attraction T-loops were analysed. The result was that T loops without preactivation bends were not quite effective for space closure mechanics. For different inter bracket distances spring design must be varied for optimal mechanics. The load deflection rate was not affected by the effects of spring placement and inter bracket distance on but on the other hand preactivation bends seemed to have an effect of minimising the load deflection rate. When the loop was placed off-centered, a resultant change in the moment magnitudes was observed and on increasing centricity of the loop it was noticed that there was increased differential in the alpha and beta moments. The activation moment, moment/displacement rate, the residual moment, and the load deflection rate of the appliance were the principal factors governing the M/F ratio of the "T-springs”. As the inter bracket distance increased, greater angular activation bends were necessary.

Vanden Bulcke MM et al (1987)[26] undertook a study to locate the center of resistance and the effect of change in force magnitude on the location of the center of resistance of anterior teeth during retraction using the laser reflection technique, studied in two dry human skulls. The units composed of two incisors, four incisors, and six anterior teeth. Results pointed out that when greater number of teeth were incorporated into the anterior segment the Cres shifted apically. Apical shift was greatest with a unit of six anterior teeth and increasing the level of force had very little effect on the location of the Cres of a given unit, suggesting that general variations exist in the displacement characteristics of the dentition when subjected to controlled force systems.

Manhartsberger, Morton, and Burstone (1989)[27] carried out a study regarding space closure with T-loop in adult patients. The springs were tested in the laboratory with consideration to the special need of conducting orthodontic treatment in adult patients. In those with periodontal bone loss changes in the force system was done due to changes in the crown-to-root ratios. The loops tested in this study had a specific curvature to the mesial and distal arms for the creation of differential alpha and beta moments for space closure. Changes in the "T-loop" design can be done to reduce the force magnitude and to increase the M/F ratio which can be achieved by changing the cross section of the wire from 0.017" x 0.025" TMA to 0.016" x 0.022"TMA or another effective method is to change the amount of activation of the loop. The M/F ratio can also be altered by changing the angulation bends. Increasing the angulation bends increases the M/F ratio and vice versa.

Faulkner et al (1989)[28] studied the effects of several parameters such as the effects of spring height, angle of activation, non-centered placement of the loops and the addition of helices of the force system produced by "T-loop" retraction springs. They used finite element analysis and experimental procedures in their evaluation of various spring designs. From their results, they brought about the conclusion that on increasing spring height resulted in it a lesser relative decrease in moment when compared to horizontal force which resulted in an increased M/F ratios as the height of the loop increased. Asymmetric changes in both the alpha and beta activation angles did not yield any significant changes in the force directed horizontally but it did have a considerable effect on the moments creating considerable vertical forces of clinical significance. Non-centered placement of the loop generates vertical forces by significantly altering the magnitude of the resultant moment that is produced. Addition of helices at the top of the spring has minor effects on the force system and therefore is of no practical value.

Ziegler and Ingervall (1989)[29] in their a clinical study to compare the effects of maxillary canine retraction with a retraction spring and sliding mechanics showed that the rate of canine retraction was much faster with less distal tipping when the spring was used than compared to the retraction of canine done using sliding mechanics. It was also pointed out that the retraction spring was not clinically superior to the sliding mechanics in controlling rotation during the canine retraction.

McLaughlin and Bennet (1991)[30] in their study regarding anchorage control during levelling and aligning with a preadjusted appliance system mentioned that during activation of the loop in frictionless mechanism, it distorts from the original shape as the tooth moves and finally but gradually returns to its preactivated position by delivering the energy stored at the time of activation. The loops are activated by pulling the arms of the loop away and cinching them tight with the end of the wire directed gingivally, back at the molar tubes. They concluded that this approach is friction free and hence can be effectively used to move group of teeth much precisely with increased and accurate anchorage control than when compared to sliding mechanics.

Hoenigl KD et al (1995)[3] in their study measured the force system i.e., horizontal and vertical forces, of a prefabricated and preactivated T-loop used for space closure and the moments were measured using a computer-controlled measuring apparatus. In order to mimic typical clinical scenarios, inter bracket distances of 21, 24, 27, and 30 mm were used. The results showed that on 7 mm activation of the T-loop, both the anterior as well as posterior segment underwent controlled tipping initially, followed by translation, and eventually root uprighting as the M/F ratio increased with deactivation.

Kulberg and Burstone (1997)[31] conducted a study to estimate the effect of off-center positioning on the force system produced by segmented 0.017 × 0.025-inch TMA T-loop which were designed to produce equal and opposite moments in the centered position. Seven positions of the closing loop i.e., centered, 1, 2, and 3 mm toward the anterior attachment, and 1, 2, and 3 mm toward the posterior attachments were tested. The horizontal and vertical force and alpha and beta moments were measured till over 6 mm of activation. The results depicted that both the alpha and beta M/F ratio was dependent only on the position of the spring and was independent of the spring activation and also springs when eccentrically placed produces a consistent moment throughout the range of its activation.

Raboud DW et al (1997)[32] performed a study to measure the three dimensional effects in retraction appliance. They used a numerical method to achieve quantitative knowledge of the 3-D effects for typical appliance designs. Due to the retraction forces being applied by the device on the tooth's buccal surface, the axial rotation of a single rooted tooth was the major disadvantage. In order to counteract this, an out-of-plane preactivated bend can be used. It was proved that the numerical method can accurately determine the force systems resulting from this out-of-plane preactivation as well as the in-plane force systems and it was concluded that the out-of-plane effects were independent of the in-plane behaviour and that the usual or normal forces and M/F ratios are maintained.

Siatkowski RE (1997)[33] in his study regarding continuous archwire closing loop design, optimization and verification stated that an orthodontic force magnitude of100 grams produced at a distance of 10mm from the Cres produces a clockwise moment of 1000gm-mm which will cause tipping of the tooth. Since the tipping is undesirable, a counter balancing moment of 1000 grams-mm should be generated thereby allowing bodily moment. This can be done by twisting the anterior segment of rectangular wire and fitting it into a rectangular slot which will help in torquing. Once the wire is engaged into the slot an inherent moment of couple is generated due to the two-point contact of the wire edges in the bracket slot which will result in translation.

Nattrass C et al (1997)[34] executed an in vitro investigation to establish how clinicians apply forces for space closure when using the straight wire appliance and sliding mechanics, and also to quantify the initial force levels produced upon activation. A single typodont was used extraction space in each quadrant in order to simulate space closure. The time frame was two months apart and 18 clinicians were made to apply the three force delivery systems to the typodont. It was scheduled in the same manner in which they would apply in a clinical situation. The three types of force delivery system investigated in the study were an elastomeric chain, an elastomeric module on a steel ligature, and a NiTi (Nickel Titanium) closed coil spring. The amounts of stretch of the three systems were measured using an Instron Universal Testing Machine, and the initial force generated by each force delivery system was established. Assessment was done regarding the consistency in the amount of stretch/activation which each one placed on the force delivery systems, their initial force application and their ability to apply equal amount of force with the different types of force delivery system. They were found to be consistent in their method of application of the force delivery systems, but there was a wide range of forces when applied as a group. It was found that most clinicians in the study, applied very different forces when using different force delivery systems. The greatest force was applied when module on a ligature was used, while the NiTi coil springs provided the least amount of force.

D J Halazonetis (1998)[35] proposed that one of the main problems in the field of biomechanics is the control of the force system that is applied to teeth. Straight archwires infrequently produce forces and moments that are of the appropriate direction and magnitude and hence orthodontic loops have been used extensively in order to decrease force magnitude or to produce a force system compatible with desired orthodontic tooth movement. Achieving force magnitudes within the considered biologic range, in combination with appropriate M/F ratios over a large range of activation has not been proven easy. The loop design influences the level of force system as well as the M/F in a way that it is difficult to change the one without adversely affecting the other.

Menghi C et al (1999)[36] analysed force systems developed by the L-loop, the T-loop, and the rectangular (R-) loop acting for first order irregularities, buccolingual movement, and rotation along the long axis of the tooth, in their study. Interbracket distance of 21 mm was chosen, and the loops were analysed in a testing machine which helped to register forces and moments in three planes of space simultaneously. Symmetrical translations of 1 mm were made in steps of 0.2 mm, corresponding to the buccolingual tooth movement, 10º rotations clockwise and counter clockwise in steps of 1º. The force systems were recorded during both loop activation and deactivation. Results showed that loops made of TMA wire delivered 40% of the force delivered by the same loops made of SS wire. The T-loop generated a force that deviated qualitatively only slightly from a force that is delivered by a straight wire. The L-loop generated a force system that was dependent on orientation and the constancy was better corresponding to the anterior part of the loop. The R-loop was capable of generating any desired M/F ratio, demonstrated high degree of constancy of the force system and is the preferred choice for making first order corrections.

Jie et al (2000)[37] invented an apparatus for measuring orthodontic force. The device is composed of a dental replica having an orthodontic appliance secured to and a force measuring device operatively coupled to the dental replica. The dental replica was created by taking a negative mold of the patient's dentition and then creating a positive dental replica. The replica was secured to the tooth holder and the device was operatively coupled to the tooth holder in order to measure the force exerted on tooth holder by the orthodontic appliance. The force was measured by: securing an orthodontic appliance to the replica, placing a force measuring device in contact with it and operating the device to measure the force exerted on the model replica by the appliance.

Chen et al (2000)[15] by experimentation, measured the load components produced by T-loops and additionally the effects of loop design variations in their study. The moments and forces produced by various orthodontic T-loop spring designs and the effects of dimension changes and the addition of gable bends with heat treatment which were within the clinically used ranges, were assessed. The study proved that on increasing the vertical or horizontal dimension the spring's load-deflection rate, its M/F ratio was reduced and that gable bends for preactivation with heat treatment had the exact opposite effects.

Iwasaki LR et al (2000)[38] undertook a study to demonstrate that by using reduced force magnitudes, tooth translation can occur without a lag phase and at velocities that are clinically significant. In the clinical scenario, often conventional orthodontic therapy uses force magnitudes in greater than 100 g to retract canine teeth. The results showed that before tooth movement occurred, approximately 21 days of lag phase was noticed making it a big disadvantage. A statistical difference was noticed in the velocity of distal movement of the canines produced by the two stresses. The lag phase was nearly eliminated and the average velocities were 0.87 and 1.27 mm/month for 18 and 60 g of average retraction force. Hence, it was concluded that lower forces produced effective tooth movement under controlled loading conditions.

Rhee and Chun (2001)[39] inspected the differences between friction and frictionless mechanics in maxillary canine retraction case with the use of a new typodont simulation system i.e., the Calorific machine system. The unit was designed to observe the tooth movement as a whole. It had three components: a temperature regulating system, an electro thermodynamic tooth and an artificial alveolar bone component. An 0.016 x.0.022-in SS labial arch was used for sliding mechanics and NiTi closed coil spring and a canine retraction spring was used for frictionless mechanics. According to the results, friction mechanics were superior to frictionless mechanics regarding rotational control and dimensional maintenance of the arch while frictionless mechanics proved to be more effective at reducing tipping and extrusion. However, clinically the differences between the two groups were minor and no significant differences were found in anchorage control and indicated that both friction and frictionless mechanics perform similarly.

Bennet and McLaughlin (2001)[40] mentioned that in the standard edgewise technique, closing-loop arches are preferred than sliding mechanics for space closure. In sliding mechanics the friction is created by first, second and third order bends, while in loop mechanics it is overcome by activating the loops usually only about 1mm at a time. 1mm activation of the closing loop is advantageous as it allows the roots to "catch up" to the initial tipping effect of the activation.

Kum M et al (2004)[41] in their in vitro study investigated the forces, moments and M/F ratios generated during activation and deactivation of three closing loop designs constructed from two different orthodontic wire alloys. The forces and moments of non-preactivated vertical U-loops, symmetrical T-loops, and asymmetrical T-loops made from TMA and Japanese NiTi were measured at 35.6º C ± - 0.5º C. For each activation and deactivation of the loop the M/F ratio was calculated. Results depicted that the forces, moments and M/F ratios produced by the NiTi closing loops were significantly less than those from the TMA loops. NiTi T-loops produced a comparatively constant force during activation compared to an equivalent design in TMA. The asymmetrical TMA loop produced a maximum M/F ratio of 9.4:1. It was found that none of the closing loops produced the optimum M/F ratio required for translational en-masse tooth movement.

