The Treatment Effects of Sliding Mechanic System During En-Masse Retraction in Adult Maxillary Dental Protrusion Patients

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I hereby certify that this work has not been accepted in substance for any degree, and is not being currently submitted in candidature for any degree.

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Candidate

ชื่อวิทยานิพนธ์ ผลของระบบการเคลื่อนฟันด้วยวิธีเลื่อนไถลตามลวดหลักขณะดึงกลุ่มฟันหน้าในผู้ป่วยผู้ใหญ่ที่มีลักษณะฟันหน้าบนยื่น

ผู้เขียน นางสาวอาวีคุณ ธนะสารสมบูรณ์

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บทคัดย่อ

บทนำ: ผู้ป่วยที่มีฟันหน้าบนยื่นและพบร่วมกับการมีปลายฟันตัดหน้าบนโผล่พ้นริมฝีปากปริมาณมาก การแก้ไขภาวะดังกล่าวนอกจากการเคลื่อนกลุ่มฟันหน้าเข้ามาด้านใน ควรคำนึงถึงการเตรียมหลักยึดแบบสูงสุดร่วมกับการป้องกันไม่ให้มีการยื่นยาวลงมาของปลายฟันตัดหน้าบนและไม่เกิดการล้มเอียงเข้ามาทางด้านเพดานที่มากเกินของฟันตัดหน้าขณะดึงกลุ่มฟันหน้า หนึ่งในวิธีการเคลื่อนกลุ่มฟันหน้าบนเพื่อลดการยื่นของฟันคือการใช้เทคนิคการดัดลวดเป็นรูปวีเบนด์แบบไม่สมมาตรเพื่อดึงกลุ่มฟันหน้าบน จึงเป็นที่มาสำหรับการศึกษานี้ **วัตถุประสงค์:** เพื่อทดสอบผลของระบบการดึงกลุ่มฟันหน้าบนที่ใช้ร่วมกับการดัดลวดเป็นรูปวีเบนด์แบบไม่สมมาตรต่อการเปลี่ยนแปลงของฟันตัดหน้า ฟันเขี้ยว ฟันกรามน้อย และฟันกราม **ระเบียบวิธีวิจัย**: ผู้เข้าร่วมวิจัย 17 คน (อายุเฉลี่ย 20.44 ± 4.75 ปี) ที่มีแผนการรักษาแก้ไขภาวะฟันหน้าบนยื่นโดยใช้ช่องว่างจากการถอนฟันกรามน้อยบนซี่ที่หนึ่งทั้งสองข้างร่วมกับการเตรียมหลักยึดฟันหลังแบบสูงสุดและจำเป็นต้องเหลือช่องว่างอย่างน้อย 4 มิลลิเมตรภายหลังฟันบนถูกปรับระดับและเรียงเรียบ การรักษาทำด้วยการยึดลวดเหล็กกล้าไร้สนิมขนาด 0.018 x 0.022 นิ้วที่ดัดเป็นรูปวีเบนด์แบบไม่สมมาตรทั้ง 2 ข้างเข้าในร่องแบร็คเก็ตของกลุ่มฟันหน้าบนขนาด 0.018 x 0.025 นิ้วที่มีขนาดพอดีกับขนาดลวด และในร่องแบร็คเก็ตขนาดใหญ่ที่ฟันกรามน้อยและท่อด้านแก้มที่ฟันกรามซี่ที่หนึ่งขนาด 0.022 x 0.028 นิ้ว และเคลื่อนกลุ่มฟันหน้าบนด้วยแรงขนาด 150 กรัม ทั้งสองข้างเป็นระยะเวลา 4 เดือน หลังจากนั้นทำการวิเคราะห์การเปลี่ยนแปลงของฟันจากภาพถ่ายรังสีศีรษะด้านข้างและแบบจำลองฟันศึกษาโดยใช้สถิติวิลคอสันเปรียบเทียบระหว่างก่อน-หลังการเคลื่อนฟัน **ผลการศึกษา:** จากการวิเคราะห์พบว่าค่าวัดทุก ๆ ค่ามีความแตกต่างกันอย่างมีนัยสำคัญระหว่างก่อนและหลังการดึงกลุ่มฟันหน้าบน โดยฟันตัดหน้าบนถูกดึงเข้าด้านใน 0.7 ± 0.3 มิลลิเมตร มีการเอียงตัวเข้าด้านใน 3.00 ± 0.85 องศา และถูกกดขึ้น 0.24 ± 0.31 มิลลิเมตร ในส่วนของฟันกรามน้อยและฟันกรามพบว่ามีการเคลื่อนมาด้านหน้า 0.31 ± 0.31 มิลลิเมตรและ 0.29 ± 0.27 มิลลิเมตรตามลำดับ ที่ฟันกรามน้อยมีการเอียงตัวฟันมาทางด้านหน้า 3.25 ± 1.47 องศาและ 3.25 ± 1.47 องศาที่ฟันกราม ในส่วนการเคลื่อนที่

แนวดิ่ง ฟันกรามน้อยถูกกดลง 0.35 ± 0.33 มิลลิเมตรและฟันกรามถูกกดขึ้น 0.12 ± 0.65มิลลิเมตร อัตราการดึงกลุ่มฟันหน้าบนเข้าด้านในเท่ากับ 0.68 ± 0.12 มิลลิเมตรต่อเดือน และอัตราการสูญเสียหลักยึดฟันหลังมาทางด้านหน้าเท่ากับ 0.08 ± 0.07 มิลลิเมตรต่อเดือน **สรุป:** ระบบการเคลื่อนกลุ่มฟันหน้าบนด้วยการดัดลวดเป็นรูปวีเบนด์แบบไม่สมมาตรสามารถดึงกลุ่มฟันหน้าบนเข้ามาด้านเพดานได้โดยไม่พบการล้มเอียงเข้ามาด้านเพดานมากเกินและไม่มีการยื่นยาวลงมาของปลายฟันตัดหน้าบนรวมถึงสามารถควบคุมหลักยึดแบบสูงสุดจากระบบการเคลื่อนฟันนี้

Thesis Title The Treatment Effects of Sliding Mechanic System During En-Masse Retraction in Adult Maxillary Dental Protrusion Patients

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ABSTRACT

Introduction: Protrusion of maxillary anterior teeth is usually found in adult patients with exposed in maximal incisal display at rest. En-masse retraction of the anterior teeth with maximum anchorage control should be done without extrusion and excessive retroclination of the incisors. One interesting method to en-masse retract with achieving these treatment goals is using the asymmetrical V-bend for retraction of the six maxillary anterior teeth. **Objectives:** To investigate the effects of en masse retraction system with asymmetrical V-bend archwire in the dental changes of the incisor, canine, premolar, and molar **Material and methods**: The 17 adult subjects (mean age 20.44 $\pm$ 4.75 years) with protrusion of the maxillary anterior teeth who were planned with bilaterally extraction of the maxillary first premolars with maximum anchorage control and presented the residual extraction space at least 4 mm after correction of crowding were selected for this study. An 0.018x 0.022- inch stainless steel wire bent as asymmetrical V-bend was engaged on full-sized anterior brackets (0.018x0.025- inch slot) and oversized premolar brackets similar in the size with buccal tubes on the first molars (0.022x0.028- inch slot). Exerting 150 g of force were used bilaterally for the en masse retraction until 4 months period of observation. Lateral cephalograms and study models were taken at pre-retraction (T1) and after 4 months of retraction (T2) periods to evaluate the treatment effects. Wilcoxon signd-ranks test was used to analyze the data. **Results**: The data analysis showed statistically significant differences ($p < 0.05$) in all dimension of tooth movement. The maxillary incisor was retracted 0.7 $\pm$ 0.3 mm, retroclined 3.00 $\pm$ 0.85°and intruded 0.24 $\pm$ 0.31 mm. The maxillary second premolar and the first molar were moved mesially 0.31 $\pm$ 0.31mm and 0.29 $\pm$ 0.27 mm, respectively. In the angulation changes, the premolar was tipped distally 3.25 $\pm$ 1.47° and the molar was tipped distally 3.25 $\pm$ 1.47°. In vertical changes, the premolar was extruded 0.35 $\pm$ 0.33 mm while the molar was intruded 0.12 $\pm$ 0.65 mm. Rate of the en-masse retraction was 0.68 $\pm$ 0.12 mm/month; meanwhile rate of the anchorage loss was 0.08 $\pm$ 0.07 mm/ month. **Conclusion**: With this en-masse retraction system consisting of asymmetrical V-bend archwire, the maxillary anterior teeth could be retracted generously with maximum anchorage control. Moreover, the system could control the incisor changes appropriately without excessive retroclination and no extrusion.

