COMPARATIVE EVALUATION OF SECTIONAL CANINE RETRACTION USING MODIFIED OPUS LOOP AND PG SPRING – A CLINICAL STUDY

Dissertation Submitted to

The Tamil Nadu Dr.M.G.R. Medical University
in partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH - V

ORTHODONTICS

FEBRUARY-2005

CERTIFICATE

This is to certify that the dissertation entitled as "COMPARATIVE EVALUATION OF SECTIONAL CANINE RETRACTION USING MODIFIED OPUS LOOP AND PG SPRING - A CLINICAL STUDY" **done by** Dr. S. HARISH BABU, **Post Graduate student, M.D.S., Branch V-Orthodontics, Saveetha Dental College and Hospitals, Chennai submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfillment for the M.D.S. degree examination in February 2005, is bonafide research work done under our guidance and supervision.**

Dr. R. Rajagopal, M.D.S.,
Professor & Head of the Department,
Department of Orthodontics,
Saveetha Dental College & Hospitals,
Chennai.

Dr. M. F. Baig, M.D.S.,
Dean
Saveetha Dental College & Hospitals,
Chennai.

Place :

Date :

CONTENTS

INTRODUCTION

Canine retraction is an important biomechanical task in Orthodontic treatment. A canine, being the corner stone of the dental arches needs to be placed in a position of stability to fulfill its role in functional occlusion. It is always desirable to distalise a canine bodily without tipping it distally or rotating it distopalatally. The morphology of the canine with its long roots however and greater buccolingual dimensions, can make this task a challenge.

Various methods are employed for canine retraction. The biomechanics involved are either friction mechanics or frictionless mechanics.

In friction or sliding mechanics the canine is made to slide distally along the arch wire. The appropriate force is applied via elastomeric modules or coil springs.

Sliding mechanics when used either for canine retraction or anterior retraction has a few inherent disadvantages. As the name suggests the technique is subject to the effects of friction. Friction, acting in the opposite direction of tooth movement, retards the rate of tooth movement which in turn requires increased force levels for retraction and eventually leads to anchorage loss. Frictional forces under clinical conditions cannot be measured accurately, hence it is difficult to calibrate the force system acting upon a tooth when one subjects it to sliding mechanics.

Sliding mechanics however do have few advantages. It requires minimum wire bending and thus chair side time is decreased. There is minimal patient discomfort as there are no loops incorporated into the arch wires and finally, the operator does not run out of space for activation of any loops.

An alternative biomechanical approach to the retraction of canines is the use of a frictionless system based upon incorporation of loops into a section of an arch wire. In situations where canine retraction is necessary, a loop may be incorporated into a section of an arch wire extending from the anchor teeth to the canine on each side, passing through the main arch wire tube of the molar and the slot of the second premolar bracket. The loops on each side are activated to retract the canines alone. This method of canine retraction is known as **Sectional canine retraction**. In this design the activated loops store energy and retract the canine by dissipating their energy into forces and moments acting on the canine and posterior teeth. Unlike sliding mechanics, forces and moments applied to any single tooth or group of teeth are predetermined and can be measured giving rise to a force system which can be optimized to meet the biomechanical requirements of the planned tooth movement.

Loops incorporated into wires have been in use for a long time. The **Bull loop** designed by **Dr. Harry Bull** was a modified vertical loop fabricated from 0.0215 x 0.025 edgewise wire. It resembled a squashed vertical loop and was used in the Edgewise technique for canine retraction. The loop was activated by separating the vertical limbs by the distance of a ‘thin dime’.

After experimenting on numerous helices, loops and wires for sectional retraction springs, **Robert Ricketts** in 1979 introduced the **Ricketts retractor**[42]. The Ricketts retractor was a double vertical helical extended crossed T closing loop spring fabricated from 16 x 16 blue elgiloy.

It produced 50 g per millimeter of activation. 3 to 4 mm of activation was sufficient for maxillary canine retraction.

In 1982 Burstone introduced his T loop 'attraction' spring [7] design as a part of his Segmental arch approach. The T loop was fabricated from a new orthodontic alloy called **TMA** which was also introduced by **Burstone** for Orthodontic use. The loop was capable of both en masse anterior and individual canine retraction. The force characteristics of the T loop however, could only produce an initial controlled tipping followed by a root uprighting phase, thus producing a net bodily movement overall.

A sectional loop for canine retraction was developed by **Poul Gjessing**[14] in 1985. He introduced the PG Universal Retraction spring design capable of being used for both anterior and canine retraction. The spring was constructed from 0.016x0.022 inch stainless steel wire and consisted of a double ovoid helix 10 mm in height gingivally and a single helix occlusally. The loop design was capable of producing a high anti-tip moment to force ratios with a low load deflection rate.