Thiesen et al (2005)[42] performed a study to determine the mechanical characteristics of beta-titanium T-loops with and without helices. The loops were fabricated with 0- and 180-degree gable from 0.017-inch x 0.025- inch and 0.019-inch x 0.025-inch wires. It was suggested that, force levels produced by T loops fabricated from 0.017-inch x 0.025-inch beta titanium wire were nearly 20 per cent lower than those fabricated from 0.019-inch x 0.025- inch wire. The transverse section of the wire had minimal influence on the M/F ratio. As the moment increased using the thicker wire, the horizontal force increased more or-less proportionately.

McLaughlin R et al (2005)[43] discovered a new device for extraction space closure called the Hycon Device which uses a rectangular support wire inserted into an auxiliary tube of first molar tubes. It comprises of a nut-and-bolt assembly soldered buccally to the rectangular wire. A ligature wire was tied to the end of the bolt and the opposing end of the wire was tied to the anterior segment. To activate the appliance to start retraction, the patient was instructed to turn the bolt. Closing loops and sliding mechanics rely on elastic forces but the Hycon Device is based on a design i.e., a screw-type mechanism. A single 360° turn of the screw provides an activation length of 0.35mm which makes it possible to deliver a precise space-closing activation at a relatively high force level, but over a short distance. Force generated on single activation was 410g as tested in a strength testing machine.

Vicelli (2006)[44] in his study, geometric modifications were determined during controlled tipping of the six anterior teeth, where there was no movement of the posterior teeth, thus configuring a type A anchorage situation. To produce an ideal T-loop design providing a more determinate force system, the effect of steps, angles, and vertical forces were combined. Optimal .017 x 0.025-in T-loop springs were designed by using a simulation performed with LOOP software to allow compensation for anterior unit-position effect on the final force system. The effects and force systems were estimations based on simplified locations of the center of resistance, assuming relatively constant behaviour of the center of rotation and might differ slightly from what happens in vivo. In order to ensure a precise force system, a finite element method or an accurate spring tester capable of reproducing the exact geometric corrections might be beneficial.

Kumar et al (2008)[45] estimated and compared the magnitude and direction of initial canine displacement by four sets of different canine retraction springs in their study. 4 oz, 5 oz, and 6 oz each load was applied by four different canine retraction springs onto the canine. The springs were closed coil, open coil, PG spring, and T-loop. The results showed that the PG retraction spring produced the highest initial displacement among all the loads that were used, which was followed by open coil spring, closed coil spring, and T-loop. The open coil spring showed maximum canine tipping, followed by the PG spring, closed coil spring, and finally the T-loop. It was concluded that whenever minimal tipping is performed, T-loop should be preferred. In cases where a higher magnitude of displacement is needed, PG retraction spring performs best over other springs. Whenever a reasonable magnitude of displacement is required and when reasonable tipping is permissible, closed coil springs is the better choice.

Martins et al (2008)[46] in their study compared the forces that were acting on curvature and preactivated V-bends in T-loop springs fabricated from 0.017- 0.025" TMA wire. The LOOP software program was used and photographs of T-loop springs preactivated by curvature and V-bends were uploaded. When both the loops were passive, they had the same length of wire and the angulation between their anterior and posterior extremities. The brackets were at the same height, separated by 23 mm and angulated 0º, loop was activated by 7mm and the forces and moments were noted after each 0.5 mm of deactivation. The results showed that preactivated curvature springs delivered horizontal forces ranging from 34- 456 gF, while the other delivered forces ranging from 54- 517 gF. It was noticed that the force magnitude decreased with every 0.5 mm of activation on the preactivated V-bend T-loop spring when compared with the preactivated curvature T-loop spring. Vertical forces were low and clinically insignificant for both springs. The M/F ratios were significantly higher on the preactivated than on the preactivated V-bend T-loop spring.

Lim et al (2008)[47] performed a study to test temperature effect on the force, moment, and M/F ratio of NiTi and TMA T-loops. Result showed that temperature indeed significantly influenced the forces and moments produced by NiTi loops, and it increased as the temperature increased. The M/F ratios of NiTi loops were least affected with no changes with temperature for the 15º and 30º preactivation loops significantly, but some minor changes were noted for the non-preactivated loops. TMA wires were generally not influenced by temperature changes.

Darnell Rose et al (2009)[48] in their in-vitro study investigated the forces, moments, and M/F generated in T loops fabricated from NiTi and TMA wires during the activation and deactivation incorporating either 0º, 15º, or 30º of preactivation. Results showed that T loops with zero degree closing loops failed to produce an optimum M/F ratio for translational movement. On increasing the degree of preactivation bends, the M/F ratio increased over the deactivation range for both springs. The NiTi T-loops produced an M/F ratio of greater than 10:1 than for the equivalent TMA T-loop and also maintains the optimum M/F ratio over a greater range of deactivation.

Tang et al (2009)[49] brought forth a method of intracorporal tooth modelling in their experiment. The patients tooth model was built first. The position of the brackets was marked and the models of the brackets were removed after marking. The tooth model was then connected to the measuring unit through a model clamping device. The tooth model which was to be measured was separated from rest after the position of the model was marked. The four corners of brackets were connected with four springs of the force measuring device. The bracket was then pulled back to the marked position by rotating the nut of the force measuring device. The elongation of the springs and the coordinates were recorded by the identification and positioning device and the orthodontic force was obtained by the composition of these spring force. The spring force of one spring is calculated by the elongation of the spring. The force sensor is connected with the band placed on the molar which measures the orthodontic force of the molar generated by the pendulum archwire.

Chen et al (2010)[50] demonstrated the 3-D orthodontic force systems of three commercial closing T-loop archwires in their study using a new method and to quantify the force systems of the T-loop archwires and explained that, coupling effects occur when a distal activation is done to T-loops and there is a need to quantify these effects in order to control the unwanted side effects. All six components of the force systems produced during activation of the loops were quantified experimentally and as a result the force increased linearly with the activation. Each type of archwire had its own marked force system. Distal activation resulted in force and moment components in both buccolingual and occluso gingival directions, which can cause undesired tooth displacement components. These unwanted components are side effects that clearly need to be eliminated. The force systems of the T-loops acting on the teeth are three dimensional in nature. Activation was done in one direction only, but as an undesired side effect, it resulted in force and moment components in other directions as well. The commercially available archwires do not provide force systems which helps in pure translation. Therefore, in conclusion, quantification of force magnitude is crucial for the selection and design of orthodontic appliances for optimum results.

Caldas SGFR et al (2011)[51] did a research to compare the effect of preactivation on the beta-titanium T-loop force systems. Significant horizontal forces were noticed in loops preactivated by curvature which were much lower than those preactivated by concentrated bends. Relating to the moment of force that was produced, no differences were found in both groups, but significant differences were found in the load-deflection rates and in neutral position. The M/F ratios were comprehensively higher on the T-loops preactivated by curvature than the springs preactivated by concentrated bends, except during 5 mm of activation. Horizontal forces were minimal in T-loops preactivated by curvature but M/F and load-deflection ratios were higher than the loops preactivated by concentrated bends.

Maia et al (2011)[52] performed a study to use photoelastic analysis to compare the forces generated by T-loops during retraction fabricated with SS and TMA wires with photoelastic analysis. Three photoelastic models had same preactivations in the two groups. In the first group, the loop was constructed with a SS wire and two helicoids were incorporated on top of the loop. In the second group TMA wire with no helicoids were used. It was observed that the force magnitude which was generated by the springs in first group with SS wire was significantly higher than that in second group however; both had symmetry for the active as well as reactive units related to the system of force. It was hence concluded that both springs had the same mechanical characteristics but TMA springs showed lower force levels.

Tang et al. (2011)[53] invented an orthodontic force measuring device based on a force sensor. The number of the measuring components needs to be confirmed initially, according to the number of teeth which need to be measured. The brackets were bonded with the teeth after connecting the bracket bottom plate, pluggable gasket, bracket and the nut. The position of the measuring components in the arch frame was determined by the position of the brackets roughly. Patients were made to wear this device and the elastic claws were connected with the brackets. The nut and the pluggable gasket are then removed. The force value before and after the nut removing is recorded and the orthodontic force can be calculated by comparing force value before and after removing.

Keng et al (2012)[54] conducted a randomized controlled clinical trial (RCT) to evaluate the space closure rate and the angulation changes during maxillary canine retraction using preactivated T-loops made from TMA and NiTi. Twelve patients were selected with age of 13 and 20 years with upper premolar extractions, and each acted as their own control. A split mouth block randomization design was carried out with NiTi T-loop allotted to one quadrant and TMA to the other. Loop activation was done by 3mm at each visit in order to deliver a load of approximately 150 g to the maxillary canine. All the used T-loops were compared with the unused ones to assess any distortion. The mean space closure rate between preadjusted NiTi T-loops and preadjusted TMA T-loops when used in combination with a base arch and changes in canine angulation per month following space closure showed no statistical differences. Preactivation configuration was maintained, shape was maintained and moreover very minor changes were observed with the preadjusted NiTi T-loops than compared to the TMA T-loops following space closure. In conclusion it was observed that TMA T-loops underwent 10 times more distortion when compared with NiTi T-loops.

Tang et al. (2012)[55] invented an orthodontic force measurement device to improve the measure effective of all his previously designed measuring devices. This was mainly composed of a base, an adjusting component and a measuring component. The measuring component includes three parts i.e., a center rod, a pressure sensor and a clamping device. The center rod is connected to the pressure sensor on one side and is connected with the adjusting device on the other side. This device can measure the orthodontic force much faster compared to his other devices. The measurement of force magnitude with this device can be carried out without tooth modelling and patient wearing which highly improves the measuring effectiveness as well as compliance.

Mehta and Sable (2013)[56] undertook a study to evaluate and compare the efficiency between T loops fabricated using SS and TMA in terms of canine retraction, canine angulation and canine rotation using T-loop designs which were identical and the activation schedule was over a 4-month period. T-loops in 0.017 × 0.025-inch TMA and 0.016 × 0.022-inch SS wires for left and right maxillary canines were activated to generate 200 gm of force every month for a period of 4 months in a standardised manner. The result of the study was that 0.017 × 0.025 TMA T-loops offered more canine retraction and tipping control whereas better rotational control was observed by T-loops fabricated from 0.016 × 0.022 SS.

Dinesh et al (2013)[57] in their study, constructed an apparatus to measure the orthodontic force delivered from elastomeric chains. The force obtained was then compared with the values measured using an Instron universal testing machine. The apparatus consisted of a mounted screw gauge arm to which orthodontic brackets can be attached, a flat steel platform and a movable arm. Orthodontic brackets were be attached to these arms. In order to estimate the forces exerted between brackets with the elastomeric chain, an electric circuit is connected to the movable arm of the apparatus. The whole circuit is connected to the signal conditioner which displays the reading. Elastomeric chain with four links was attached to the arms. The movable arm of the apparatus can be adjusted to create orthodontic forces and it was calibrated on the digital displayer. The values of the force magnitudes were then compared with the values calibrated with the Instron universal testing machine in order to test and compare the efficacy of the novel apparatus. The force values obtained after activation in the Instron universal testing machine and the novel apparatus were within the range of 100 to 150 grams initially at 1mm activation and then had a steep rise to 300 to 350 grams at 5mm activation. After which it had a gradual increase for the remaining 5mm activation, reaching up to values ranging between 400 to 450 grams. It was concluded that the Indigenous apparatus proved to be very efficient in measuring the tensile forces generated by auxiliaries.