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Aweekhun Thanasansomboon

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LISTS OF ABBREVIATIONS AND SYMBOLS

mm	=	illimeter
et al	=	and others
g	=	gram
º	=	degree
Fig.	=	figure
”	=	inch (es)
/	=	per
NiTi	=	Nickel Titanium
SS	=	Stainless steel
T1	=	Before en-masse retraction
T2	=	After 4-months of retraction
U1	=	the maxillary central incisor
U3	=	the maxillary canine
U5	=	the maxillary second premolar
U6	=	the maxillary first molar
RT	=	right side
LT	=	left side
OL	=	a line through incisal tip of the maxillary incisor and the distobuccal cusp of the
OLp	=	a vertical reference line that perpendicular to the OLs passing Sella
OLs	=	a horizontal reference line that parallel to the occlusal plane and passing the sella
SNL	=	a line connecting the sella (S) to the N point

CHAPTER 1

INTRODUCTION

Background and rationale

In day-to-day practice, maxillary dental protrusion is one of the most chief complaints in adult orthodontic patients, mainly due to the esthetic involvement it has. This is a condition characterized by a protrusion and proclination of the maxillary incisors with respect to increased procumbency of the upper lip and decreased nasolabial angle[1].

The treatment of choice for maxillary dental protrusion patients often is extraction of the two maxillary first premolars or four premolars to provide space for anterior teeth retraction and decreasing the lip protrusion. The control of both antero-posterior and vertical position resulting from maxillary anterior teeth movement is important because the position of maxillary anterior teeth is known to be essential for function of the stomatognathic system, stability and esthetic appearance of the face. Based on mode of anterior teeth retraction, en-masse retraction (retraction of all six anterior teeth) is considered as esthetic teeth movement method more than two-step retraction (retraction of canine teeth followed by retraction of all four incisors) because two-step retraction creates the temporarily unaesthetic spaces distally to the lateral incisors. However, during the maxillary anterior teeth retraction, the teeth movement may result in extrusion of the anterior teeth, and this undesired side-effect can be caused by uncontrolled tipping of the retracted teeth or by the vertical forces generated as an adjunct to the moment induced for palatal root torque.[2] The extrusion of the maxillary anterior teeth can contribute to the excessive maxillary incisor display causing worsen esthetics. Ideal maxillary incisor display (incision-stomion distance), 3 mm, is recommended for good esthetics.[3]

During en-masse space closure with sliding mechanics, inclination (torque) and angulation of the maxillary anterior teeth is important to control because they dictate the esthetic smile, lip posture, and ultimately the interdigitation of the posterior teeth[4]. However, in most instances, the point of force application for en-masse retraction is usually near the crown of the tooth; therefore, the anterior teeth will be tipped palatally. Moreover, placing a force through the center of resistance is not practical because of anatomical limitations in the oral cavity.

The resolution of these problems involves inclination control on the maxillary incisors and angulation control on the maxillary canines. In 2000, Gianelly[5] developed a preadjusted edgewise bidimensional technique that was modified from Schudy's edgewise bimetric system[6]. For this technique, the smaller bracket slots (0.018-inch slots) will be placed on the incisors and the larger bracket slots (and 0.022-inch slots) will be placed on the canines, premolars, and molars; so that, root torque can be controlled simply and precisely on the maxillary incisors by using full fitting and rigid rectangular wire (0.018 × 0.022-inch stainless steel wire) to completely fill the vertical height of the incisor bracket slots. Additionally, using this technique to slide the smaller main archwire through the larger posterior bracket slots is a great benefit to minimize the friction between the wire and the bracket slot.

An interesting alternative approach in sliding mechanics is using a combination of bidimensional edgewise bracket (placing 0.018-inch bracket slots on the incisors and the canines) and tip-back bend[7] placed on a rigidly full fitting rectangular stainless steel archwire for maxillary anterior teeth inclination and angulation control during en-masse retraction. For all that, there is no study that directly assessed the treatment effects of using the fitting and rigid wire in the positive torque prescription bracket of maxillary anterior teeth to control torque of the incisors and angulation of the canines during maxillary en-masse retraction with sliding mechanics.

Review of literatures

Maxillary dental protrusion and treatment for correction

Maxillary dental protrusion characterized by dental flaring of maxillary anterior teeth with resulting protrusion of the upper lip, is commonly presented both in Angle Class I malocclusion with bimaxillary dental protrusion[8] and Angle class II division 1 malocclusion[9].

Three important factors in treatment of maxillary dental protrusion are goal of the treatment, namely, esthetic improvement, efficiency functional establishment and structural balance of the dento-facial area[8]. Based on patient's chief complaint and the diagnosis of the malocclusion, one of the most practicable treatment options for maxillary dental protrusion is to extract the maxillary first premolars and/or mandibular premolars and follow by maxillary anterior teeth retraction for decreasing the upper lip protrusion.

Extraction space closure

Space closure in extraction cases is one of the most important procedures in orthodontic treatment after extraction. This procedure needs an efficient appliance and method which can produce efficient force system to control tooth movement during space closure. Additionally, the use of simplified, available and non-invasive appliances that they will accomplish the objective of extraction space closure without adverse effects can be a pleasing way for making friendly relationship between doctors and their patients.

There are many theoretical aspects of space closure; one is based on how many steps in anterior retraction and the other is relied on biomechanical concepts.

Two-step retraction versus en-masse retraction

In nowadays, there are two techniques of space closure based on steps in anterior retraction, namely, two-step retraction and en-masse retraction. Two-step retraction technique is a sequential procedure including two separated steps to close the space; the first step is canine retraction, and followed by incisor retraction[10-12]. The other approach is en-masse retraction technique. From the glossary of orthodontic terms[13], en-masse retraction is defined as retraction of a number of teeth (usually the four incisors, or all six anterior teeth) together, as a group.

In the past, many clinicians sense believed that two-step retraction technique is less detrimental to the anchorage than en-masse retraction technique. But the current study found that it is unnecessarily true in all instances. This is supported by Heo W et al[14] , who found there is no significant difference in the degree of anchorage loss of the upper posterior teeth between en-masse retraction of the six anterior teeth and two-step retraction with sliding mechanics. In another study, Xu TM et al[15] evaluated the effectiveness of anchorage preservation between en-masse retraction and two-step retraction, he found an interesting result that contrary to what some clinicians commonly believe, two-step retraction is slightly greater distance of anchorage loss than that for en-masse retraction, but it was no statistical significance. About treatment time, both studies found two-step retraction took longer treatment time.