In 1997 Raymond Siatkowski introduced a continuous arch closing loop design called the Opus loop[44]. The Opus loop design was originally obtained by using the Castigliano's theorem by deriving equations for M/F in terms of loop geometry. The design was further refined using Finite element Modeling. The design is capable of delivering a non varying M/F ratio without the incorporation of Gable bends. The Opus loop was designed to produce en masse translatory movement of the anterior teeth.

Appropriate M/F ratios incorporated into canine retraction springs can help in retracting the canine bodily without rotation in a vertical or horizontal plane.

Though the effects of M/F ratios on different root lengths have been studied using Finite Element Modeling and the M/F ratios of various spring designs have been assessed *in vitro*, clinical studies to evaluate the effects of the force systems produced by the various sectional loop designs having different M/F ratios are lacking.

The aim of this clinical study was to study the utility of a modified continuous arch wire loop design - the **Opus loop** as a sectional canine retraction spring and to compare the effects of this spring with that of a known sectional canine retraction spring – the PG spring.

The Opus loop was chosen in our study because of its unique property of delivering constant and high M/F without preactivation bends. The Opus loop has delivered promising results as an anterior retraction loop by producing bodily retraction of the anterior teeth. The low load deflection rate and simple design provided further reasons to test this spring as a canine retraction spring.

REVIEW OF LITERATURE

Peavy and Kendrick(1967)[36] observed that the rugae pattern remained essentially the same for each case. They studied fifteen subjects in whom the maxillary first premolars were extracted and the anterior teeth were subsequently retracted. However they also found that the lateral ends of the rugae were greatly affected by the movement of the teeth. They did not assess stability of the medial ends of the rugae. They concluded that only slight morphological alterations were seen in 127 rugae studied, as a result of tooth movement indicating that the rugae pattern were not appreciably altered.

Nikolai (1975)[32] using a maxillary canine model based on measurements given by Wheeler concluded that, increasing the counter tipping couple from zero causes the centre of rotation to move from a point near the apical end of the middle third of the root to the root apex and then to infinity. He also stated that increasing the rotational stiffness of the canine retraction appliance will result in greater inherent potential for root control and chances of achieving bodily canine retraction. Rotational control was also emphasized in this study. The use of a wire connecting a lingual attachment of the canine to the arch wire distal to the canine was suggested.Using a maxillary canine model based on measurements given by Wheeler estimated the centre of resistance to be at approximately mid root for the single rooted tooth. He estimated the centre of rotation at three tenths to four tenths of the distance from the root apex to the alveolar crest.

Burstone and Koenig (1976)[8] used a computerized mathematical model based on the theory of a small deflection beam alongside a spring tester capable of measuring moments and forces of various spring designs in order to optimize loop designs for anterior and canine retraction. They considered the M/F ratio as the most important property of the spring which decided the path and position of the tooth being retracted. Results of the study showed that the M/F ratio of a spring can be increased by increasing the height of the spring design. They pointed out the fact that the M/F ratio can never be higher than the vertical length of the loop. Increasing the vertical length also increased the activation range of the loop. It was also observed that incorporating more wire in the gingival portion of the spring decreased load deflection rate and also increased the M/F ratio of vertical loops. Off centering the loop either towards the anchor teeth or the teeth being retracted resulted in undesirable tooth movement in the vertical plane. Incorporation of Gable bends within the loop design was shown to increase the inherent M/F ratio of the loop design, however incorporation of the gable bends lead to a force system in which the M/F ratio changed even for small amounts of deactivation of the spring. The effects of incorporating helices ino the loop design were also studied. They found that the helices decreased the load deflection rate of the spring but did not influence the M/F ratio.

Philipp and Hurst (1978)[37] studied the influence of the cant of the occlusal plane on distortion of the panoramic radiograph. They used a testing device consisting of a protractor and soldered wires and a Panorex machine by S.S. White. On changing the cant of the occlusal plane form -4 to +20 degree they found that the relationship of the long axis to the occlusal plane changed minimally in the canine premolar region however parallelism between canine and premolar roots was less reliable. Mesiodistal angulations were sensitive to changes in buccolingual angulation .The amount of linear and angular distortion increased as one proceeded distally. A standard head position was also recommended wherein the occlusal plane is at a angle of 6 degree to the horizontal.

Van der Linden(1978)[51] observed that the relationship between the canine and the lateral ends of the first rugae was stable, but the first molar moved mesially relative to the lateral end of the third rugae in untreated cases over a 10 year period. He however did not evaluate the changes in tooth position relative to the medial ends of the rugae.

Robert Ricketts and Ruel Bench (1979)[42] incorporated the sectional arch treatment into Bioprogressive therapy by breaking up the arches into various segments during treatment. They stated that such a treatment modality would make tooth movements in harmony with the anatomical structures. They also found that tooth movement can be controlled and better evaluated in all three dimensions by using the sectional arches. Cuspid retraction around the corner is also best handled on a sectional arch in order to respect the supporting structures and avoid complications of continuous arch mechanics. Various designs of cuspid retraction sections were developed for both maxillary and mandibular arches depending upon anchorage requirements.