Mencattelli et al. (2014)[58] designed a customized load cell for universal 3-D force-moment measurements in orthodontics. The experimental platform composed of six load cells. The shape of the load cell allows detecting six mechanical actions independently that the tooth is subjected to and an acquisition system was used to collect data simultaneously. The load cells were calibrated by applying known loads in a range between 0 N and 2 N. Each load cells were installed with a strain gauge in order to measure the orthodontic force in all three dimensions and the experiment was carried out based on a plaster dental model. The orthodontic forces generated by four super elastic archwires and two invisible orthodontic appliances were measured and analysed. The load was successfully calibrated, by showing a good linearity for all the six strain gauges voltage outputs. The experimental tests showed excellent sensor repeatability.

Techalertpaisarn and Versluis (2015)[59] in their study investigated about the consequences of vertical steps on a T-loop force system at three inter bracket distances (IBDs) and also studied about its association with the V-bends. 18 T-loop configurations for the study were taken up with 6-, 9-, and 12-mm IBD and with a 2.5-mm canine bracket (CB) end and with vertical steps of 0, 0.5, or 1mm. During simulated loop pulling the loop response were determined for all the loop configurations. The results showed that on adding vertical steps to the T-loops the M/F ratio increased at the premolar bracket (PB) ends which was enough to produce sufficient root movement, while reducing the M/F ratios at the CB ends. On increasing the step bends for shorter IBDs, the force system increased and caused rapid changes in M/F ratios. Increasing activation in stepped T-loops caused significant variations in M/F ratios and in the amount and direction of force system, unlike plain T-loops. Step T-loops drastically modify the force system and show combined effects of V-bends and step bends considerably.

Roscoe MG et al (2015)[60] analysed various factors to work out the association of orthodontic force system and root resorption on an evidence based level. The results showed that positive correlations exist between increased force levels and increased orthodontic treatment time with increased level of root resorption. Another vital finding in their study was that a pause in tooth movement seems to be helpful in reducing root resorption because it permits the resorbed cementum to heal.

Júnior et al (2016)[61] aimed to access regions of TMA T-loop springs affected the most by the stress relaxation over a period of twelve weeks. Fifty springs were activated by concentrated bends and divided into five groups of ten each according to their evaluation periods i.e., immediate assessment, 24 hours, 48 hours, 1 week and 12 weeks. All the springs were scanned for measurement of their angles after the experimental time was over, and were numbered from 1 to 9. It was concluded that the stress relaxation was observed in the T-loops. It was increased within 24 hours and gradually accelerated up to 12 weeks. In the study two regions were identified responsible for the relaxation of the spring i.e., one at the bend between the vertical extensions of the springs and also the base arch and the other at the region of the preactivation bends in the base arch wire.

Prem N et al (2017)[62] performed a finite element analysis study to find out the magnitude of optimum orthodontic force and to quantify the stresses in the periodontal ligament during the retraction of maxillary canine using different methods both sliding and loop mechanics. The result was that the stress patterns clearly indicated that the optimum orthodontic force for canine retraction using sliding mechanics is 210 grams and for loop mechanics is 200 grams. In sliding mechanics 0.019 × 0.025" rectangular archwire showed bodily movement of the tooth while round 0.018" archwire only showed tipping of canine. In case of loop mechanics, at 200 grams of force the T loop design was found to be the better loop design than the tear drop loop and also similar stress patterns in each loop design were showed by both permachrome and beta III titanium archwires.

Xia et al. (2017)[63] invented a measuring device to measure the orthodontic force between the periodontal ligament (PDL) and the alveolar bone. The tooth model (build by 3-D technology) composed of the tooth, the PDL and the alveolar bone was built first. Then the tooth model was connected with the support table. Multi-axis force sensor is driven by the driving component to connect with the tooth model. The measuring device composed of the support base, the multi-axis force sensor and the support table which is used to fix the tooth model and the multi-axis force sensor is connected to the driving component. The purpose of this device was to measure the orthodontic force between the PDL and the alveolar bone with the multi-axis force sensor. The influence of the PDL deformation on the orthodontic forces can be simulated by this device.

Shintcovsk RL et al (2018)[64] compared the load systems produced by rectangular loops and continuous arches for the correction of extruded second molars with a mesial inclination and a distal inclination. The results showed that within the mesial inclination group, the rectangular loop produced a force system that could correct the second molar. Both the mechanics produced a force system that was compatible with the correction of the second molar in the distal inclination group, but the moments created by the continuous system was higher and that each groups showed a tendency for mesial crown tipping of the first molar.

Makhlouf M et al (2018)[65] carried out a study to compare the amount of tooth movement during canine retraction and the effect on root resorption using Cone Beam Computed Tomography (CBCT) with two different retraction mechanics; friction mechanics versus frictionless mechanics which was represented by a NiTi closed coil spring and T - loop fabricated from 0.017 X 0.025 TMA wires respectively. NiTi coil spring with 150 gm of retraction force was used to retract the left maxillary canines. The T-loop side had greater mean anteroposterior measurement than NiTi coil spring side, thus indicating significant lesser canine movement pre and post a canine retraction. Regarding the root resorption, no significant change was observed in the mean measurements of canine root length post retraction. It was hence concluded that NiTi coil springs showed greater distal movement than the T-loop, and that both retraction mechanics did not cause root resorption when controlled orthodontic retraction force system was used.

Davis S et al (2019)[66] compared the efficiency of canine retraction using modified Marcotte springs and T-loops in a split-mouth design study. Opposite quadrants were randomly allocated either modified Marcotte spring (MS) or T-loops for canine retraction, involving bilateral extractions of upper first premolars. Lateral cephalometric radiographs and study models were used to measure the rate of canine retraction and to compare the rotational changes in the canines and anchorage loss in molars, following retraction. Subjective assessment of pain and discomfort was compared using Visual Analog Scale (VAS). The results depicted that MS exhibited increased rate of retraction and rotation control when compared with T-loops during sectional canine retraction. Patient comfort was better for MS as scored by the VAS, but T-loops showed reduced tipping and anchorage when compared with MS.

Wu J et al (2020)[67] aimed to investigate a technological method for measuring dynamic force by tooth movement simulation which was simulated in a softened wax model. A canine was selected for evaluation and was divided into two sections- the crown and root. A force transducer was plugged in and fixed between the two parts in order to measure the force magnitude. Forces on this tooth was applied by ordinary NiTi wire, hyperelastic NiTi wire, low-hysteresis (LH) NiTi wire and self-made glass fibre-reinforced shape memory polyurethane (GFRSMPU) wire. The results showed that the canine moved to the desired location, and only a 0.2 mm deviation remained. The tooth had a higher moving velocity with ordinary NiTi wires in comparison with the others. Force attenuation for the GFRSMPU wire was the lowest at the end of the test, indicating that it provided light but continuous force. Mimicked tooth movements and dynamic force measurements were successfully determined in this tooth movement simulation and these findings could help with estimating treatment effects and optimising the treatment plan.

Chakraborty S et al(2020)[68] in their study advocated the use of a portable digital weight measuring gauge for orthodontic force measurement to avoid the demerits of orthodontic dynamometer. A portable weight measuring gauge is a digital gauge, routinely used to measure the weight of baggage or other household goods which can measure from 5 grams to 50 kgs of weight, and shows four different measuring units i.e., kilogram, pound, ounce and jin. The digital gauge was incorporated into orthodontic practice as both the dynamometer and the digital gauge work on the same principle. The bigger hook was replaced with a 20-gauge SS wire bent like a hook at the end in order to engage elastics or wire. The readings were checked multiple times for reliability and reproducibility with both the instruments showing nearly similar values. Therefore, with just the click of a button any of the four units could be measured. Thus, the use of the portable weight measuring gauge can save valuable chair side time and also and reduce errors in force measurement. The dynamometer comes as a gauge with sixteen-line markings with a double marking in every fourth marking to facilitate reading, counting these markings can give rise to visual errors due to the closely packed lines and this increases the chair side time.

RELEVANCE

RELEVANCE OF THE STUDY

A thorough understanding of biomechanics leads to a better ability to decide on the treatment options and prognosis of various clinical scenarios. Extraction space closure which is an integral part of orthodontic treatment is achieved either by friction (sliding) or frictionless (loop) mechanics. Moving the teeth along an arch wire is what sliding mechanics comprises of while closing fabricated loops either in a full or sectional arch wire is what makes frictionless mechanics. Although both mechanics have been practised commonly by orthodontists, they seem to have their own merits and demerits.

Loop mechanics is a frictionless method but it comes with certain disadvantages

1. Increased chair time.
2. Superior wire bending skills needed.
3. Varying levels of loop activation on subsequent visits delivering unequal forces.
4. Difficult to activate the loops if second molars are banded and included in the anchorage unit.
5. Accessibility issues in patients with reduced mouth opening.

Therefore, an ideal retraction system with loop mechanics should meet the following requirement:

1. The amount of force should be quantifiable
2. It should deliver the same amount of force on either side as determined by the clinician
3. It should deliver predictable forces on subsequent visits
4. It should be easily accessible for activation
5. It should reduce chair side time
6. It should be simple to use

MATERIALS & METHODS

MATERIALS

- Rectangular TMA wires of 0.017 x 0.025 inch (Ormco Corp.)
- Orthodontic brackets- (Straight Wire Appliance) 0.022” MBT Mini Diamond (Ormco Corp.)
- Elastic modules (Ormco Corp.)
- Bird beak plier
- Mathieu plier
- Heavy wire cutter
- Pin and ligature cutter
- Mouth mirror
- Explorer
- Ligature wire (Leone)
- Preformed upper molar band (Ormco Corp.)
- Double weldable molar tubes (Ormco Corp.)
- Typodont jaw set with teeth mounted (Dentaurum)
- Novel molar tube assembly with screw
- Key of self-ligating bracket system (Damon)
- Glass Ionomer Cement (Fuji I)
- Transbond XT composite resin (3M Unitek)

EQUIPMENTS

- Digital force gauge: M5-05, Series 5 (Mark-10 Corporation. USA)
- Digital Vernier calliper (0-300 mm, Masel Ortho, UK)
- Curing light: BLUE PHASE N R MC light cure unit (Ivoclar)

STUDY SETTING

- Department of Orthodontics and Dentofacial Orthopaedics, St. Gregorios Dental College, Kothamangalam.
- Department of Orthodontics and Dentofacial Orthopaedics, Indira Gandhi Institute of Dental Science and Research, Kothamangalam.

SAMPLE SIZE CALCULATION

$$n = \frac{(\frac{Z\alpha}{2}+Z\beta)^2}{d^2} \times SD^2$$

Z α/2 =Type 1 error (5%) =1.96

Z β = Type1 error (10%) =1.28

SD =Standard deviation =0.6(From literature)

d =minimally detectable difference=0.5

$$n= \frac{(1.96+1.28)^2 \times 0.6^2}{(0.5)^2}$$

$$= \frac{10.49 \times 0.36}{0.25} = 15.10 \approx 16 \text{ (8per group)}$$

INCLUSION CRITERIA

- Typodont set with first premolars removed
- Typodont set with bilateral first premolars removed from the arch

EXCLUSION CRITERIA

- Typodont set with second premolars removed/ missing
- Typodont set with unilateral first premolars removed from the arch

SORTING OF SAMPLES

The sample size of the study was taken as 20.

The samples were divided into two groups of ten each.

1. The control group in which double molar tubes were welded on the preformed molar bands used for the conventional "pull-and-cinch" method of T-loop activation.

2. The experimental group in which the Novel Tube-and-Screw assembly was welded to the preformed molar band for T loop activation.

DIGITAL FORCE GUAGE

M5-05 digital force gauge, Series 5 (Mark-10 Corporation. USA)

- Capacity: 250 gF
- Resolution/ Least count: 0.05 gF
- Measurement units: lBF, ozF, gF, N
- Safe overload: 200% of full scale
- Mesur Lite Software included
- 1,000-point data memory with statistics and outputs

DIGITAL VERNIER CALIPER

- Masel Ortho, UK
- Capacity: 0-300 mm
- Resolution: 0.01 mm
- Accuracy: ± 0.02 mm/0/0.001″
- Repeatability: 0.01mm/0/0.0005″

METHODOLOGY

PREPARATION OF THE SAMPLE

In-vitro set up

Two typodont jaw sets were used for the study. The teeth were set in ideal occlusion with the first premolars removed simulating an extraction case. 0.022" slot MBT prescription Straight Wire Brackets were bonded on the typodont teeth using composite resin and cured with LED unit. One typodont had the molar band, with the conventional molar tubes welded (Control group), while the other had the molar band, with the novel tube-and-screw assembly welded (Experimental group) on the buccal surface, respectively. The molar bands were then cemented onto the first molars using GIC (Glass Ionomer Cement).