Moreover, two-step retraction is the technique establishing unaesthetic spaces distal to the lateral incisors during canines retraction, which last for a considerably long time[16]. En-masse retraction, unlike two-step retraction, permits retraction of all six anterior teeth in a single step. In my opinion, it is a good technique to allow doctors and their patients to evaluate changes in inclination and position of the maxillary incisors and the lips in relation to facial esthetics simultaneously retraction of canine, whether it is during position of resting or smiling, and no matter whether in frontal or profile smile.

For that reason, only patients who have anterior arch-length discrepancies with anterior crowding require separate canine retraction. Upon attaining incisor aligning, en-masse retraction of the six anterior teeth should be the best technique for space closure. In order to close space with en-masse retraction, it is important to design the suitable appliance based on the desired biomechanics of space closure that control the retraction of all six anterior teeth in a single stage.

Biomechanical considerations of en-masse retraction

Three dimensional controls during en-masse retraction to correct tooth position and inclination of anterior teeth are important for esthetic, function, and stability improvement on dento-facial area [17]. Orthodontic tooth movement is determined by forces applying on the tooth. The tooth or the group of teeth can move in one of three general ways[18], that are translation, pure rotation, or combined rotation and translation. Translation, or bodily movement, occurs when a force with a line of action passing through the center of resistance. In order to understand effects of forces applied on the maxillary anterior teeth during en-masse retraction, first of all, we need to know where the center of resistance of the maxillary anterior teeth is located.

Center of resistance of maxillary anterior teeth during retraction

In a restrained object, such as a tooth, a point analogous to the center of gravity is used; this is called the center of resistance. The location of the center of resistance of a tooth is controlled by the supporting stress resisting tissue, i.e., the alveolar bone, periodontal ligament, and gingival tissue. Moreover, it is controlled by the form, length, and number of roots of the tooth. There are many studies reported the center of resistance of the six maxillary anterior teeth as the above show in the subtopic of center of resistance of the maxillary anterior teeth

Vanden Bulcke et al[19]used a metal splint in two dry skulls to examine the center of resistance of the maxillary anterior teeth during palatal movement. From his study, the center of resistance of the maxillary anterior teeth lies approximately 7 mm apically to the incisor interproximal bone level.

Melsen et al [20], based on a laser holography study, reported that the center of resistance of the six maxillary anterior teeth is located halfway between the midpoint of four incisors' center of resistance and canines' center of resistance (Fig. 1)[20-22].The authors estimated the center of resistance of maxillary anterior teeth lay 0.72 mm distally to the maxillary canine bracket on the horizontal plane (Fig. 1).

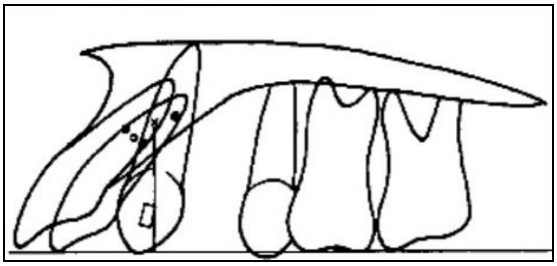

Fig. 1 Estimation of center of resistance for anterior segment[20]

Yoshida et al.[23] also found that the center of resistance of two or four maxillary incisors approximately coincide at 4.3 mm apically to the palatal osseous plate, whereas the center of resistance of the six maxillary anterior teeth lies 0.8 mm more incisally.

Finally, Jeong GM et al[24], 2009, using 3-dimensional finite element analysis, found that the center of resistance of the six maxillary anterior teeth was at 13.5 mm apical and 14.0 mm posterior to the incisal edge of the upper central incisor (Fig. 2).

Clinically, determining the position of the center of resistance is impacted to force systems that comprise two components (force and moment).

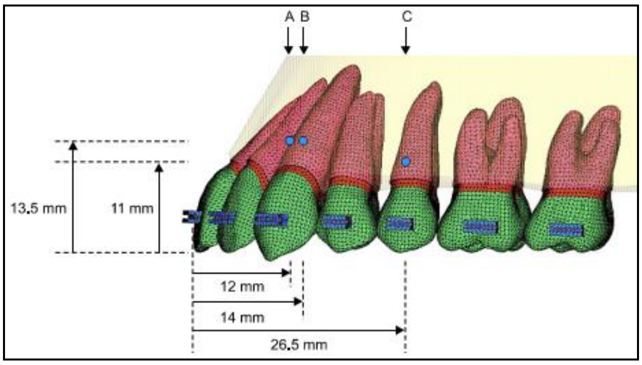

Fig. 2 Position of the center of resistance. A, The center of resistance of four anterior teeth; B, the center of resistance of six anterior teeth; C, the center of resistance of the maxillary dentition.[24]

Differential force system considerations

The force system produced by orthodontic appliances can be dissected into two components: one is force and the other is moment. This force system determines the type of tooth movement presented. The forces act in all three planes of space (first, second, or third order). However, in extraction space closure, the second order (the antero-posterior view) is the most concerned. The components of any force system in antero-posterior are listed as follows (Fig. 3).

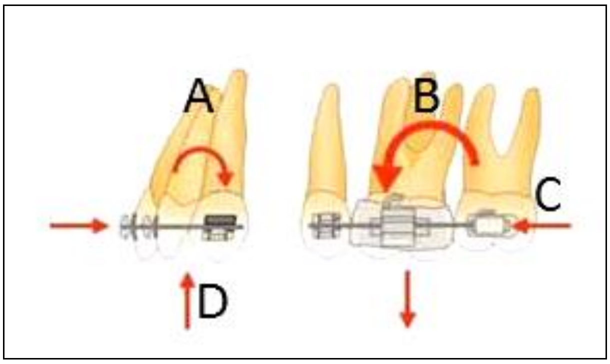

Fig. 3 Force systems. A: Alpha moment; B: Beta moment; C: Horizontal force; D: Vertical force[25]

Alpha moment: This is the moment acting on the anterior teeth.

Beta moment: This is the moment acting on the posterior teeth.

Horizontal forces: These are the mesio-distal forces acting on the teeth. The distal forces acting on the anterior teeth always equal the mesial forces acting on the posterior teeth.

Vertical forces: These are intrusive-extrusive forces acting on the anterior or posterior teeth. These forces generally result from unequal alpha and beta moments. The magnitude of vertical forces is dependent on the difference between the moments and the bracket distance.

Friction versus frictionless mechanics on anterior retraction

Orthodontic tooth movement during space closure is accomplished by two types of mechanics as free body tooth movement or by moving of a tooth along an archwire. The first mechanism, e.g. frictionless mechanics, can be achieved by closing loops fabricated either continuous or sectional retraction archwire[26-29]. The second mechanism of moving a tooth along an archwire, e.g. frictional mechanics or sliding mechanics includes either moving the brackets along an archwire or sliding the archwire through the brackets and tubes[28, 30].

Friction-based mechanic (Sliding mechanic)

From the introduction of the Andrews Straight-wire® Appliance in the 1970s, this innovation allows sliding mechanics or movement of groups of teeth along an archwire because all bracket slots lay in the same level after the levelling phase. Orthodontic space closure with sliding mechanics, there is friction as the important factor between an archwire and bracket slot which leads to delay in tooth movement, and increase in anchorage requirement, or both [31, 32]. Friction is defined from the glossary of orthodontic terms [13] as a resistance to the relative displacement of contacting bodies in a direction tangent to the plane of contact, plays a significant role in sliding mechanisms. However, the greatest benefit of using this technique compared to the use of closing loops is the minimal wire-bending required[33]. And this technique is superior patient comfort (hygiene problems, soft tissue irritation) than the looped wires[28].