Burstone and Pryputniewicz (1980)[9] using the non invasive technique of double-exposure hologram interferometry of a 10:1 scaled central incisor studied the position of the centre of resistance and also the effects of varying M/F ratios on the location of the centre of rotation. The location of the centre of resistance was estimated to be at 9.9mm apical to the bracket slot. When the 10:1 model of the maxillary central incisor was used, it was found experimentally that tipping at the apex requires a moment-to-force ratio of – 7.1; to translate the tooth, a moment-to-force ratio of – 9.9 is needed; rotation at the incisal edge is caused by M/F = – 11.4.

Burstone C.J (1982)[7] described the segmental arch approach wherein he divided the entire dental arch into two segments and treated them as two multirooted teeth. He also presented the T loop ‘attraction’ spring. He described the T loop as having a M/F ratio of 5.1 at maximum activation which increased to 6.0 after 1mm of deactivation. The load deflection rate of the spring was 33 g/mm and the force developed at maximum activation was 201g.

Nikolai (1982)[33] distinguished the difference between the instantaneous centre of rotation and the orthodontic centre of rotation. He also described the ‘space centrode’ as a path traveled by the instantaneous centers of rotation between the initial and final positions of the tooth. The orthodontic centre of rotation, he describes, does not lie on the long axis of the tooth being moved, but depends on the initial and final positions of the tooth.

Smith and Burstone (1984)[47] reviewed the various biomechanical principles and the relationship between forces and tooth movement.

Forces were represented as vectors through vector diagrams. Vectors have both magnitude and direction. The magnitude was represented by the length of the arrow and the direction by the arrow head. They stated that all forces applied in a clinical situation will have three dimensional effects.

Centre of resistance was described as the point in a restrained body, such as a tooth, analogous to the center of gravity in a free body. By definition, a force with a line of action passing through the center of resistance produces translation.

Moment of a force was defined as the potential for rotation of a force. If the line of action of an applied force does not pass through the center of resistance, the force will produce some rotation. The magnitude of the moment of the force can be calculated as the product of the magnitude of the force and the perpendicular distance between the point of application of the force and the centre of resistance.

A *couple* was defined as two forces of equal magnitude, with parallel but non collinear lines of action and opposite senses.

The ratio of the net moment acting on the bracket and the force applied was described as the *Moment-to-force ratio (M/F)*. The type of tooth movement that resulted was dependent on the M/F ratio. A M/F ratio of 8/1 will shift the center of rotation to the apex and the type of tooth movement which results would be a controlled tipping, whereas a M/F ratio of 12/1 will put the center of rotation at the incisal edge, and result in root movement. Only a M/F ratio of 10/1 will result in bodily movement by locating the centre of rotation at infinty. Small changes in this ratio were considered to have major effects on clinical tooth movement.

Poul Gjessing (1985)[14] presented a new sectional canine retraction spring fabricated from 0.016x0.022 stainless steel wire. It had a double ovoid loop extending gingivally with a single occlusal helix. A sweep bend was incorporated distally to prevent unwanted side effects on the premolar. An anti rotation bend was added for rotational control in the occlusal plane. Bench testing of this particular loop design was done using a load transducer to measure the forces and moment transducers to measure moments at the canine bracket and molar tubes. Results showed that the force exerted by the spring drops from 163g to 93g over 1mm and the M/F ratio increased from 10 to 12.5.

Quinn and Yoshikawa (1985)[39] made a review on various studies that related force magnitude and the rate of tooth movement. They put forth four hypotheses relating force magnitude and the rate of tooth movement. Based on the results and limitations of previous studies they concluded that the rate of tooth movement has a linear relationship with the force magnitude up to a certain limit, after which a plateau is reached and no further increase in rate of tooth movement is observed. They recommended a force range between 100 and 200 gm for maximally efficient canine retraction, based on previous clinical data. This would yield mean compressive stresses for the average cuspid root (assuming one half of the root surface to be under compressive stress) of approximately 70 to 140 gm/cm.

Kusy and Tulloch (1986)[24] stated that the effects of forces and moments on tooth movement should be studied with the help of equivalent force systems at the centre of resistance of the tooth rather than at the bracket. When tooth movement is evaluated by evaluating moment/force ratios at the bracket, they state that inconsistencies appear in results which reveal different forces at different points of application giving rise to similar type of tooth movements. They emphasized that tooth movement was dependent on two components of the force system – the first was the force (F) that translated the tooth parallel to the line of the force. The second was the moment (M) that rotated the tooth around its centre of resistance. They further stated that the force system together with the specific biologic variables within the support system like alveolar bone height and root length ultimately determined the type and amount of tooth movement.