200 T-loop continuous arch wires were fabricated manually by a single operator from 0.017x0.025-inch TMA wires using Tweed's and Bird beak pliers. The wires were then placed such that the T-loop was centrally positioned in the extraction space and ligated to the brackets using elastic modules. The ends of the archwire which was visible distal to the molar tubes was cinched gingivally in the control. The distal ends of the wires in the novel assembly were cinched at right angle to the horizontal plane of the archwire along the distal groove of the assembly.

The typodont was placed on one platform while on the other, the digital force gauge was positioned. The phantom head was then positioned over the typodont and secured. Before starting the activation, the reading on the gauge was set to zero and the mode was set to measure force in gram. A ligature wire was then secured to the distal legs of the T-loops bilaterally and engaged to the hook of the digital force gauge. The orthodontist was then made to activate both sides of the T-loop continuous archwire in the control and experimental group. The reading was then recorded and the results compared. A panel of 10 orthodontists with minimum 8 years of work experience was chosen for this study. Each one was made to activate the 10 archwires with T-loops bilaterally by 1mm in both the control and the test groups to avoid errors due to selection bias

Control group

The control group had T-loops activated bilaterally by the conventional "pull-and-cinch" method. Preformed molar bands were selected which fitted snuggly around the first permanent molars in the typodont and was contoured. Molar tubes were then welded into the buccal surface of the contoured molar bands such that it aligned along the center of the tooth horizontally and the opening of the tube was along the mesio-buccal cusp of the molar vertically. The molar band with the tube was then cemented onto the tooth using GIC.

Experimental group

In the experimental group the T-loop continuous archwire was activated by the Novel tube-and-screw assembly. Preformed molar bands were selected which fitted snuggly around the first permanent molars in the typodont and was contoured. The novel assembly was then welded into the buccal surface of the contoured molar band such that it aligned along the center of the tooth horizontally and the opening of the tube was along the mesio-buccal cusp of the molar vertically. This was then cemented onto the molars using GIC.

Making of the jig

A custom-made jig was fabricated from stainless steel sheets having a dimension of 100.5 cm length and 67.5cm width. The base was inclined at 45º from the floor in order to stimulate the reclined head position of the patient lying on the dental chair. Over the base, two housings were soldered in order to hold both the typodont as well as the force gauge in place.

Novel tube-and-screw assembly

The novel tube-and-screw assembly was made of stainless steel resembling a double molar tube. The superior tube receives the main archwire, while the lower slot is a round tube with internal threads through which the screw can be advanced. The superior archwire tube has a vertical cut at the distal end which acts like a guide to position the cinched distal portion of the archwire at right angle to the main archwire. At passive position, the distal end of the archwire will be in contact with the distal end of the screw.

Calibration of the screw

Before the start of activation, a digital vernier calliper was used to calibrate the screw. 360º turn of the screw separated the legs of the T-loop by 0.4mm, as measured by the calliper, hence for 1mm of T-loop activation, the screw was turned by two-and-half turns.

Activation of loop in the control group

In the control group (Group 1), the method of activation was by the conventional “pull-and- cinch” method. The orthodontists were made to activate the loop by pulling the distal leg of the T-loop such that the legs of the loop separated by only 1mm and then cinched. Activation was done bilaterally and was based on each one’s perception. The force magnitude was then measured and recorded.

Activation of loop in the experimental group

In the experimental group (Group 2), the calibrated Novel tube-and-screw assembly was used for the loop activation. The orthodontists were made to passively cinch the distal leg of the wire occlusally such that it aligned inside the horizontal cut on the distal end of the novel tube assembly. Once cinched, the distal leg of the loop contacted the distal end of the screw. In order to activate the loop, they were instructed to turn the screw by two-and-half turns, which activated the loop by 1mm, in a clockwise direction using the key of self-ligating bracket system which acted as the screw-driver. Activation was done bilaterally. The force magnitude was then measured and recorded.

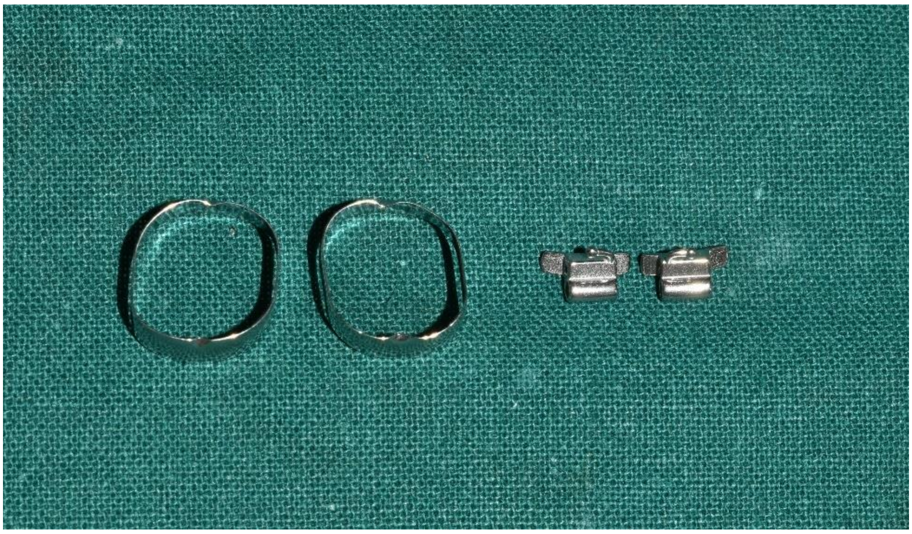


FIG 1: Preformed upper right and left first molar bands and molar tubes

FIG 2: Preformed upper right and left first molar bands and
the novel tube-and-screw assembly

FIG 3: Instruments- Heavy archwire cutter, Mathieu forceps, Bird beak plier, Pin and Ligature cutter, Key of self-ligating system, Mouth mirror, Explorer

FIG 4: Novel tube-and-screw assembly

FIG 5: Welding double molar tubes on molar bands

FIG 6: Molar bands with Novel tube-and-screw assembly welded (left) and molar bands with double tubes welded (right)

FIG 7: Digital force gauge

FIG 8: Digital Vernier calliper

FIG 9: 0.017x0.025 TMA wires (left) and 0.022" slot Ormco Mini Diamond brackets (right)

FIG 10: Ligature wire and elastomeric modules

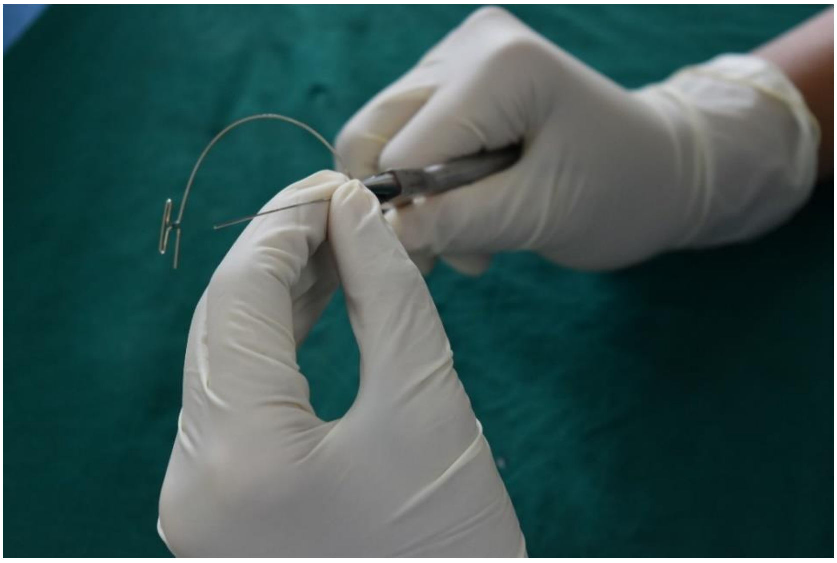


FIG 11: Fabrication of continuous T-loop archwire by single operator

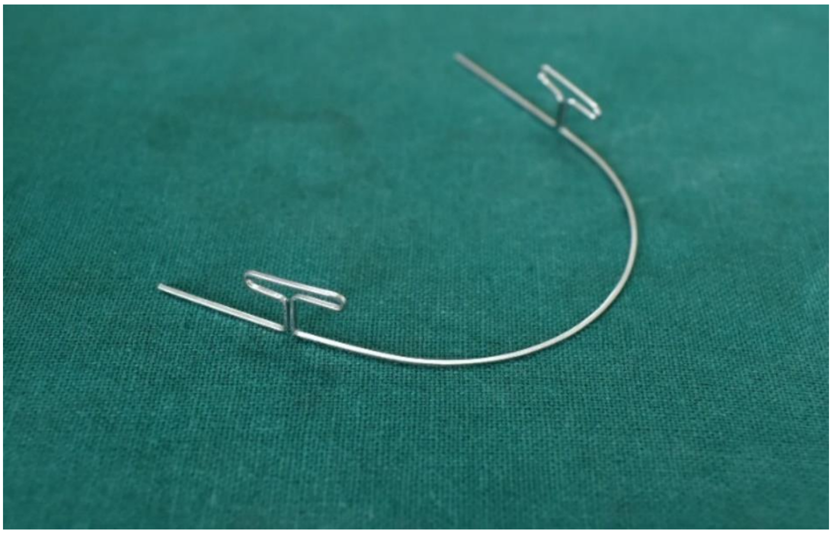
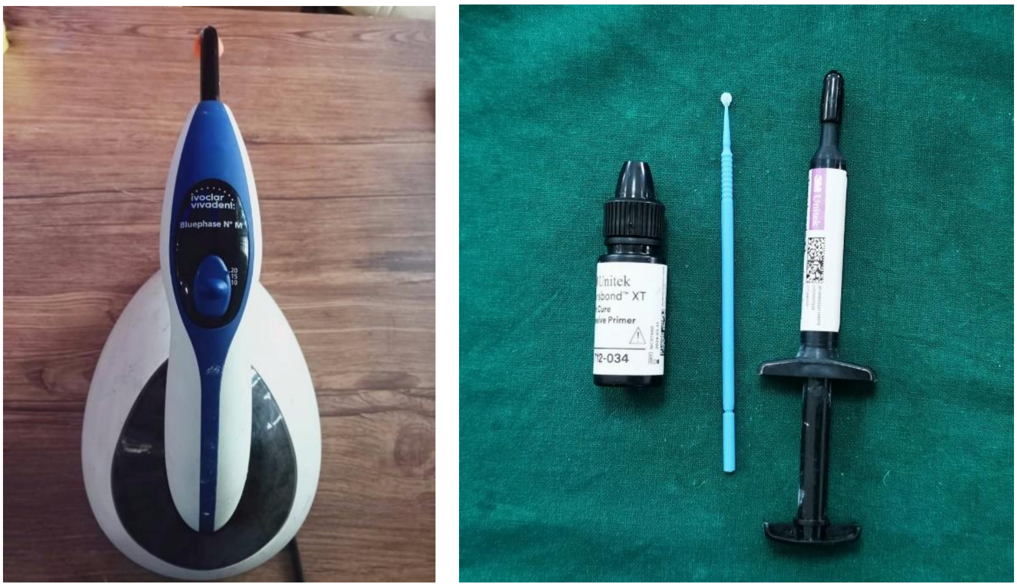


FIG 12: Continuous T-loop archwire fabricated from 0.017x0.025” archwire



A **B**

FIG 13: (a) Bluephase curing light, (b) Bonding agent, Applicator brush and Composite resin

FIG 14: Mixing pad, Scoop, Plastic spatula, GIC liquid and GIC powder

A **B**

FIG 15: Passive continuous T-loop in place: (a) Control group and (b) Experimental group