To reduce the friction, there is several numbers of factors influencing frictional forces during orthodontic tooth movement. The sizes and material of bracket slot, the bracket width, the dimension and material of archwire are clinically important factors to select the type and size of orthodontic appliances for space closure with sliding mechanics.

The role of friction in sliding mechanics

During utilization of sliding mechanics, friction always occurs at the bracket-wire interface. Frank and Nikolai[32] stated that the tooth movement is initiated once the generated orthodontic force exceeds the maximum static frictional forces. Therefore, some of orthodontic force applied is dissipated by friction, and the remaining force is caused the tooth movement (Fig. 4). The amount of applied force lost due to the resistance to sliding is ranged from 12% to 60%[34]. From this knowledge, the optimal range of forces necessary for tooth movement with sliding mechanics is sufficient magnitude of forces to adequately overcome friction and lie within the optimum force value for tooth movement.

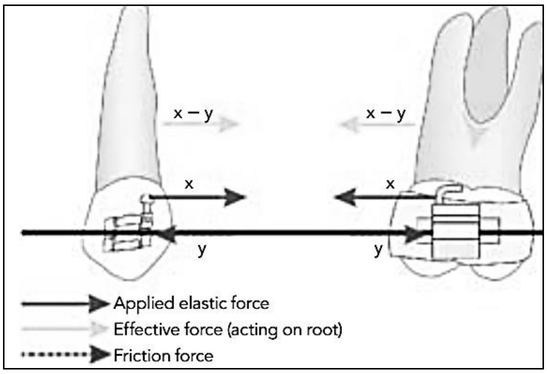

Fig. 4 Representation of how orthodontic force applied is dissipated by friction[35]

The force systems in sliding mechanics

Understanding of two factors: one is type of force system required to produce a given center of rotation and the other is optimal force magnitudes, is critical for tooth movement.

Therefore, a force with a line of action passing through the center of resistance will produce translation of the tooth. However, in most instances, it is not practical to place a line of force through the center of resistance due to anatomical limitations in the oral cavity. To overcome this problem with the point and the line of force attack at the level of crown tooth, a proper force system must be placed on the crown of tooth at the bracket to create a moment which is equal in magnitude and opposite in direction to the moment resulting from the force applied at the bracket

Retraction forces

Point of force application

The point of force application is one of the important factors to be considered in sliding mechanics. Since the tooth movement resulting from a force delivered at the bracket depends on the distance of the line of application of the force from the center of resistance. The more the retraction force is far away from the center of resistance, the greater the magnitude of moment of the force, and the greater the chance of palatal crown tipping of the maxillary incisor teeth.

Optimum forces for en-masse retraction

For en-masse retraction with sliding mechanics to occur and friction to overcome, what is the optimal force for tooth movement?

From many previous studies, the optimal force used for maxillary anterior teeth retraction varies according to different authors. In 1989, McLaughlin and Bennett[33] suggested that 150g was proper amount of force for maxillary en-masse retraction during sliding mechanics. In 1992[36], they also went onto suggest that a force of 100g to 150g is required bilaterally to retract the maxillary labial segment during overjet reduction. Additional studies by M W Heoa[14] in 2007, Upadhyay[37] in 2008, Kumar et al[38] in 2009and S.S. Chopra[39] in 2015 also used bilaterally 150g of force for en-masse retraction with sliding mechanics.

Control of mechanical side effects during space closure

Antero-posterior aspect

From the antero-posterior view (the third order), the critical side effect during space closure is the tipping of the anterior and posterior segments into the extraction site. Increasing the alpha and beta moment is a correction method for these side effects (Fig. 5)[40].

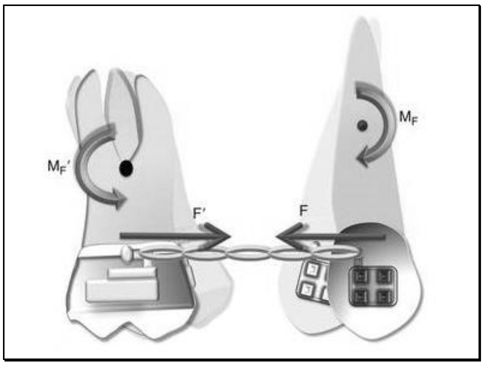

Fig. 5 Antero-posterior perspective[41]

In the 1989 and 1990, McLaughlin and Bennett propose a method of controlled space closure using sliding mechanics[33, 42]. The authors recommend the method consisting of a large and rigid archwire for overbite control and extra-palatal root torque on maxillary incisor brackets and anti-distal crown tipping on maxillary canine brackets for inclination control of the incisor teeth during en-masse retraction. The rectangular 0.019×0.025 steel wires are recommended with the 0.022 slot. However, from case report in 1990, the effect of this method on maxillary anterior teeth were palatal crown tipping about 11^{o} (1 to Max. plane)[43]. Two reasons causing loss of palatal root torque control on the maxillary incisor teeth; one is a small area of torque application compared with the bulk of the tooth and the other is slop of play about 10^{o} between the rectangular 0.019×0.025 steel wire and the 0.022 slot (Fig. 6). As a result of the inefficiency of preadjusted brackets in delivering torque, it is necessary to add torque into the incisor teeth in order to control the inclination during en-masse retraction.

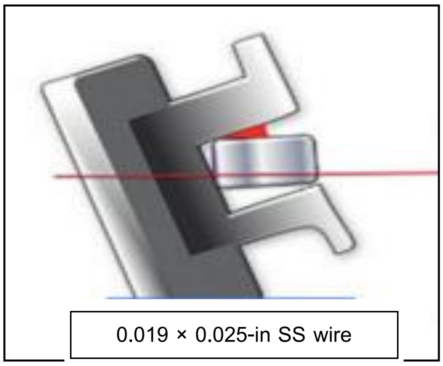

Fig. 6 A rectangular 0.019×0.025-inch steel wire in 0.022-inch slot will have approximately 10^{o} of slop.

In the 2001, Bennett and McLaughlin add 10^{o} – 20^{o} palatal root torque by curving on the rectangular steel wires (Fig. 7). These torque changes contribute to the bite-opening process. Placing a bite-opening curve in the maxillary archwire increases the inclination control of the maxillary incisor teeth during retraction. Nevertheless, treatment effect of the rigid archwire combined with the bite-opening curve are palatal crown tipping of the maxillary incisor teeth. According to case report in 2001, the effect of palatal crown tipping approximately 17^{o} occurred after en-masse retraction with this method. Likewise the effects from many of previous studies[14, 15, 44, 45], range of palatal crown tipping 11^{o} – 16^{o} presented after the retraction.

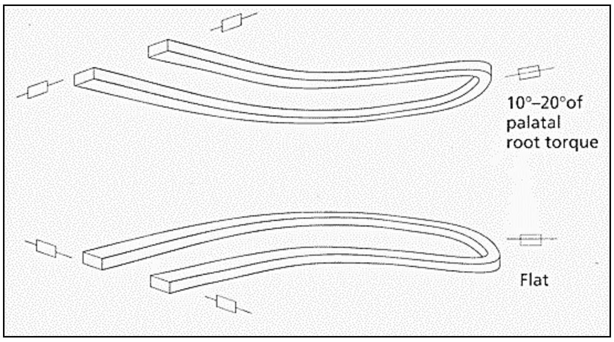

Fig. 7 Bite-opening curves in maxillary and mandibular rectangular steel wires

Vertical aspect

This palatal crown tipping of maxillary incisor teeth also brings the incisal edges downward, which is bad if maintaining or decreasing incisor display and correcting an anterior deep bite is needed. During en-masse retraction, maxillary incisor teeth need simultaneous retraction and intrusion of the anterior teeth to avoid bite deepening.