Larheim and Svanaes (1986)[25] studied the reproducibility of nine mandibular variables (linear dimensions and angles) assessed from panoramic radiographs with the Orthopantomograph 5 (Siemens). Two separate exposures of three groups of patients were made under different radiographic conditions, each group representing one method. It was observed that vertical and angular variables showed acceptable reproducibility, the method variance being mostly within 3% of the total variance. (according to Midtgård, Björk, and Linder-Aronson, the method variance should not exceed 3% of the total variance if a method of recording orthopantomograms is to be valid). Horizontal variables were clearly more unreliable in this study. No statistically significant differences were observed between the reproducibility of the right and left sides. A negative correlation was found between the angular variables within two groups. For most variables, only small differences among the methods were found. The highest reliability was obtained when the same radiographer made both exposures.

Richmond(1987)[41] described a technique to record the dental casts in three dimensions using the Reflex Metrograph (RMG). The accuracy of the Reflex Metrograph was tested and the error was found to be less than 0.27mm (<0.3%) with an angular error of less than 0.76%.

Kazuo Tanne et al (1988)[47] investigated the relationship between moment to force (M/F) ratios and the centers of rotation by use of the finite element method (FEM) of the upper right central incisor on the basis of average anatomic dimensions. The center of resistance and centers of rotation were determined for varying M/F ratios applied at the midpoint of the crown. The center of resistance was located at 0.24 times the root length measured apical to the level of alveolar crest. The centers of rotation varied with the M/F ratios following a curve of hyperbola. The M/F ratio was – 9.53 for root movement, – 8.39 for translation, and – 6.52 for tipping around the apex. It was found that even a small difference in the M/F ratios produced clinically significant changes in the centers of rotation.

Lucchesi et al (1988)[29] used a mandibular phantom with mounted pins to investigate the suitability of the panoramic radiograph for assessment of the mesiodistal angulation of teeth in the buccal segments of the mandible. A plane-film technique was used as a comparison for accuracy. Results indicated that plane-film techniques were more accurate than the panoramic technique for assessing mesiodistal root angulation. The measurements obtained from the panoramic radiographs were closer to the actual angulation in only eight instances, whereas the plane-film measurements were closer to the actual angulations in 45 instances. In 25% of cases, the plane-film technique resulted in correct estimation, whereas this occurred only in five of 60 panoramic measurements. Moreover, differences from the actual angulations were accentuated with increased lingual inclination of the teeth. Both techniques were less accurate at greater degrees of lingual inclination of the steel pins. However they pointed out to the fact that on eight occasions the panoramic radiograph proved more accurate than the plane-film view. And on seven instances the two methods proved equally accurate.

Peter Ziegler and Bengt Ingervall (1989)[52] in a clinical study compared the efficiency of maxillary canine retraction by means of sliding mechanics along an 0.018-inch labial arch and an AlastiK chain with that using the canine retraction spring designed by Gjessing. The rate of canine retraction and degree of tipping, and rotation of the canines were studied in 21 subjects by one of these two methods on either side of the dental arch. Measurements were made in the mouth and on photographs of dental casts. the amount of rotation and mesial molar movement during canine retraction was recorded by using the midpalatine raphe and medial end of third primary ruga as a stable reference landmark. It was observed that the canine was retracted faster and with less distal tipping with the spring than with the sliding mechanics. The canine retraction spring was not superior to the sliding mechanics in controlling canine rotation during the retraction.

W.J.S. Ursi et al (1990)[50] established norms for mesiodistal angulation of teeth using an orthopantomogram. The accuracy of these norms were verified and the results obtained from different orthopantomogram machines were compared. Fourteen male and 28 female Caucasian subjects, ranging in age from 12 to 17, were selected for the study. All 42 subjects were first radiographed with a Funk Model X-15. Sixteen of the subjects were then radiographed with a different unit of the same make and model; of these, eight patients were exposed again with a Siemens Orthopantomograph and the other eight with a Yoshida Panoura. All the othopantomograms were recorded with the patient positioned according to the recommendations of Phillip and Hurst. They stated that the Linear measurements were unreliable, especially horizontal ones, as they are influenced not only by a projection factor, but by a motion factor. It was observed that the angular measurements are not so variable and also that for clinical purposes, variations of as much as 5 ° in the angulation of two adjacent teeth or between two exposures of the same tooth are not serious. The standard deviation of error in assessing the angulation of the canine varied from 3.68 to 1.98. It was also observed that the error in assessing angulation increased as one moved to more posterior teeth. Ursi et al finally concluded that the orthopantomogram is as predictable as other two dimensional methods to assess mesiodistal axial inclination.

Pawan Kumar Chandra (1990)[10] designed a removable appliance capable of bodily canine retraction. The centre of resistance was calculated based on Wheeler's tooth anatomy measurements and the force was made to pass through the centre of resistance. The results of tooth movement were assessed with the help of an Orthopantomogram. Superimpositions showed translatory movement of the canine.