FIG 16: Typodonts bonded with 0.022” straight wire MBT prescription and T-loops ligated in place

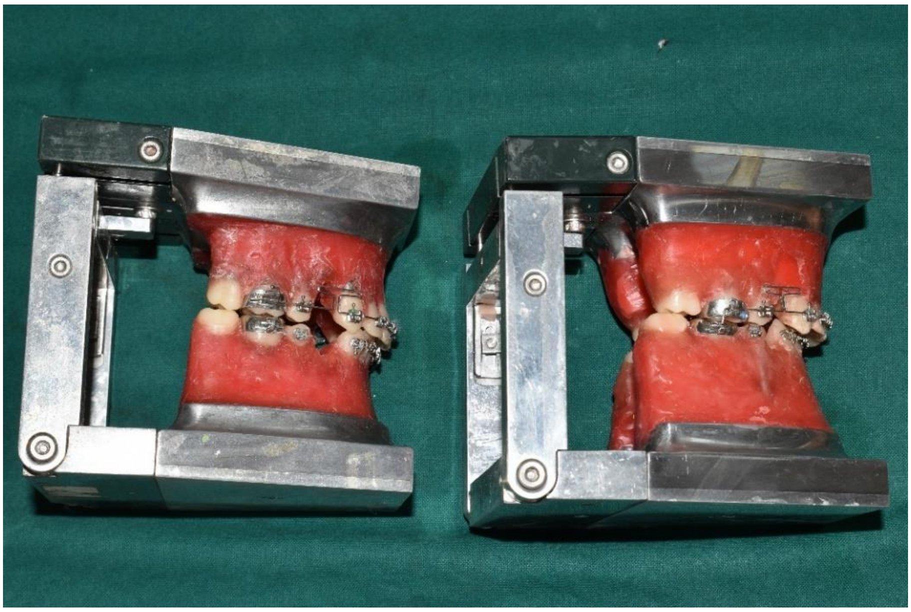
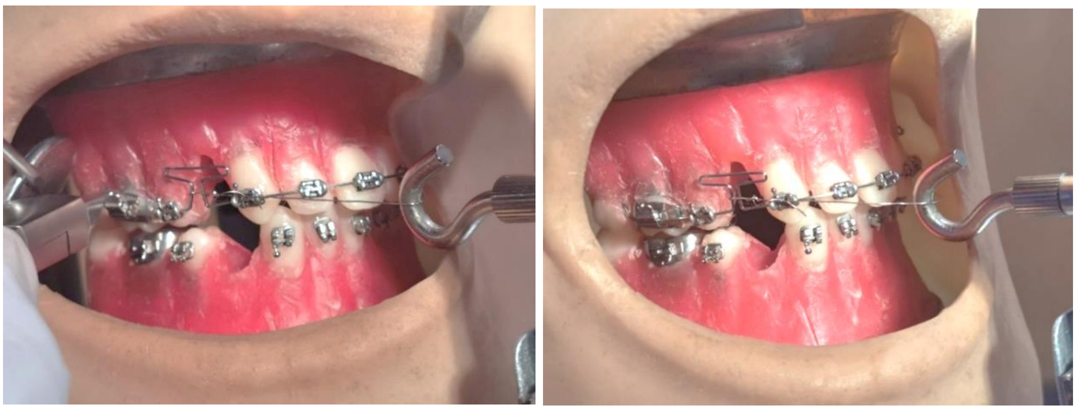


FIG 17: Typodonts with molar bands cemented in place in the experimental group(left) and control group (right)

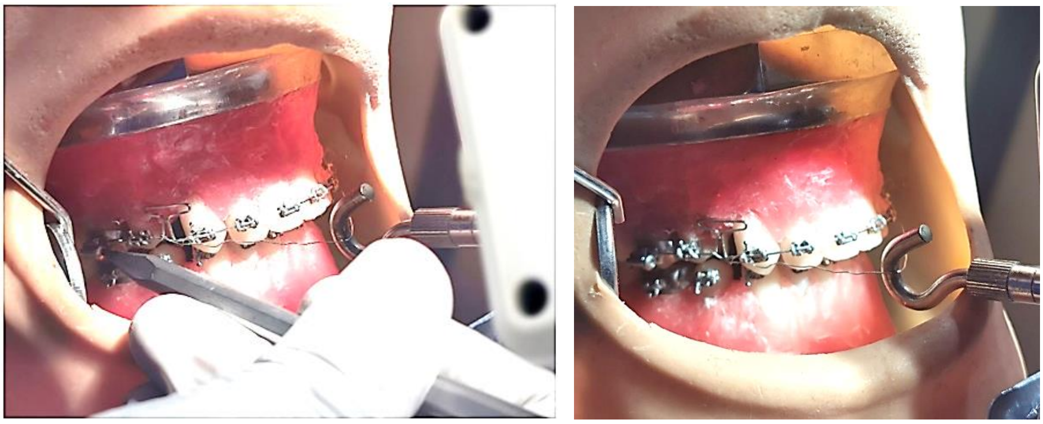
FIG 18: Custom-made jig with typodont jaw set and head and digital gauge in place

FIG 19: Activation of T-loop continuous arch wire bilaterally by the orthodontist



A **B**

FIG 20: Conventional "pull-and-cinch" method: (a) during activation and (b) after activation



A **B**

FIG 21: Novel calibrated tube-and-screw assembly method: (a) during activation and (b) after activation

RESULTS

RESULTS

This study involved comparison of force delivery during T-loop activation using the conventional “pull-and-cinch” method and the Novel tube-and-screw assembly. The study had two main groups, the control group which included loop activation with the conventional method and the experimental group, which included the Novel assembly. A group of 10 orthodontists, with minimum 8 years of clinical experience was made to activate the loops – ten in the control group and ten in the experimental group.

Force generated by 1mm bilateral activation of T-loops were measured and compared. Table 1 to Table 10 represent the overall results. These tables show the experimentally observed force magnitude in both control and experimental group during 1mm bilateral activation of T-loop continuous archwire. The results showed a significant amount of the variation of the magnitudes of forces within the control group, and were also higher when compared to the experimental group. There were both inter examiner and well as intra examiner variability in the control group. The horizontal force was found to be dependent on the amount of loop activation. The minimum force values measured in the control group was 109.10 gm and the maximum force was 121.75 gm, in the experimental group, the minimum force measured was 108.10 gm and the maximum value was 112.75 gms. This showed minimum variation of force magnitudes within the group. It was also found that the inter-examiner and the intra-examiner variability were minimum in the experimental group.

The greatest variation was found in the forces generated by activation of loops in the control group. This is represented by the standard deviations as depicted from Table 1 to 10. There was a consistency in the force values in the experimental group with a standard deviation of 1.14 while in the control the standard deviation was 4.84.

OBSERVER 1	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	116.36	110.06
SD	5.36	0.94

TABLE 1: Measurement of force in experimental and control group in observer 1

OBSERVER 2	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	117.33	109.98
SD	4.31	1.15

TABLE 2: Measurement of force in experimental and control group in observer 2

OBSERVER 3	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	118.19	110.31
SD	4.14	1.22

TABLE 3: Measurement of force in experimental and control group in observer 3

OBSERVER 4	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	116.28	110.42
SD	4.64	1.10

TABLE 4: Measurement of force in experimental and control group in observer 4

OBSERVER 5	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	115.98	110.05
SD	5.97	1.02

TABLE 5: Measurement of force in experimental and control group in observer 5

OBSERVER 6	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	119.825	110.97
SD	5.26	0.99

TABLE 6: Measurement of force in experimental and control group in observer 6

OBSERVER 7	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	114.59	110.23
SD	5.33	1.22

TABLE 7: Measurement of force in experimental and control group in observer 7

OBSERVER 8	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	117.3	110.32
SD	5.17	1.41

TABLE 8: Measurement of force in experimental and control group in observer 8

OBSERVER 9	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP	EXPERIMENTAL GROUP
MEAN (gm)	116.33	110.56
SD	4.09	1.25

TABLE 9: Measurement of force in experimental and control group in observer 9

OBSERVER 10	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	**NOVEL CALIBRATED METHOD (GROUP II)**
	CONTROL GROUP	**EXPERIMENTAL GROUP**
MEAN (gm)	115.34	110.72
SD	4.22	1.14

TABLE 10: Measurement of force in experimental and control group in observer 10

STATISTICAL ANALYSIS

Data was analysed using the statistical package **SPSS 22.0** (SPSS Inc., Chicago, IL) and level of significance was set at **p<0.05**. **Descriptive statistics** was performed to assess the proportion of each category of the respective groups. Normality of the data was assessed using **Shapiro Wilkinson test**. **Inferential statistics** was done using **Independent T Test** for the continuous data to find out the difference between the groups.

COMPARISION OF MEAN FORCES BETWEEN THE CONTROL AND EXPERIMENTAL GROUP

No. of bilateral activations	PULL AND CINCH CONVENTIONAL METHOD (GROUP I)	NOVEL CALIBRATED METHOD (GROUP II)
	CONTROL GROUP (gm)	EXPERIMENTAL GROUP (gm)
OBSERVER 1	116.36 ± 5.36	110.06 ± 0.94
OBSERVER 2	117.34 ± 4.32	109.98 ± 1.16
OBSERVER 3	118.19 ± 4.14	110.31 ± 1.22
OBSERVER 4	116.28 ± 4.64	110.42 ± 1.10
OBSERVER 5	115.98 ± 5.96	110.05 ± 1.02
OBSERVER 6	119.83 ± 5.26	110.97 ± 1.0
OBSERVER 7	114.59 ± 5.33	110.26 ± 1.22
OBSERVER 8	117.3 ± 5.13	110.32 ± 1.41
OBSERVER 9	116.33 ± 4.09	110.56 ± 1.25
OBSERVER 10	115.34 ± 4.22	110.72 ± 1.14
OVERALL MEAN	116.75	110.36
SD	3.85	1.20
T VALUE	5.01	
P VALUE	0.0001*	

TABLE 11: Comparison of mean forces between control and experimental group

*p<0.05 is statistically significant

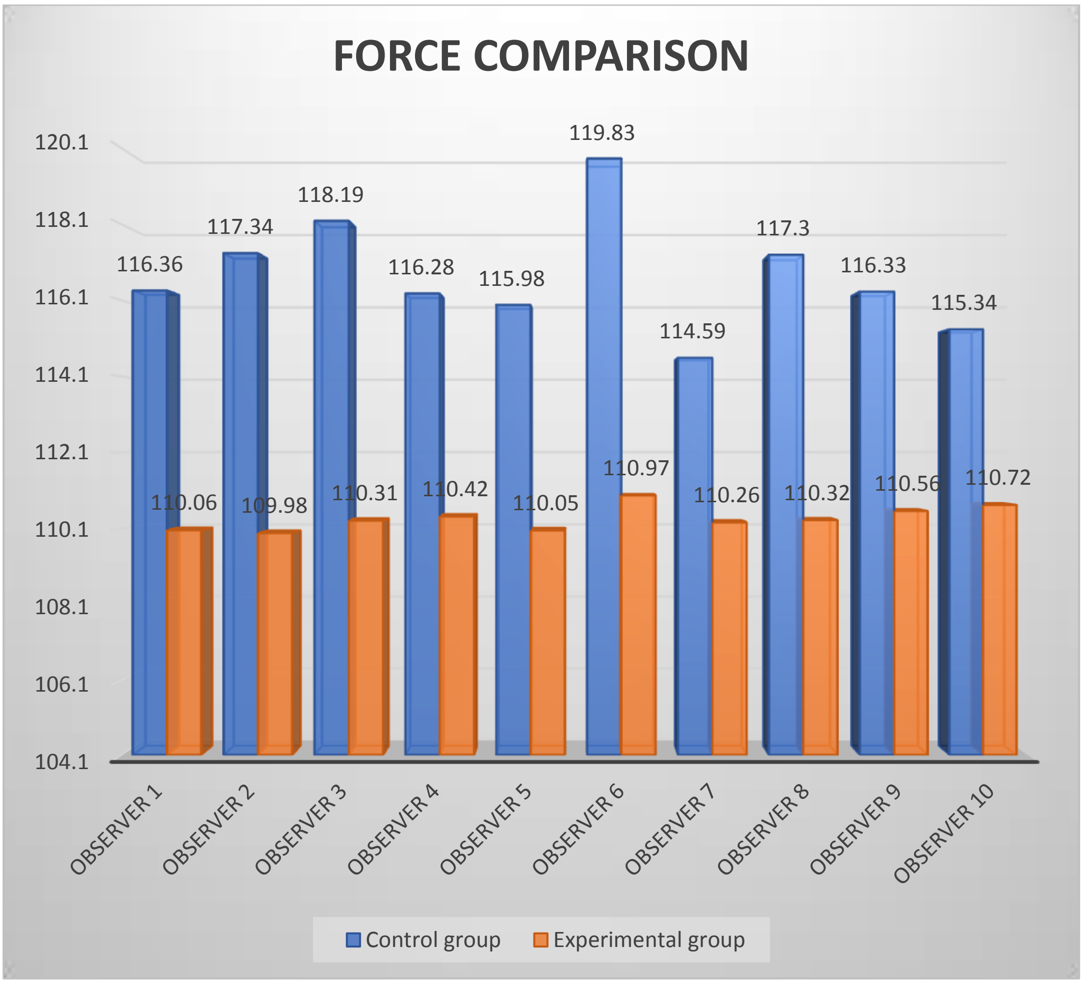
Independent T test shows that mean values (force) of the test and control groups differ significantly. (p<0.05)