En-masse retraction of the six maxillary anterior teeth with bite-opening curve as proposed by Bennett and McLaughlin in 2001[46] is one of techniques that makes retraction and relative intrusion to prevent the bite deepening. However, the curve of this wire makes labial crown torque on maxillary incisors and mesial crown tipping on the maxillary canines that conform to shape of the curve with few intrusive forces on the incisor teeth (Fig. 8).

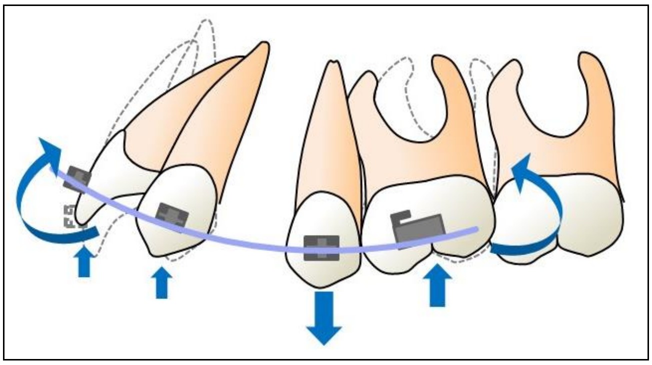

Fig. 8 Diagrammatic representation of the force system of the bite-opening curves in maxillary arch

In comparison with asymmetrical V-bend mechanics, intrusion force on the maxillary canines and the maxillary incisors teeth will be provided if the V-bend is placed closer to the premolar bracket and located between 1/3-1/2 of inter-bracket distance of the premolar-canine. Therefore, a larger counter-clockwise moment will occur at the premolar and a smaller clockwise moment will occur at the canine (Fig. 9). Note that the directions of the moments are opposite. Static equilibrium is reached with counter-clockwise rotation and intrusion on the canine and extrusion on the premolar. The magnitudes of the intrusive forces of this mechanics are higher than the ones in the bite-opening curve. So, if this force is an optimal intrusive force for the six maxillary anterior teeth intrusion and not much for optimal extrusive forces of the premolar-molar extrusion, the asymmetrical V-bend mechanics is superior technique to control the inclination and vertical position of the six maxillary anterior teeth during en-masse retraction.

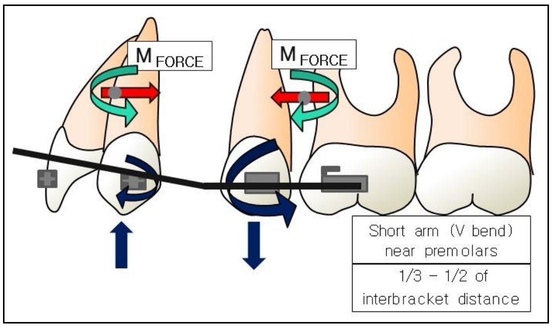

Fig. 9 Diagrammatic representation of the force system of the asymmetrical V-bend in maxillary arch

Occlusal aspect

From the occlusal view (the first order), the major side effect during space closure is mesio-palatal rotation of the molars and disto-palatal rotation of canines (Fig. 10) The horizontal forces are applied buccally to the center of resistance of the molar and canine. So, there is a moment of the force causing these rotations.

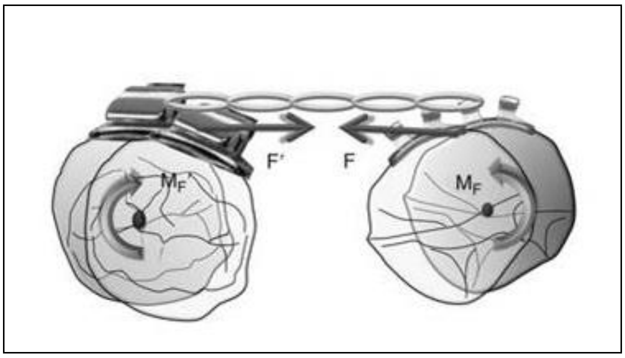

Fig. 10 Occlusal perspective[41]

Control of the molar rotation can accomplish with a rigid transpalatal arch. Toe-in bend is another method to control this rotation on the molars that is easier and effective approach than the transpalatal arch with laboratory processing-needed.

Frictionless-based mechanics

Space closure in frictionless mechanics can be achieved by closing loops fabricated either continuous or segmented archwire technique.

Loop mechanics in continuous archwire

Loop mechanics uses closing loop for generating forces to move teeth. There is no friction generated between wire and bracket. Hence forces are applied directly to the teeth. Loop designs have evolved from simple vertical loops[47] to present more complex loop designs, such as tear drop loops[48], T-loops[49, 50], L-loops, and Gjessing's springs[51, 52] to achieve better moment/ force ratio and constant delivery of force.

The continuous archwire technique is performed with a closing loop bent on the main archwire. No matter the technique, the spring characteristics of a closing loop is a critical part of its design that are determined by three factors, namely, size of the arch wire, configuration of the loop, and distance between points of attachment (inter-bracket distance)[41].

There are several disadvantages to use this method for space closure. Extra wire bending time was needed, patients discomfort due to impingement of the closing loop on gingival mucosa, causing hygienic problems and the mechanism had only a short range of activation[53]. Therefore, the closing loop archwires are not recommended for routine space closure with preadjusted brackets.

Orthodontic anchorage

Fundamentally, anchorage is defined as the amount of the movement of the posterior teeth (molars, premolars) to close the extraction space to achieve planed orthodontic treatment. Additional definition by Graber[54] is "the nature and degree of resistance to displacement offered by an anatomic unit for the purpose of effective tooth movement".

Using differential moments for anchorage control

To obtain differential tooth movement (i.e. anchorage control), biomechanical strategies using differential moments must be incorporated into the appliance design. Changing the mesio-axial inclination of buccal teeth to disto-axial inclination can increase posterior anchorage because this technique resists to mesially pulling force. This mechanics is known as "the differential moment" from Begg technique[55]. There is no need to use auxiliary appliances but control the anchorage only with intra-arch bends. Moreover, this mechanics nullify the concept of multiple teeth on the anchorage side to form large reactive units.

The most practicable treatment option for maxillary dental protrusion is to extract the maxillary first premolars and/or mandibular premolars [4]. In this extraction space, it presents a long interbracket distance between canine bracket and the second premolar bracket (at least 13 mm initially). Using an off-center V-bend closing to the premolars, which cause a higher moment on the posterior segments results in mesial root torque. This mechanics provides the premolars and the molars becoming the source of anchorage.

With this mechanics, anchorage is obtained with placement of tip-back bends to produce differential torque. The tip-back bend is an off-center bends that is located between the canine and the second premolar brackets. The posterior (beta) moment is more than the anterior (alpha) moment. This smaller moment could be upward and forward, downward and backward or absent depending on the location of the tip-back bends.

Rajcick and Sadowsky[40] used the 45° tip-back bend to control maximum anchorage without bonding the maxillary second premolars for retraction of maxillary canines.