Kazuo Tanne et al (1991)[48] used a finite element model of a upper central incisor and varied the alveolar bone heights and the root length. Initial tooth displacements on force application were determined at various root lengths and alveolar bone heights and the apicogingival levels of the center of resistance and centers of rotation were calculated. The results showed that moment-to-force values at the bracket level for translation of a tooth decreased with shorter root length and increased with lower alveolar bone height. In addition, it was observed that decrease in root length shifted the apicogingival levels of the center of resistance gingivally to the cervix, or the alveolar crest. Alveolar bone loss also shifted the center of resistance toward the alveolar crest, whereas its position was more apical relative to the cervix. However, the relative distances of the centers of rotation from the alveolar crest in comparison with the alveolar bone heights were constant at 0.4 mm, with variations in the root length and alveolar bone height. They inferred that root length and alveolar bone height affect the patterns of initial tooth displacements both in the center of resistance and the centers of rotation and also in the amount of displacement. Therefore it was concluded that forces applied during orthodontic treatment should take into consideration the anatomic variations in the root length and alveolar bone height so as to produce optimal and desired tooth movement.

Andersen et al (1991)[3] studied stress profiles in the periodontal ligament using three dimensional finite element modeling of the mandible with the dentition. They observed that there was a marked variation in the stress distribution from cervix to apex when tipping forces were applied. Bodily movement of the tooth produced an almost uniform stress distribution; root movement produced stress patterns opposite to those observed during tipping.

Jones (1991)[21] compared the accuracy of two dimensional and three dimensional measurements in assessing orthodontic treatment changes. He used the Cephalogram and the Reflex metrograph respectively for this study. He concluded that the Reflex Metro Graph showed marginally better precision in measuring treatment changes and it also allowed a more thorough and accurate assessment of incisor position and measurement error.

Eden and Waters (1994)[13] used the strain energy method to derive a theoretical model of the type II PG spring to characterize the force system produced by the PG spring. Their findings were later verified experimentally using a scaled model of the spring mounted on jigs connected to strain gauges. They found a good correlation between the theoretically derived force systems and the force systems detected experimentally. Findings revealed that the M/F ratio of the gabled PG spring ranged from 10.7 to 16.1 which was in agreement with Gjessings experimental findings.

Gjessing (1994)[15] described the uses and properties of the PG universal retraction spring. He stated that at initial activation the M/F ratio of the spring is only 9mm. he also advocated a force of activation of 100g instead o the 160g of force initially advocated in the original article.

Bailey et al(1996)[5] analyzed the dental casts of 57 adult patients to study the stability of the palatal rugae after tooth movement in extraction and non extraction cases. They concluded that the medial and lateral points of the third primary rugae appear to be stable and are suitable to be used as anatomic reference points in longitudinal cast analysis.

Daskalogiannakis J and Mclachlan K.R (1996)[11] studied the rate of canine retraction under constant and short duration forces. The study was conducted on six individuals with a vertical loop sectional arch wire on one side and a vertical loop sectional arch wire constantly activated by a neodymium-iron-boron magnet on the other side. The results of the study showed that the canine retracted under a constant force by the help of the magnet distalised by a significant amount when compared to the canine being retracted by the vertical loop alone. They concluded that the duration of the force is more important in determining the rate of tooth movement when compared to the magnitude of the force.

Nikolai R.J (1996)[34] emphasized the importance of the three dimensional nature of tooth movement. He located eight points on the maxillary canine to describe the six types of orthodontic tooth movement. He stated that characterizing the entire tooth movement based on the displacement of a single point would be insufficient and that expressing the tooth movement in terms of translational and rotational phases may clarify rigid body kinematic analysis.

Takayki Kuroda et al(1996)[23] introduced a three dimensional dental cast analyzing system and its preliminary clinical applications. In this system, he used a standardized Laser beam scanning method to obtain the images of the dental casts and a computer based study was made and concluded that this study has more accuracy, was less time consuming and had a high speed measuring and proceesing system built in it.

Lawrence P Lotzof et al (1996)[28] used a palatal plug analysis to calibrate the amount of canine retraction and anchorage loss. A detachable acrylic plug with reference wires placed in it was fabricated on the pre retraction models. This palatal plug was later transferred to the post retraction models to assess the amount of tooth movement.

Rajcich and Sadowsky(1997)[40] made photocopies of dental casts and used the midpalatine raphe and the medial end of third primary rugae to measure canine and molar movements during canine retraction.

Raboud et al (1997)[39] stated that all loop designs have three dimensional effects on the teeth being retracted. They observed that teeth apart from being distalised on a lateral plane also underwent rotation in an occlusal plane. In order to counteract the undesirable rotational effects of loops in both these planes, they suggested incorporating preactivation bends in the vertical plane and out-of-plane (OOP) anti rotation bends in the horizontal plane.