INTERPRETATION OF STATISTICAL ANALYSIS

Statistical analysis with Independent T test to compare the difference of mean force magnitude between the conventional “pull-and-cinch” method (Group 1) and the Novel calibrated tube-and-screw method (Group 2) showed significant difference. Independent T test shows that mean values (force) of the control and experimental groups differ significantly. ($p<0.05$)

GRAPHS

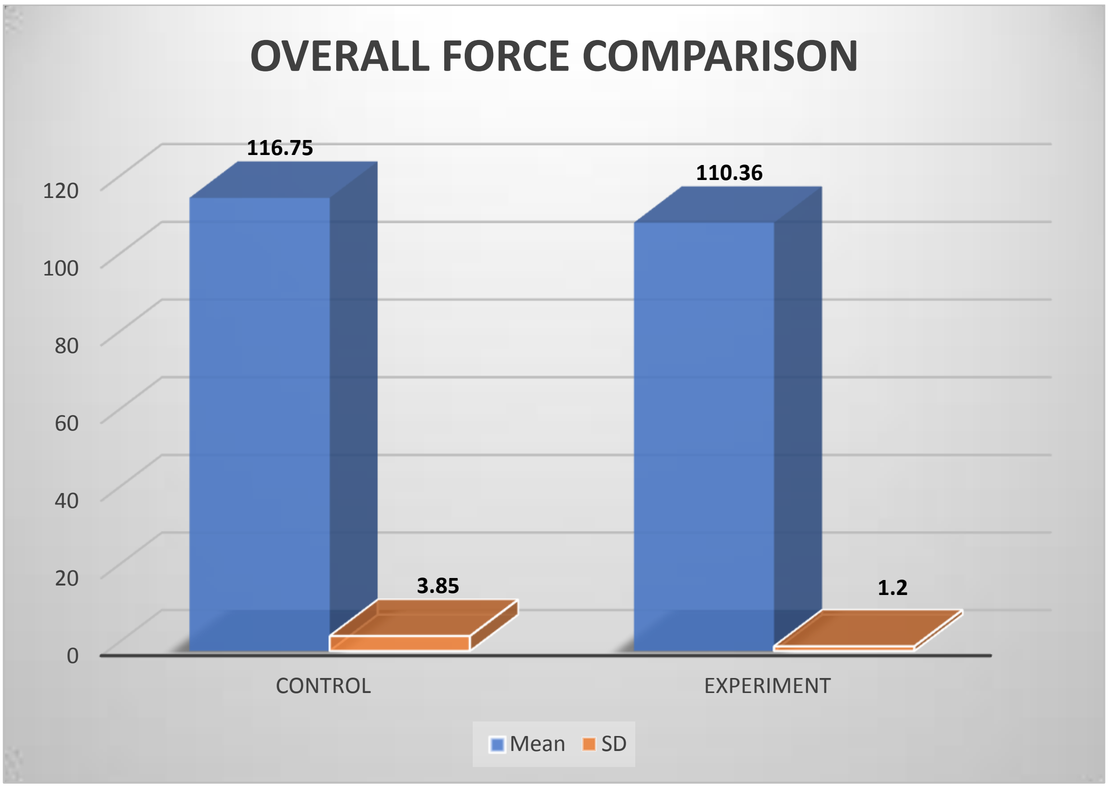
COMPARISON OF FORCE MAGNITUDE BETWEEN THE GROUPS



Graph 1: Comparison of force magnitude between the control and experiment group

OVERALL FORCE COMPARISON

BETWEEN THE TWO GROUPS



Graph 2: Overall force comparison between the control and experimental group

DISCUSSION

DISCUSSION

In orthodontics, closing loops are used to generate force magnitudes to move tooth or group of teeth in order to close spaces between them. Clinicians can repeatedly activate a loop by pulling and cinching the wire at the distal end of the molar tube during subsequent visits for space closure. Seemingly simple closing loops can have intricate mechanical reactions when activated. Desired tooth movements can be achieved by estimating the resultant force magnitudes and M/F ratios with the closing loop geometry and activation. Depending upon the techniques employed, a number of procedures are used for retraction of the anterior segment in the treatment of extraction cases such as compression or tension coil springs or orthodontic elastics, allowing the anterior teeth to slide along the archwire. Unfortunately, with such mechanisms great amount of friction is produced between the bracket and the arch wire which can affect tooth movement.[59] Consistent and optimal orthodontic force delivery would increase the treatment efficiency and improve patient comfort.[69]

Sliding mechanisms have two major disadvantages:

1. The friction may hinder tooth movement partially or completely as one approaches translatory types of movement.
2. Force magnitudes cannot be precisely determined since the amount of friction is relatively unknown and unpredictable.
3. A second approach to the retraction of anterior teeth is the use of a frictionless system based upon incorporation of a loop into a continuous arch wire or a section of an arch wire.[19]

By applying engineering principles, T-loops were developed to increase M/F ratios and optimize their force delivery system.[28,19,70] As the wire becomes more flexible it releases less force.[71] A number of variables must be considered when using closing-loop mechanics such as bracket slot size, wire size, loop design, and the amount and frequency of loop activation. Hence, when preadjusted appliances were available to be used, many clinicians began to use sliding mechanics as their primary method of space closure. The friction in the system is overcome by activating the loops in a closing-loop arch. They are activated only about 1mm at a time, which allows the roots to “catch up” to the initial tipping effect of the activation.[43]

The present study focuses on anterior teeth retraction by frictionless mechanics by a novel tube-and-screw assembly. Conventional activation of closing loop is by pulling the distal end of the loop and cinching it tight distal to the molar tube. Although it is commonly practised by many orthodontists, the major drawback of the conventional method is the varying amount of activation on subsequent visits, yielding unequal forces.

The novel assembly was first calibrated and the pitch of the screw was set in such a way that one turn of the screw activates the T-loop by 0.4mm, which is in accordance with the screw of the Hycon device[43] where a single 360° turn of the screw provides 0.35mm of activation length. Hence, in order to activate the loop by 1mm the screw should be turned two and a half turns.

In an in-vitro investigation by Nattrass C et al[34] established how clinicians apply forces for space closure with straight wire appliances and also quantified the initial force levels produced upon activation. A single typodont was used with extraction space in each quadrant in order to simulate space closure. Activation was scheduled in the same manner as in a clinical situation. Assessment was done regarding the consistency in the amount of stretch/activation in both sliding and loop mechanics and their ability to apply equal amount of force with the different types of force delivery system. They were found to be consistent in their method of application of the force delivery systems, but there was a wide range in the magnitude of forces when applied as a group. It was found that most clinicians in the study, applied different force magnitudes when using different systems. The main advantage of the novel tube-and-screw assembly is that the forces delivered were consistent during each activation and both sides of the continuous T-loop archwires can be activated uniformly.

Orthodontic appliances produce forces and moments in each of the three planes of space. A spring may be producing a horizontal force pulling the teeth in a mesiodistal direction toward one another and a vertical force extruding or intruding a tooth or a group of teeth. Additionally, moments may be produced due to the force systems. The moment acting on the anterior segment is termed an alpha moment and acting on the posterior teeth is the beta moment.

Similar to the working mechanism of the Novel tube-and-screw assembly certain devices have been mentioned in literature.[49] In 1980s, a device for extraction space closure was developed in Germany. In the original design, a small screw was connected to the first molars and to the anterior segment.[75] Another device working with similar mechanism is the Hycon Device[43], which uses a rectangular support wire that inserted into an auxiliary tube of the double or triple first molar tubes. It consists of a bolt-and-nut assembly soldered to the rectangular wire buccally; a ligature wire was tied to the end of the bolt, and the opposing end of the wire tied to the anterior segment.

The novel assembly is compatible with all common fixed appliance systems. Closing loops and sliding mechanics rely on elastic forces for activation and space closure, the novel assembly is based on a design that has been used successfully since the early days of orthodontics: a screw-type mechanism. Liou and Huan[72], Sayin and colleagues[73], and Iseri and colleagues[74] have used similar appliances to retract canines and referred this movement as "distraction" of the periodontal ligament.

Ease of accessibility for activation is an added advantage using the novel assembly. In cases where second molar has to be in cooperated into the anchor unit, using the conventional method for activation is cumbersome as it involves excessive stretching of the cheeks or buccal mucosa in order to pull and cinch the distal leg of the loop gingivally. The novel assembly can be welded onto the second molar band and activation can be done with ease, as the driver/key is held parallel to the occlusal plane buccally. This avoids over stretching of the cheek and buccal mucosa and improves the ergonomics of activation. Owing to these benefits, this assembly works well with patients with reduced mouth opening or trismus. the chair side time is also reduced during subsequent visits.

The tube-and-screw mechanism is easier to control when compared with the conventional method of space closure. With pull-and-cinch method, the orthodontist is constantly trying activate the T-loop just by perception, which has both inter examiner and intra examiner variability. The separation of the legs of the T-loop by pulling the distal wire segment determines the amount of activation conventionally. With the novel assembly, the amount of tooth movement is determined strictly by the advancement rate of the screw and the number of turns the screw makes. Since the activation is over such a short distance, deflection will not pose a problem.

In the novel assembly, a full-sized archwire can be used, reducing deflection and thereby improving torque control.

In clinical scenarios, space closure is initiated only after both levelling and alignment and rectangular archwires placement is completed. The novel tube-and-screw assembly can be employed at the very beginning of the treatment as it can be welded on the molar band and cemented in place. Upon start of space closure, the screw can be engaged to the tube which will facilitate space closure and retraction. Hence the same molar tube can be used throughout the treatment till desired space closure is achieved. The assembly is not only limited to activation of T-loop alone, but also can be effectively used with other closing loops as well, making it a versatile system.

Unlike the Hycon device[43], this assembly is much smaller, just the size of the conventional molar double tube. Once the continuous closing loop archwire is inserted, it is secured by bending back the end of the wire that extends distally from the molar tube. Using a small screw driver/key, the orthodontist activates the appliance by turning the screw clockwise until the slack is taken out of the connecting wire. The screw is then turned by two-and-half turns to achieve 1mm of loop opening. This will provide approximately 1mm of space closure per month, which is equal to the recommended amount of force for retraction.

Studies by Chen et al.[50], Tang et al.[55], Dinesh et al.[57], Mencattelli et al.[58] and Xia et al.[63] used various methods to measure orthodontic forces in an in-vitro set up. Most of them made use of a platform with a gauge or load cells connected to the teeth set up for accurate force measurement. Chakraborty S et al.[68]in their study advocated the use of a portable digital weight measuring gauge for orthodontic force magnitude measurement to avoid the demerits of an orthodontic dynamometer. A portable weight measuring gauge is a digital a device routinely used to measure the weight of baggage or other household goods which can measure from 5 grams to 50 kgs of weight, and shows four different measuring units i.e., kilogram, pound, ounce and jin. The digital gauge was incorporated into orthodontic practice as both the dynamometer and the digital gauge work on the same principle. In the present study, a digital force gauge was used for measuring the force magnitude and the results obtained were statistically significant.