Nevertheless, differential moments are not without side effects. The unequal moments must be balanced by a third moment. This third moment is a pair of vertical force, intrusive force to the anterior teeth and extrusive force to the posterior. No matter what the strategy, some biomechanical side effects will occur. The proper selection of appliance design depends on the comparative disadvantages or advantages of those side effects.

Conceptual framework

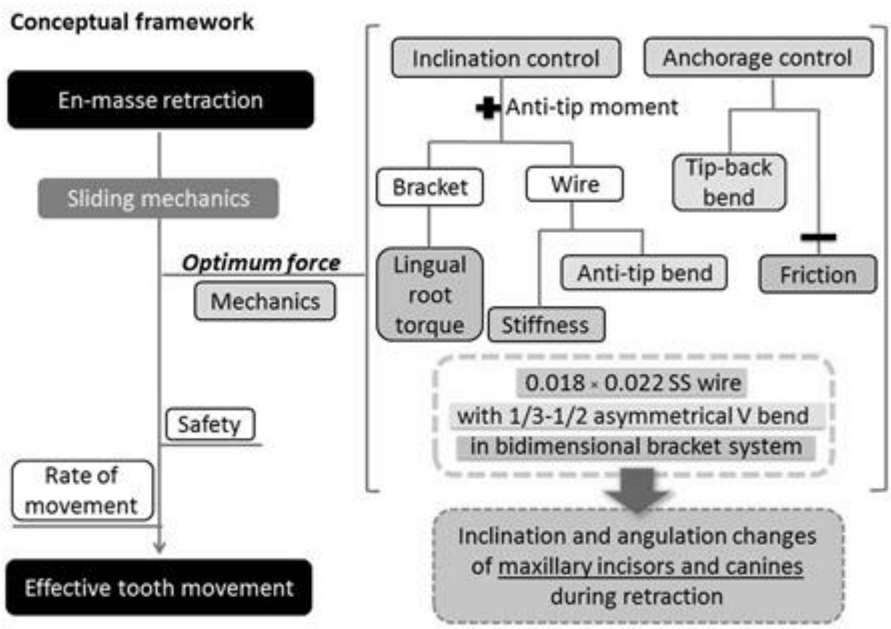

Fig. 11 Conceptual framework

Objectives

To investigate the treatment effects of an en-masse retraction system with the asymmetrical V-bend on dental changes of the maxillary anterior teeth (canines and incisors) and posterior teeth (the second premolars and the first molars) between pre- retraction and post-4 months of retraction as followed:

1. To present amount of horizontal changes
2. To compare amount of inclination/ angulation changes
3. To compare amount of vertical changes
4. To present rate of en-masse retraction as represented by the horizontal movement of the maxillary central incisors within a month
5. To present rate of anchorage loss as represented by the horizontal movement of the maxillary first molars within a month
6. To compare amount of rotational changes
7. To compare amount of dental archwidth changes

Hypothesis

When the en-masse retraction system with the asymmetrical V-bend was used, the null hypothesis tested were that:

1. The horizontal change in the maxillary central incisor position on pre-retraction and post 4 months of retraction would have significant differences, indicating the incisors were significantly retracted posteriorly.
2. The horizontal change in maxillary first molar position on pre-retraction and post 4 months of retraction would not have significant differences, indicating the molars were insignificantly moved mesially.
3. The inclination change in the maxillary central incisor on pre-retraction and post 4 months of retraction would have significant differences, indicating the incisors proclination would be minimized.

4. The angulation change in the maxillary first molar on pre-retraction and post 4 months of retraction would have significant differences, indicating the molars would be distal crown tipped.
5. The vertical change in the maxillary central incisor on pre-retraction and post 4 months of retraction would not have significant differences, indicating the incisors would have similar vertical position.
6. The vertical change in the maxillary first molar on pre-retraction and post 4 months of retraction would not have significant differences, indicating the molars would have similar vertical position.
8. The rate of en-masse retraction would be observed and presented as the horizontal movement of the maxillary central incisors within a month.
9. The rate of anchorage loss would be observed and presented as the horizontal movement of the maxillary first molars within a month.
10. The rotational change in the maxillary canines, second premolars, and first molars on pre-retraction and post 4 months of retraction would not have significant differences.
11. The archwidth change in the maxillary canines, second premolars, and first molars on pre-retraction and post 4 months of retraction would not have significant differences.

Significance of the study

If the study found that the maxillary anterior teeth could be retracted with maximum anchorage control and reduced proclination with provided vertical control of the incisors tooth, this en-masse retraction system with the asymmetrical V-bend could be another technique for treating in the adult maxillary protrusion patients.

CHAPTER 2

RESEARCH METHODOLOGY

Samples

This study was approved by Ethics committee on human experimental of Faculty of Dentistry, Prince of Songkla University.

The sample size used for this study was calculated by using the Power and Sample Size Calculation software (PS); version 3.0.43 (Vanderbilt University, Nashville, TN).

The values of parameters were taken from the study of Liu et al[45] as follow:

$\overline{X}_2$-$\overline{X}_1$ (difference of mean values between before and after treatment of vertical changes of the maxillary central incisors) was 1.17.

SD diff (difference of standard deviation between before and after treatment of inclination changes of the maxillary central incisors) was 1.5

The level of significance of the change was established at 95% (α=0.05).

The power of the test in this study was established at 80% (β =0.2).

From the sample size calculation, 15 patients were necessary.

The samples were recruited from patients who received orthodontic treatment at orthodontic clinic in the Faculty of Dentistry, Prince of Songkla University. The inclusion criteria were:

1. Male or female adult patients, age range between 18-30 years
2. Maxillary dental protrusion with Angle Class I or Angle Class II division 1 malocclusion
3. From treatment plan, bilaterally extraction of the maxillary first premolars was required.
4. Presence of residual extraction space at least 4 mm after leveling and correction of crowding
5. Need of maximum anchorage control

6. No underlying disease.
7. No sign and symptoms of periodontal disease

The exclusion criteria were:

1. Space between the canines and the second premolars were remained less than 4 mm.
2. Anchorage loss have occurred and the remaining space to allow losing was less than 1 mm.
3. Failure to bond the attachment in maxillary arch during period of the study
4. The patients whose taking NSAID during period of the study

All of patients were given detailed about experimental procedure and willing to participate. Then, the orthodontist informed the patients in detail about oral and written information of the study and the consent form was signed prior to the study. The patients had received standardized instructions on oral hygiene procedures for using of toothbrush, dental floss, and proxabrush during the treatment period. Moreover, the patients were instructed to avoid non-steroidal anti-inflammatory drugs in the period of study. In case of toothache due to orthodontic procedure, the patients were instructed to take acetaminophen for reducing the pain.

Material and method

Treatment sequences of en-masse retraction

1. Roth's prescription preadjusted edgewise fixed appliances (Ormco™) with 0.018 × 0.025- inch slots were bonded on the six maxillary anterior teeth and 0.022 × 0.028- inch slots were bonded on the premolars and 0.022 x 0.028- inch buccal tube for the first molars. During the period of the study, the second molars were not bonded.
2. In the maxillary arch, 0.012- inch round NiTi wires were used as starting archwires in all cases without the first premolar extraction and progressed to 0.018 × 0.022- inch rectangular stainless steel archwire (Highland Metals Inc, San Jose, Calif), which was maintained at least 4 weeks to ensure the archwire be passive in the bracket slots. The maxillary teeth were grouped with 0.010" stainless steel ligature as an anterior unit (from the right canine to the left canine) and a posterior unit (the second premolar and the first molar on each side). After that, bilaterally extraction of the maxillary first premolars was done.
3. 2 Weeks after extraction, the patients were recalled to follow-up wound healing. When the 0.018 × 0.022- inch stainless steel archwire had been in placed at least 4 weeks, pre-retraction data (T1) was recorded consisting of taking maxillary and mandibular alginate impressions and lateral cephalometric radiograph.
4. Then, the maxillary anterior en-masse retraction was started with the 0.018 × 0.022- inch stainless steel archwire which was bent bilaterally with an asymmetrical V-bend and heat-treated[56]. The bend was placed between one-third to one-half of the interbracket span between the mesial wing of the second premolar brackets and the distal wing of the canine brackets. With this placement of the asymmetrical V-bend, short segment was located closer to the premolar (Fig. 12A). Angulation of the asymmetrical V-bend were indicated from an *in vitro* test which depending on amount of the residual space distal to the canine.