A numerical procedure was used to study the three dimensional effects of various loop designs used for canine retraction. This numerical procedure uses a completely nonlinear formulation in which the appliance is broken into several segments. These segments are analyzed sequentially, starting from one end of the appliance. Force and displacement compatibility between the segments is used to move from one segment to the next. Results of the study indicated that incorporation of pre activation bends increased M/F ratios whereas out-of-plane bends did not significantly affect M/F ratios of the loop, but however reduced the amount of maximum elastic activation of the loop. They have also stated that anti rotation bends of 20 degree incorporated into the spring design are sufficient to produce occlusal moments to counteract the rotational tendency of buccaly applied forces by these springs.

Kuhlberg and Burstone (1997)[22] emphasized the importance of loop positioning when they studied the effect of off-center positioning on the force system produced by segmented 0.017 x 0.025-inch TMA T-loops. A T-loop was designed to produce equal and opposite moments in the centered position. The spring was tested in seven positions, centered, 1, 2, and 3 mm toward the anterior attachment, and 1, 2, and 3 mm toward the posterior attachments. The horizontal force, vertical force, and alpha and beta moments were measured over 6 mm of spring activation using a spring tester apparatus. The results showed that the alpha/beta moment ratio was dependent only on the spring position, and independent of spring activation. They conclude that a centered T-loop produces equal and opposite moments with negligible vertical forces. Whereas, off-center positioning of a T-loop produces differential moments. More posterior positioning produces an increased beta moment. More anterior positioning produces an increased alpha moment.

Raymond E. Siatkowski (1997)[44,45] designed a continuous arch closing loop design for bodily retraction of the incisors. The loop was optimized and designed using a mathematical theorem called Castigliano’s theorem. The loop was further refined using finite element modeling. The loop design was capable of delivering an inherent M/F ratio of 8 to 9.1 which was non varying with deactivation. The loop did not require incorporation of any gable bend to achieve the given magnitude of M/F. The loop can be fabricated from wire of any material in orthodontic use of any dimension. Though the load-deflection varied with material and dimension, the M/F ratio remained the same. The M/F ratio however was sensitive to changes in loop design. The greatest negative impact on M/F is crossing the loop legs – crossing the loop legs leads to decrease in M/F. Decreasing loop height decreases M/F. Decreasing the loop angulation also decreases M/F. Dropping the anterior end of the loop decreases M/F. Increasing loop length beyond 10 mm has no effect on M/F, but decreasing loop length decreases M/F. Incorporation of "lingual" comfort bends in the anterior of the loop, did not degrade M/F or F/D.

Halozentis D.J (1998)[17] described the use of a computer aided loop designing program. He optimized the T loop as a sectional canine retraction spring using this computer program.

Gulati et al(1998)[16] made photocopies of pre and post retraction casts with a 1 to 1 duplication. He dropped perpendicular lines from the points on the maxillary permanent molars to the incisive papilla perpendicular reference plane and thus measured antero posterior movements of maxillary molars.

Raymond E Siatkowski (2001)[46] described the rate of tooth movement of the Opus loop with the help of the osteologic curve. He states that the PDL stress levels that develop with the use of the opus loop are far lesser than the patients systolic blood pressure, thus ischaemic cell death in the PDL does not occur and chances of hyalinization are greatly reduced. The advantages of an Opus loop made of 0.0175X0.025 TMA is also described. The use of TMA, according to the author facilitates larger amounts of activation, up to 4mm of activation capable of closing spaces of up to 8mm in a single activation.

Hoggan and Sadowsky(2001)[20] evaluated the use of palatal rugae as reference point for the measurement of tooth movement, in a manner comparable with the Cephalometric superimposition. The study consisted o pre and post treatment maxillary study casts and lateral Cephalometric radiographs of 33 patients who received orthodontic treatment that involved extraction of first premolars. A computerized system (Orthodontic Logic) was used to digitize the study casts and Cephalograms. Their findings suggested that the rugae landmarks can be used reliably as cephalograms to assess the anteroposterior molar and incisor movements.

Santoro, Scott and Galkis (2003)[43] used computer based method of analysis to measure the orthodontic tooth movements of pre and post orthodontically treated cases using dental casts and their photographs taken in a digital camera which was imported into a computer system for analysis. They found that there were no significant differences in measurements made by computer and manual methods and if at all present it was clinically insignificant. It was concluded that the software used (ORTHO-CAD) was a valid method of studying dental casts.

SUMMARY AND CONCLUSION

From the study conducted it can be concluded that:

- The Sectional Opus loop produces significantly more rapid tooth movement than the PG spring.
- The Sectional Opus loop has poor mesiodistal root control over the canine and produces significantly more tipping than the PG spring.
- Rotational control over the canine was found to be satisfactory.
- Anchor loss was found to be minimal.
- The Opus loop may be used in selected cases where the anchorage requirement is high, with the canine placed mesioangularly.