This study demonstrates the importance of having a quantifiable method of loop activation. The magnitude of force is directly dependent on the amount of loop activation. During orthodontic space closure a clinically optimum response is more likely to occur when precisely calibrated force systems are used. A study by Thiesen et al.[42] evaluated forty TMA T-loops which were centrally positioned in a universal testing machine and the horizontal force and the M/F ratios were recorded during activation at 1 mm intervals, up to a maximum of 7 mm. A 1mm of single T-loop activation, yielded 53gm of force and 2mm activation yielded 109gm of force. This is in accordance with the present study, where one millimetre of bilateral activation of the test group yielded forces in the range of 110.36 ± 1.14 gm, while the force magnitude recorded in the control group was 116.75 ± 4.84 gm. It was noticed that the force magnitude was higher and consistent in the control group when compared with the test group.

The consistency of force delivered upon activation is noteworthy. The control group had a range of force values from 109.15 gm to 127.6 gm, while the forces were within 108.1 gm to 112.75gm in the experimental group, indicating a controlled delivery of force throughout subsequent activations. The standard deviation for control group was 4.84 while that of the experimental group was 1.14, denoting that the force magnitude was more consistent in the experimental group when compared with the control group which had varying range of force levels, upon subsequent activations. As the novel method was calibrated, the activation was more alike and precise, delivering optimal retraction forces when compared to the control group. Activation in the control group was based on each orthodontist's perception which had a higher bias and inter/intra examiner variability compared to the experimental group. Hence the measured force values were higher and had greater variations in the control group when compared with the experimental group.

LIMITATIONS OF THE STUDY

1. As this study was done in an in-vitro set up, the results cannot be conclusive as the intra-oral environment is different.
2. The tube-and-screw system which was used does not have a locking system and therefore there are chances of loosening of screw, when it is done intra-orally.
3. The limit of activation is equal to the length of the screw used. Activations beyond that limit will need a different screw or mid-retraction re-cinching of the archwire.
4. This system may require a redesign when used in lingual orthodontics as it projects into the tongue space.

.

FUTURE SCOPE OF THE STUDY

This study gives an insight into using a standardized and calibrated apparatus for closing loops in orthodontics which permits precise and controlled force delivery during subsequent activations.

For better and accurate measurements of force delivered upon loop activation, the study has to be conducted in an in-vivo environment. This can evaluate further changes in the force delivery, periodontal ligament changes, bone remodelling and the rate of space closure which will help to achieve clinically accurate results.

CONCLUSION

CONCLUSION

Force delivery upon bilateral T-loop activation using both the methods were measured in this study. A digital force gauge was used for force measurement in both groups. The novel tube-and-screw assembly was calibrated. 360º turn of the screw activated the T-loop by 0.4mm and hence in order to achieve 1mm activation, the screw was advanced by two-and-half turns. The retraction forces were within optimal force range in the experimental group, but were higher in the control group. Unlike the tube-and-screw assembly, the forces were not consistent upon subsequent activations in the conventional pull-and-cinch method. The force magnitudes had a consistency and precision in the experimental group, while in the control group the forces measured had a varying range during each activation.

Therefore, the novel tube-and-screw assembly, being compatible with most of the fixed appliances, can be considered as a useful adjunct for delivering a known and quantifiable force during retraction mechanics which will help to deliver optimal forces upon subsequent loop activations.

REFERENCES

REFERENCES

1. Kharbanda O. Orthodontics: Diagnosis and Management of Malocclusion and Dentofacial Deformities. 3rd ed, Elsevier India; 2019. 1258 pages, 12 Videos ISBN. 978-81-312-4881-2, e-ISBN 978-81-312-4936-9. 2019.

2. Tanne K, Sakuda M, Burstone CJ. Three-dimensional finite element analysis for stress in the periodontal tissue by orthodontic forces. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1987 Dec;92(6):499–505.

3. Hoenigl KD, Freudenthaler J, Marcotte MR, Bantleon HP. The centered T-loop--a new way of preactivation. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1995 Aug;108(2):149–53.

4. Nanda R. Biomechanics and esthetic strategies in clinical orthodontics. Elsevier Health Sciences; 2005 Apr 12.

5. Kuhlberg A. Force Systems from T-Loop Orthodontic Space Closure Springs: The Effects of Asymmetric Placement and Angulation on the Alpha-Beta Moment Differential. In 1992.

6. Chiang P-C, Koga Y, Tominaga J, Ozaki H, Hamanaka R, Sumi M, et al. Effect of gable bend incorporated into loop mechanics on anterior tooth movement: Comparative study between en masse retraction and two-step retraction. Orthod Waves. 2015 Sep 1;74(3):55–61.

7. Force systems from T-loop orthodontic space closure springs: The effects of asymmetric placement and angulation on the alpha-beta moment differential: Andrew J. Kuhlberg, DMD, MDS. University of Connecticut School of Dental Medicine, Division of Orthodontics, 1992. Am J Orthod Dentofacial Orthop. 1993 Oct 1;104(4):423.

8. Burstone CJ. The mechanics of the segmented arch techniques. Angle Orthod. 1966 Apr;36(2):99–120.

9. Proffit W, Fields H, Sarver D. Contemporary Orthodontics. Fourth Edition. 2007.

10. Burstone CJ. Rationale of the segmented arch. Am J Orthod. 1962 Nov;48:805–22.

11. Marcotte MR. The mechanical plan of the segmented arch technique. Semin Orthod. 2001 Sep 1;7(3):191–206.

12. Smith RJ. Mechanics of tooth movement. 1984;85(4):14.

13. Gjessing P. Controlled retraction of maxillary incisors. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1992 Feb;101(2):120–31.

14. Cureton SL, Storie D. Simplified activation of closing loops. J Clin Orthod JCO. 1998 Aug;32(8):490–2.

15. Chen J, Markham DL, Katona TR. Effects of T-Loop Geometry on Its Forces and Moments. Angle Orthod. 2000;70(1):4.

16. Katona TR, Le YP, Chen J. The effects of first- and second-order gable bends on forces and moments generated by triangular loops. Am J Orthod Dentofacial Orthop. 2006 Jan;129(1):54–9.

17. Burstone CJ. Rationale of the segmented arch. Am J Orthod. 1962 Nov;48(11):805–22.

18. Boester CH, Johnston LE. A clinical investigation of the concepts of differential and optimal force in canine retraction. Angle Orthod. 1974 Apr;44(2):113–9.

19. Burstone CJ, Koenig HA. Optimizing anterior and canine retraction. Am J Orthod. 1976 Jul;70(1):1–19.

20. Sowerby R, Tomita Y. On the bauschinger effect and its influence on U.O.E. pipe making process. 1977;

21. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials. Semin Orthod. 1997 Sep;3(3):166–77.

22. Burstone CJ. The segmented arch approach to space closure. Am J Orthod. 1982 Nov;82(5):361–78.

23. Smith RJ, Burstone CJ. Mechanics of tooth movement. Am J Orthod. 1984 Apr;85(4):294–307.

24. Quinn RS, Yoshikawa DK. A reassessment of force magnitude in orthodontics. Am J Orthod. 1985 Sep;88(3):252–60.

25. Sachdeva RC. A study of force systems produced by TMA '91T' loop retraction springs. [masters thesis.] Farmington (CT): The University of Connecticut School of Dental Medicine; 1985

26. Vanden Bulcke MM, Burstone CJ, Sachdeva RC, Dermaut LR. Location of the centers of resistance for anterior teeth during retraction using the laser reflection technique. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1987 May;91(5):375–84.

27. Manhartsberger C, Morton JY, Burstone CJ. Space closure in adult patients using the segmented arch technique. Angle Orthod. 1989;59(3):205–10.

28. Faulkner MG, Fuchshuber P, Haberstock D, Mioduchowski A. A parametric study of the force/moment systems produced by T-loop retraction springs. J Biomech. 1989;22(6–7):637–47.

29. Ziegler P, Ingervall B. A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1989 Feb;95(2):99–106.

30. McLaughlin RP, Bennett JC. Anchorage control during leveling and aligning with a preadjusted appliance system. J Clin Orthod JCO. 1991 Nov;25(11):687–96.

31. Kuhlberg AJ, Burstone CJ. T-loop position and anchorage control. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1997 Jul;112(1):12–8.

32. Raboud DW, Faulkner MG, Lipsett AW, Haberstock DL. Three-dimensional effects in retraction appliance design. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1997 Oct;112(4):378–92.

33. Siatkowski RE. Continuous arch wire closing loop design, optimization, and verification. Part II. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1997 Nov;112(5):487–95.

34. Nattrass C, Ireland AJ, Sherriff M. An investigation into the placement of force delivery systems and the initial forces applied by clinicians during space closure. Br J Orthod. 1997 May;24(2):127–31.

35. Halazonetis DJ. Understanding orthodontic loop preactivation. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1998 Feb;113(2):237–41.

36. Menghi C, Planert J, Melsen B. 3-D experimental identification of force systems from orthodontic loops activated for first order corrections. Angle Orthod. 1999 Feb 1;69(1):49–57.

37. Chen J, inventor; Indiana University Research, Technology Corp, assignee. Apparatus and method for measuring orthodontic force applied by an orthodontic appliance. United States patent US 6,120,287. 2000 Sep 19.

38. Iwasaki LR, Haack JE, Nickel JC, Morton J. Human tooth movement in response to continuous stress of low magnitude. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2000 Feb;117(2):175–83.

39. Rhee JN, Chun YS, Row J. A comparison between friction and frictionless mechanics with a new typodont simulation system. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2001 Mar;119(3):292–9.

40. McLaughlin RP, Bennett JC, Trevisi HJ. Systemized orthodontic treatment mechanics. Mosby, Edinburgh, 2001.

41. Kum M, Quick A, Hood JA, Herbison P. Moment to force ratio characteristics of three Japanese NiTi and TMA dosing loops. Aust Orthod J. 2004 Nov;20(2):107–14.

42. Thiesen G, do Rego MVNN, de Menezes LM, Shimizu RH. Force systems yielded by different designs of T-loop. Aust Orthod J. 2005 Nov;21(2):103–10.

43. McLaughlin R, Kalha A, Schuetz W. An alternative method of space closure: the Hycon Device. J Clin Orthod JCO. 2005 Sep 1;39:474–84; quiz 471.

44. Viecilli RF. Self-corrective T-loop design for differential space closure. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2006 Jan;129(1):48–53.

45. Kumar YM, Ravindran NS, Balasubramaniam MR. Holographic analysis of the initial canine displacement produced by four different retraction springs. Angle Orthod. 2009 Mar;79(2):368–72.

46. Martins RP, Buschang PH, Viecilli R, dos Santos-Pinto A. Curvature versus v-bends in a group B titanium T-loop spring. Angle Orthod. 2008 May;78(3):517–23.

47. Lim Y, Quick A, Swain M, Herbison P. Temperature effects on the forces, moments and moment to force ratio of nickel-titanium and TMA symmetrical T-loops. Angle Orthod. 2008 Nov;78(6):1035–42.

48. Rose D, Quick A, Swain M, Herbison P. Moment-to-force characteristics of preactivated nickel-titanium and titanium-molybdenum alloy symmetrical T-loops. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2009 Jul 1;135:757–63.

49. Jiang J-G, Ma X, Zhang Y, Han Y, Wang K. Orthodontic Force Measuring Devices: Current and Future. Recent Pat Mech Eng. 2018 Aug 8;11.

50. Chen J, Isikbay SC, Brizendine EJ. Quantification of three-dimensional orthodontic force systems of T-loop archwires. Angle Orthod. 2010 Jul;80(4):566–70.