5. To stabilize the forming of the asymmetrical V-bend, a heat-treating process[56] on the archwire were done by passing the archwire repeatedly through the flame of an alcohol lamp until a reddish-brown colour was observed.
6. After that, the archwire was inserted into the bracket slots and the buccal tube and confirming position of the asymmetrical V-bend located between one-third to one-half of the interbracket span. After that, the archwire was cinched exactly at distal end of the molar buccal tube with a weing guard plier. For archwire ligation, stainless steel ligature wires were used on the premolars to reduce amount of friction registered during sliding mechanics, while elastic ligatures were used on the anterior teeth.
7. The six maxillary anterior teeth were en-masse retracted by applying 150 g of force bilaterally with 8-mm length NT coil springs of heavy grade (Dentos Inc, Daegu, South Korea). The NT coil springs were extended between hooks of the molar buccal tubes and the hook of the canine brackets (Fig. 12B). The force was measured with a Correx tension gauge™ (Dial-type stress and tension gauge; Dentaurum Germany) to control the en-masse retraction force.
8. At each follow-up visit, the archwire was removed and the position of the V-bend was adjusted to place between one-third to one-half of the interbracket span and match with the remaining space. The angulation of the asymmetrical V-bend was maintained in the same degree for 4-month period of the study.
9. After 4 months of the maxillary anterior en-masse retraction, the maxillary and mandibular alginate impressions and lateral cephalometric radiograph were repeatedly taken for post 4-month retraction data (T2).

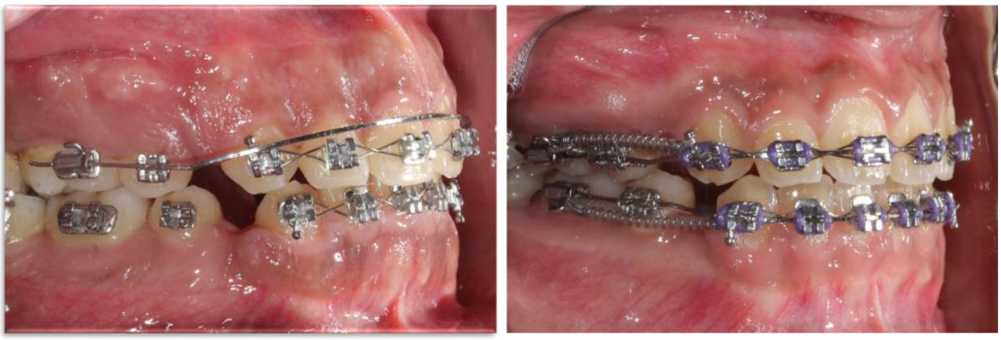

Fig. 12: **A:** An asymmetrical V-bend archwire placed between 1/3 to1/2 of inter-bracket span, **B**: En-masse retraction with the asymmetrical V-bend

***In vitro* test to determine the angulation of asymmetrical V-bend**

This study developed the six maxillary anterior teeth retraction system with providing maximum anchorage control. The asymmetrical V-bend placed on a 0.018” × 0.022” stainless steel archwire was used for obtaining a desired mechanic and identified to locate between 1/3 to 1/2 of interbracket span between the mesial wing of the second premolar brackets and the distal wing of the canine brackets, which the short segment was placed closer to the premolars. To determine angulation of the V-bend, amount of optimal intrusive force exerted on a group of the maxillary anterior teeth was considered to estimate the angulation. From literature reviews, there were many force levels used for intrusion of the six maxillary anterior teeth. Proffit[57] suggested 10-20 g in a movement of intrusion of individual anterior teeth should be applied. Therefore, an optimal intrusive force for the six maxillary anterior teeth was approximately 80 g. This amount of force was used to determine the angulation of the asymmetrical V-bend and then converted to be a specific height of deflection in relation to the degree of angulation (Fig. 13). However, the limitation of this study was unpredictable and inexplicable the moments and the forces transferred from the continuous archwire to each tooth on the maxillary teeth.

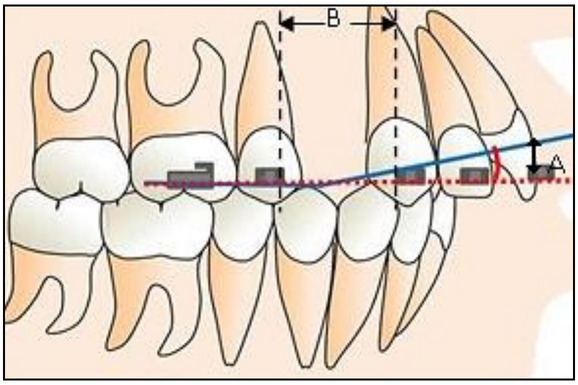

Fig. 13 The height of archwire deflection (A) in relation to the degree of angulation of the asymmetrical V- bends

In this study, a load-deflection test was conducted using an universal testing machine to measure the degree of deflection distance that the archwire produced the optimal intrusive force (80 g). The samples consisted of fifteen 0.018 × 0.022 inch of stainless steel archwires. All archwires were bent at 1/3 – 1/2 of inter-bracket distance as V-bend between the second premolar brackets and the vertical line of the canine brackets with the shorter part placed closer to the premolar brackets. The reference inter-bracket distances were 9, 10, 11, 12 and 13 mm, respectively. Three archwires for each inter-bracket distance were tested. The values of mean and standard deviation of each inter-bracket distance were calculated. From laboratory investigation (Fig. 14), we found there were different degree of the deflective distances on the V-bend depending on the distance of the inter-bracket span. It was presented that the longer inter-bracket distance, the greater deflective distance was needed to generate the deactivation force of approximately 80 g. In this study, the mean values of each deflection range in vertical direction were used as a guideline to be an appropriate height of the asymmetrical V- bends (Table 1).

Fig. 14 Universal testing machine and testing method

Table 1: Tensile forces measured in simulated the decreasing of inter-bracket distance

Interbracket distance (mm)	Deflective range (mm)	Deactivation force (g)	
		Mean	SD
13	7	83.22	3.31
12	6	82.89	1.83
11	4.5	78.44	1.42
10	4	79.89	1.36
9	3.7	79.56	1.13

SD, standard deviation

Records and data analysis

Cephalometric analysis

Lateral cephalometric radiographs were taken from natural head position which the patient was in the cephalostat and looked straight ahead into a mirror. The patient was observed from the side to confirm that the pupil was in the middle of the eye, and the head was repositioned if there was even a slight discrepancy. As the patient began to feel comfortable with a relaxed position that the head was not tilted or tipped[58]. The lateral cephalograms were done before the beginning of maxillary anterior teeth retraction (T_1) and after 4 months of the retraction (T_2). Tooth positional locating devices (wire jigs) fabricated from section of 0.018 × 0.025-inch stainless steel wire were inserted to bracket of the canines, the second premolars and the molar buccal tubes before taking T1 and T2 radiographs. These wire jigs allowed the operator to locate the angulation and separate the right side from the left side of the teeth. The vertical part of the wire jigs was bent perpendicularly to long axis of these teeth. For the right side, the wires were bent into a circular shape and the other side were bent into a rectangular shape (Fig. 15). Same wire jigs using in T1 were repeatedly inserted on the tooth at T2.