BIBLIOGRAPHY

1. **Almedia and Tulloch,** Stability of the palatal rugae as landmarks for analysis of dental casts. Am. J. Orthod Dentofac Orthop. 1996; 110 : 191-196.

2. **Alpern M.C**, Analysis of Panoramic cephalometrics using a skeletal cephalostat. British Journal of Orthodontics. 1979; 49(2) : 110-120.

3. **Andersen K.L and Pedersen E.H**, Material parameters and stress profiles within the periodontal ligament. Am. J. Orthod Dentofac Orthop. 1991; 99(5) : 427-440.

4. **Ash M.M. Jr**.: Wheeler's Dental Anatomy, Physiology and Occlusion, 6th ed., W.B. Saunders, Philadelphia, 1984, p. 155.

5. **Bailey L.J, Esmailnejad and Almedia,** Stability of the palatal rugae as landmarks for analysis of dental casts in extraction and non extraction cases. The Angle Orthodontist; 66(1): 73-78.

6. **Braun S and Marcotte M.R,** Rationale of the segmented arch approach to orthodontic treatment. Am. J. Orthod Dentofac Orthop. 1995; 108(1) : 361-378.

7. **Burstone C.J**, The segmented arch approach. Am. J. Orthod Dentofac Orthop. 1982; 82(5) : 361-378.

8. **Burstone C.J and Koenig H.A**, Optimizing anterior and canine retraction. Am. J. Orthod Dentofac Orthop. 1976; 70(1) : 1-19.

9. **Burstone C.J and Pryputniewicz R.J**, Holographic determination of centers of rotation produced by orthodontic forces. Am. J. Orthod Dentofac Orthop. 1980; 77(4) : 396-408.

10. **Chandra P.K,** Sliding tube appliance for maxillary canine retraction. Journ of Clin Orthod; 24(2) : 729-732.

11. **Daskalogiannakis J and McLachlan K.R**, Canine retraction with rare earth magnets: An investigation into the validity of the constant force hypothesis. Am. J. Orthod Dentofac Orthop. 1996; 109(5) : 489-495.

12. **Dincer M, Gulsen and Turk T**, The retraction of upper incisors with the PG retraction system. Eur Jorun Orthodontics. 1994;105(1):49-60.

13. **Eden J.D and Waters N.E**, An investigation into the characteristics of the PG canine retraction spring. Am. J. Orthod Dentofac Orthop. 1994; 105(1) : 49-60.

14. **Gjessing P,** Biomechanical design and clinical evaluation of a new canine retraction spring. Am. J. Orthod Dentofac Orthop. 1985; 87(5) : 353-362.

15. **Gjessing P,** A universal retraction spring. Journ of Clin Orthod; 28(4) : 222-224.

16. **Gulati S, Kharbandha O.P and Prakash H**, Dental and skeletal changes after intraoral molar distalization with sectional jig assembly. Am. J. Orthod Dentofac Orthop. 1998; 114(1) : 319-327.

17. **Halozentis D.J**, Understanding loop preactivation. Am. J. Orthod Dentofac Orthop. 1998; 113(2) : 237-241.

18. **Hart A, Taft L and Greenberg S.N**, The effectiveness of differential moments in establishing and maintaining anchorage. Am. J. Orthod Dentofac Orthop. 1992; 102(5) : 434-442.

19. **Hoenigl K.D, Freudenthaler J, Marcotte M.R and Bantieon H**, The centered T-loop – a new way of preactivation. Am. J. Orthod Dentofac Orthop. 1995; 108(5) : 149-153.

20. **Hoggan B.R and Sadowsky C**, The use of palatal rugae for the assessment of anteroposterior tooth movements. Am. J. Orthod Dentofac Orthop. 2001; 119(5) : 482-488.

21. **Jones**, A comparison of orthodontic treatment changes as measured from study casts and Cephalometric radiographs. British Journal of Orthodontics 1990; 18: 99-103.

22. **Kuhlberg A.J and Burstone C.J**, T-loop position and anchorage control. Am. J. Orthod Dentofac Orthop. 1997; 112(1) : 13-18.

23. **Kuroda T, Motohashi N, Tominaga R and Iwata K**, Three dimensional dental cast analyzing system using laser scanning. Am. J. Orthod Dentofac Orthop. 1996; 110(1) : 365-369.

24. **Kusy R.P and Tulloch J.F.C**, Analysis of moment to force ratios in the mechanics of tooth movement. Am. J. Orthod Dentofac Orthop.

25. **Larheim T.A and Svanaes D.B**, Reproducibility of rotational panoramic radiography. Am. J. Orthod Dentofac Orthop. 1986; 90(2) : 127-131.

26. **Lindauer S.J,** Biomechanics in Orthodontics, Seminars in orthodontics; 7(2) 25-32.