51. Caldas SGFR, Martins RP, Galvão MR, Vieira CIV, Martins LP. Force system evaluation of symmetrical beta-titanium T-loop springs preactivated by curvature and concentrated bends. Am J Orthod Dentofac Orthop Off

Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2011 Aug;140(2):e53-58.

52. Maia LGM, de Moraes Maia ML, da Costa Monini A, Vianna AP, Gandini LG. Photoelastic analysis of forces generated by T-loop springs made with stainless steel or titanium-molybdenum alloy. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2011 Sep;140(3):e123-128.

53. Wu J, Liu Y, Peng W, Dong H, Zhang J. A biomechanical case study on the optimal orthodontic force on the maxillary canine tooth based on finite element analysis. J Zhejiang Univ Sci B. 2018 Jul;19(7):535–46.

54. Keng F-Y, Quick AN, Swain MV, Herbison P. A comparison of space closure rates between preactivated nickel-titanium and titanium-molybdenum alloy T-loops: a randomized controlled clinical trial. Eur J Orthod. 2012 Feb;34(1):33–8.

55. Yang Y, Tang W. Analysis of the influences of bracket and force system in different directions on the moment to force ratio by finite element method. EURASIP J Wirel Commun Netw. 2018 Jul 4;2018(1):169.

56. Mehta K, Sable R. Comparison of the Amount of Maxillary Canine Retraction, with T-Loops, using TMA and Stainless Steel Wires: A Clinical Study. J Indian Orthod Soc. 2013 Oct 1;47:178–83.

57. Dinesh SPS, Arun AV, Sundari KKS, Samantha C, Ambika K. An Indigenously Designed Apparatus for Measuring Orthodontic Force. J Clin Diagn Res JCDR. 2013 Nov;7(11):2623–6.

58. Mencattelli M, Donati E, Cultrone M, Stefanini C. Customized Load Cell for Three-Dimensional Force-Moment Measurements in Orthodontics. In 2014.

59. Techalertpaisarn P, Versluis A. T-loop force system with and without vertical step using finite element analysis. Angle Orthod. 2016 May;86(3):372–9.

60. Roscoe MG, Meira JBC, Cattaneo PM. Association of orthodontic force system and root resorption: A systematic review. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2015 May;147(5):610–26.

61. Júnior RSS, Caldas SGFR, Martins LP, Martins RP. Effects of stress relaxation in beta-titanium orthodontic loops: Part II. Angle Orthod. 2016 May;86(3):386–90.

62. Prem N, Mascarenhas R, Husain A, Hashim A. Comparison of sliding mechanics and loop mechanics in orthodontic tooth movement: A three dimensional finite element study. J Comput Methods Sci Eng. 2017 Feb 10;17:1–10.

63. Toogood R, Carey J, Heo G, Major P. Three-dimensional orthodontic force measurements. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2009 Oct 1;136:518–28.

64. Shintcovsk RL, Martins LP, Shintcovsk LK, Tanaka OM, Martins RP. Continuous arch and rectangular loops for the correction of consistent and inconsistent load systems in extruded and tipped maxillary second molars. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2018 Mar;153(3):396–404.

65. Makhlouf M, Aboul-Ezz A, Fayed MS, Hafez H. Evaluating the Amount of Tooth Movement and Root Resorption during Canine Retraction with Friction versus Frictionless Mechanics Using Cone Beam Computed Tomography. Open Access Maced J Med Sci. 2018 Feb 15;6(2):384–8.

66. Davis S, Sundareswaran S, James J. Comparative evaluation of the efficiency of canine retraction using modified Marcotte and T-loop retraction springs – A split-mouth, randomized clinical trial. J Orthod Sci. 2019 May 23;8:9.

67. Wu J, Liu Y-F, Wang D, Huang S, Zhang J, Chen J, et al. Dynamic measurement of orthodontic force using a tooth movement simulation system based on a wax model. Technol Health Care Off J Eur Soc Eng Med. 2020 Sep 4;29.

68. Chakraborty S, Kidiyoor H, K Patil A. Orthodontic Force Measurement Using Portable Digital Weight Measuring Gauge. IOSR Journal of Dental and Medical Sciences [Internet]. 2020 [cited 29 July 2020];19(7 Ser.15):03-05.

69. Chakravarthy CN, Kumar PK. 'Loops in Orthodontics'—A Review. Indian J Mednodent Allied Sci. 2014;2(1):57.

70. Martins RP, Buschang PH, Martins LP, Gandini LG. Optimizing the design of preactivated titanium T-loop springs with Loop software. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2008 Jul;134(1):161–6.

71. Manhartsberger C, Morton JY, Burstone CJ. Space closure in adult patients using the segmented arch technique. Angle Orthod. 1989;59(3):205–10.

72. Liou EJ, Huang CS. Rapid canine retraction through distraction of the periodontal ligament. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 1998 Oct;114(4):372–82.

73. Sayin S, Bengi AO, Gürton AU, Ortakoğlu K. Rapid canine distalization using distraction of the periodontal ligament: a preliminary clinical validation of the original technique. Angle Orthod. 2004 Jun;74(3):304–15.

74. Işeri H, Kişnişci R, Bzizi N, Tüz H. Rapid canine retraction and orthodontic treatment with dentoalveolar distraction osteogenesis. Am J Orthod Dentofac Orthop Off Publ Am Assoc Orthod Its Const Soc Am Board Orthod. 2005 May;127(5):533–41.

75. Schuetz, W.: Edgewisetechnik mit Schraube—ein Hybrid in der Kieferorthopaedie, Inform. Orthod. Kieferorthop. 5:351-362, 1983.

ANNEXURE

ANNEXURES

Annexure 1. Measurement of force in test and control group

OBSERVER 1	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
No of bilateral activations	GROUP I (Pull-and-cinch method)	GROUP II (Novel calibrated tube-and-screw assembly)
	CONTROL GROUP (gm)	EXPERIMENTAL GROUP (gm)
1	115.5	109.2
2	118.1	110.55
3	113.35	109.5
4	109.15	110.85
5	121.1	110.95
6	116.2	109.5
7	109.35	111.15
8	125.55	109.7
9	121.75	110.9
10	113.5	108.35

Annexure 2. Measurement of force in test and control group

OBSERVER 2	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	117.65	110.35
2	120.45	110.55
3	118.25	109.95
4	115.1	108.15
5	120.45	110.9
6	117.95	108.45
7	109.75	109.1
8	110.5	111.5
9	122.35	109.5
10	120.9	111.3

Annexure 3. Measurement of force in test and control group

OBSERVER 3	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	113.45	109.3
2	112.1	110.1
3	116.75	111.25
4	115.25	110.15
5	121.65	110.3
6	124.35	110.3
7	118.85	109.45
8	123.35	112.25
9	119.9	108.15
10	116.25	111.8

Annexure 4. Measurement of force in test and control group

OBSERVER 4	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	117.95	109.55
2	111.55	110.1
3	115.75	108.5
4	109.25	110.35
5	117.95	110.4
6	119.65	110.45
7	121.75	111.35
8	118.25	112.75
9	121.25	110.25
10	109.45	110.45

Annexure 5. Measurement of force in test and control group

OBSERVER 5	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	114.35	110.5
2	116.35	110.75
3	127.6	109.35
4	112.95	110.25
5	110.25	110.35
6	125.65	111.55
7	115.35	110.95
8	114.65	109.5
9	110.5	109.15
10	112.15	108.1

Annexure 6. Measurement of force in test and control group

OBSERVER 6	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	115.15	110.55
2	110.5	110.15
3	122.25	110.1
4	119.15	111.75
5	118.95	110.55
6	125.85	112.6
7	115.35	110.55
8	123.95	109.6
9	127.55	111.65
10	119.55	112.15

Annexure 7. Measurement of force in test and control group

OBSERVER 7	FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP	
No of bilateral activations	GROUP I (Pull-and-cinch method)	GROUP II (Novel calibrated tube-and-screw assembly)
	CONTROL GROUP (gm)	EXPERIMENTAL GROUP (gm)
1	109.85	108.9
2	120.15	110.45
3	118.95	110.3
4	112.95	110.75
5	118.75	111.75
6	123.65	112.15
7	109.15	110.15
8	113.1	110.35
9	109.95	108.1
10	109.35	109.35

Annexure 8. Measurement of force in test and control group

OBSERVER 8	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	109.35	110.35
2	114.8	108.8
3	120.85	111.75
4	122.95	110.4
5	117.35	110.45
6	113.95	112.65
7	112.65	110.95
8	125.15	108.1
9	118.65	109.45
10	109.35	110.35

Annexure 9. Measurement of force in test and control group

OBSERVER 9	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	115.1	110.6
2	117.35	110.55
3	110.1	110.25
4	119.25	112.75
5	122.15	110.3
6	117.15	111.95
7	113.35	108.1
8	110.25	109.55
9	120.45	110.8
10	118.15	110.75

Annexure 10. Measurement of force in test and control group

OBSERVER 10	**FORCE GENERATED BY 1mm BILATERAL ACTIVATION OF T-LOOP**	
No of bilateral activations	**GROUP I (Pull-and-cinch method)**	**GROUP II (Novel calibrated tube-and-screw assembly)**
	CONTROL GROUP (gm)	**EXPERIMENTAL GROUP (gm)**
1	121.55	110.95
2	115.85	110.3
3	112.45	110.15
4	118.45	112.1
5	121.25	111.35
6	109.75	110.15
7	110.35	108.4
8	113.1	112.5
9	113.35	110.75
10	117.25	110.55

ST. GREGORIOS DENTAL COLLEGE

UNDER THE MANAGEMENT OF MJSCE TRUST, PUTHENCRUZ
CHELAD, KOTHAMANGALAM, ERNAKULAM DIST, KERALA - 686681

SGDC/152/2019/3731 15/11/2019

ETHICAL CLEARANCE CERTIFICATE

To,

Dr.Kareena Miriam Kafeel Reynold
St.Gregorios Dental College
Chelad, Kothamangalam.

Dear Dr.Kareena Miriam Kafeel Reynold,

Subject: Ethics Committee Clearance - reg.

Protocol: A comparative study on T-loop activation between the conventional "pull and cinch" method & a novel calibrated activation system

After the Institutional Ethics Committee (IEC) held on 15th of November 2019, this study was examined and discussed. After the consideration, the committee had decided to approve and grant clearance for the aforementioned study.

The members who attended the meeting at which the protocol was discussed were:

1) Dr.C.K.K Nair - Former BARC Scientist.
2) Dr.Cinu Thomas A - Scientist, Senior lecturer, Department of Pharmaceutical Sciences Centre for Professional and Advanced Studies.
3) Dr.Lissy Jose - Former member Women's Welfare Association.
4) Adv.Jose Aranjani - Advocate.
5) Dr.Sauganth Paul - Reader, Department of Biochemistry, St.Gregorios Dental College.
6) Dr.Eapen Cherian - Secretary.
7) Dr.Jain Mathew - Principal and Head of the Department, Department of Conservative Dentistry and Endodontics.
8) Dr.George Francis - Head of the Department, Department of Prosthodontics and Crown & Bridge.
9) Dr.Binoy Kurian- Head of the Department, Department of Orthodontics & Dentofacial Orthopaedics.

Dr. C.K.K Nair
Chairman Institutional Ethics Committee
St.Gregorios Dental College, Chelad

Dr.Eapen Cherian
Secretary

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LIST OF ABBREVATIONS

C_{rot}	Centre of rotation
C_{res}	Centre of resistance
F	Force
M	Moment
d	Distance
M/F	Moment to force ratio
TMA	Titanium Molybdenum Alloy
3-D	Three dimensional
NiTi	Nickel Titanium
SS	Stainless Steel
gF	Gram force
PG	Poul Gjessing
RCT	Randomised clinical trial
CB	Canine bracket
IBD	Interbracket distance
PB	Premolar bracket
Pdl	Periodontal ligament
MS	Marcotte spring
VAS	Visual Analog Scale
CBCT	Cone Beam Computed Tomography
LH	Low hysteresis
GFRSMPU	Glass Fibre-Reinforced Shape Memory Polyurethane
GIC	Glass Ionomer Cement