27. **Lindauer S.J, Isaacson R.J and Britto A.D,** Three dimensional force systems from activated Orthodontic appliances. Seminars in Orthodontics; 7(3): 207-214.

28. **Lotzof L.P, Fine H.A and Cisneros G.J,** Canine retraction: a comparison of two pre adjusted bracket systems. Am. J. Orthod Dentofac Orthop. 1996; 110(2) : 191-196.

29. **Lucchesi M.V, Wood R.V and Nortje C.J,** Suitability of the Panoromic radiograph for assessment of mesiodistal angulation of teeth in the Buccal segments of the mandible. Am. J. Orthod Dentofac Orthop. 1998; 94(2) : 303-310.

30. **Marcotte M.R,** Biomechanics in Orhodontics. B.C Decker Inc, 1990, p56.

31. **Marcotte M.R,** The Plan of the Segmented Arch Technique. Seminars in Orthodontics; 7(3): 191-206.

32. **Nikolai R.J**, On optimum force theory as applied to canine retraction. . Am. J. Orthod Dentofac Orthop. 1975; 68(3) : 290-302.

33. **Nikolai R.J**, Analytical mechanics and analysis of orthodontic tooth movements. Am. J. Orthod Dentofac Orthop. 1982; 82(2) : 164-166.

34. **Nikolai R.J,** Rigid-body kinematics and single-tooth displacements. Am. J. Orthod Dentofac Orthop. 1996; 110(1) : 88-92.

35. **Nikolai R.J,** The biomechanics of canine retraction with arch wire guidance. Seminars in Orthodontics ; &(3): 182-190.

36. **Peavy D.C and Kendrick G.S,** The effects of tooth movement on the palatine rugae. Journ of Prosth Dent; 18(6): 536-542.

37. **Philipp R.G and Hurst R.V.V**, The cant of the occlusal plane and distortion in the panoramic radiograph. British Journal of Orthodontics 1978; 48(4) : 317-323.

38. **Quinn R.S, Yoshikawa D.K,** Reassessment of force magnitude. Am.J.Orthod Dentofac Orthop 1985 : 252-260.

39. **Raboud D.W, Faulkner M.G, Lippsett A.W and Haberstock D.L**, Three dimensional effects in retraction appliance design. Am. J. Orthod Dentofac Orthop. 1997; 112(4) : 378-392.

40. **Rajcich M and Sadowsky C**, Efficacy of intraarch mechanics using differential moments for achieving anchorage control in extraction cases. Am. J. Orthod Dentofac Orthop. 1997; 112(3) : 441-448.

41. **Richmond S**, Recording the dental cast in three dimensions. Am. J. Orthod Dentofac Orthop. 1987; 92(3) : 199-206.

42. **Ricketts R.M, Bench R.W, Gugino C.F, Hilgers J.J and Schulhof R.J,** Bioprogressive therapy. Rocky Mountain Orthodontics, 1979.

43. **Santoro.M, Scott and Galkis, Comparison of measurements made digiral and plaster models**Am. J. Orthod Dentofac Orthop. 2003; 124(4) : 101-5.

44. **Siatkowski R.E**, Continuous arch wire closing loop design, optimization and verification. Part 1. Am. J. Orthod Dentofac Orthop. 1997; 112(4) : 393-402.

45. **Siatkowski R.E**, Continuous arch wire closing loop design, optimization and verification. Part 2. Am. J. Orthod Dentofac Orthop. 1997; 112(5) : 487-495.

46. **Siatkowski R.E,** En Masse space closure with precise anchorage control. Seminars in Orthodontics; 7(3) : 141-149.

47. **Smith R.J and Burstone C.J**, Mechanics of tooth movement. Am. J. Orthod Dentofac Orthop. 1984; 85(4) : 426-431.

48. **Tanne K, Koenig H.A and Burstone C.J**, Moment to force ratios and the centre of rotation. Am. J. Orthod Dentofac Orthop. 1988; 94(5) : 426-431.

49. **Tanne K, Nagataki T, Inoue Y, Sakuda M, Burstone C.J**, Patterns of initial tooth displacements associated with various root lengths and alveolar bone heights. Am. J. Orthod Dentofac Orthop. 1991; 100(1) : 66-71.

50. **Ursi W.J.S, Almedia R.R**, Tavano O, Hendriques J.F.C, Assessment of mesiodistal axial inclination through Panoramic Radiography. Journ of Clin Orthod; 1990; 24(3)

51. **van der Linden F.P.G.M**, Changes in the position of posterior teeth in relation to ruga points. Am. J. Orthod Dentofac Orthop. 1978; 74(2) :142-161

52. **Zeigler P and Ingervall B**, A clinical study of maxillary canine retraction with a retraction spring and with sliding mechanics. Am. J. Orthod Dentofac Orthop. 1989; 95(2) : 99-106.