Fig. 15 Tooth positional locating devices (wire jigs) on the right and left sides

In this study, the same cephalostat and cephalometric X-ray machine were used for taking all lateral cephalometric radiographs. Cephalometric tracing was drawn on a piece of acetate paper, and then reference points and lines were marked for the determination of angles and linear by one observer with 0.3 mm fine point of a mechanical pencil to avoid interoperating errors. Linear and angular measurements were measured by the same protractor. Repeating the tracing of 10 randomly selected lateral cephalograms were done independently at least 4 weeks after the initial tracing to evaluate intraoperator error. The Method error (ME) in locating and measuring the changes of each landmarks were calculated by Dahlberg's formula[1]. Total error about 0.1 mm for linear measurement and 0.2 degree for angular measurement were acceptable levels of accuracy[60].

References and measurements on the lateral cephalometric analysis that used in this study were partly applied from the study of Pancherz et al[61]. With using S-N plane to construct a reference line, it was rarely changed and easy to construct when compare to another reference line such as Frankfort plane or occlusal plane[61]. Therefore, distance and angular measurement made between the pre-retraction and the post 4-months of retraction could ensure that they were quantified from the same S-N line. To investigate the dental changes in this study, changes of the tooth in sagittal dimension, vertical dimension, and angular dimension were assessed from the cephalograms (Fig16-19). The mean and standard deviation of the cephalometric values were presented and compared the result between T1 and T2 data.

Reference points (Fig. 16):

- S (sella): the midpoint of the cavity of sella turcica
- N (nasion): the anterior point of the intersection between the nasal and frontal bones
- U1O: the most incisal point on the crown of the maxillary central incisor
- U1A: the root apex of the maxillary central incisor
- U3O: the most cusp point of the maxillary canine
- U3A: the root apex of the maxillary canine
- U3D: the most anterior point on the distal outline of the crown of the maxillary canine
- U5O: the buccal cusp point of the maxillary second premolar
- U5M: the most anterior point on the mesial outline of the crown of the maxillary second premolar
- U6MB: the mesio-buccal cusp point of the maxillary first molar
- U6M: the most anterior point on the mesial outline of the crown of the maxillary first molar

Reference lines:

- Occlusal line Sella (OLs): the horizontal reference line that parallel to the occlusal plane passing sella[62]
- Occlusal line perpendicular (OLp): the vertical reference line that perpendicular to the OLs passing sella[63]
- SN plane (SNL): the line connecting the sella (S) to the N point
- Occlusal plane (OP): the bisecting line cdrawn between the overlapping regions of the first permanent molar and second premolar cusp[63]
- U1axis (long axis of the maxillary central incisor): the line connecting 1in to 1apex

<u>Linear measurements</u>:

- Horizontal linear measurements (Fig. 17): the measured by the distance from the occlusal line perpendicular (OLp) to U1O, U1A, U3O, U3A, U3D, U5M, and U6M to evaluate the dental horizontal changes
- Vertical linear measurements (Fig. 18): the measured by the distance from the occlusal line Sella (OLs) to U1O, U1A, U3O, U3A, U5C, and U6MB to evaluate the dental vertical changes

<u>Angular measurements</u> (Fig. 19):

- U1-SN: the angle formed from the long axis of the maxillary incisor (1axis) and the SN plane (SNL)
- U3-SN: the angle formed from the vertical part of wire jig of the canine and the SN plane (SNL)
- U5-SN: the angle formed from the vertical part of wire jig of the second premolar and the SN plane (SNL)
- U6-SN: the angle formed from the vertical part of wire jig of the molar and the SN plane (SNL)

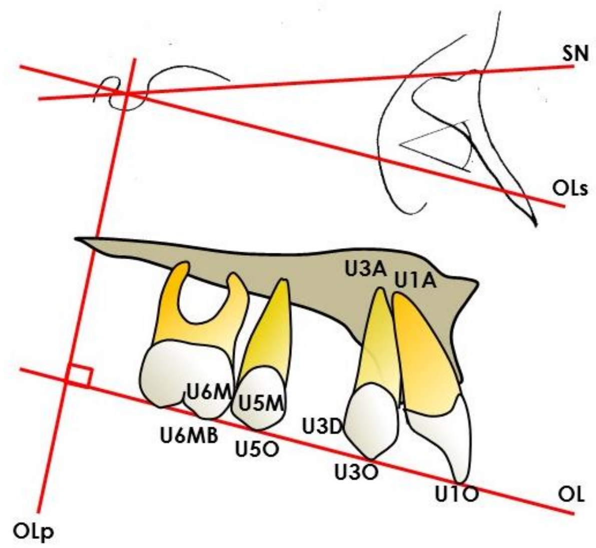

Fig. 16 The cephalometric reference points

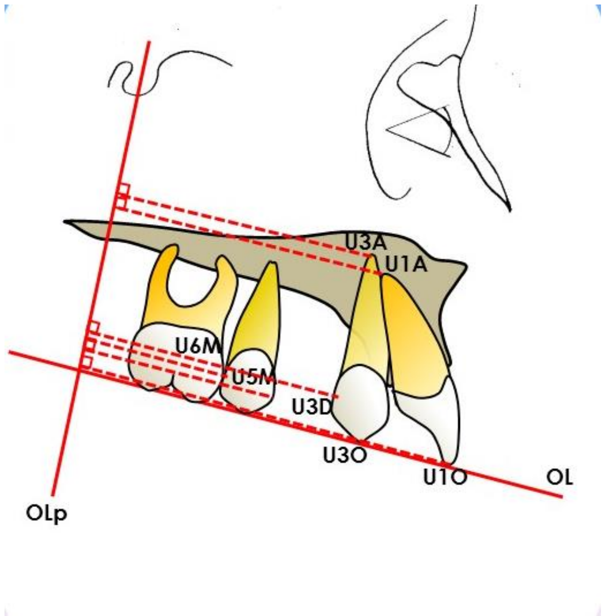

Fig. 17 Cephalometric landmarks and reference lines for the horizontal measurements

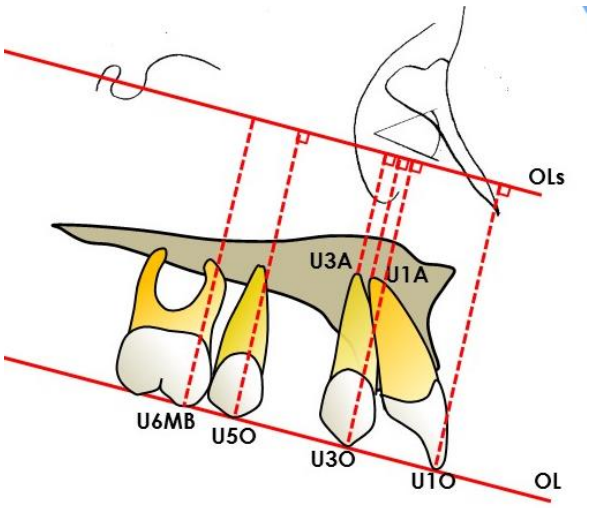

Fig. 18 Cephalometric landmarks and reference lines for the vertical measurements

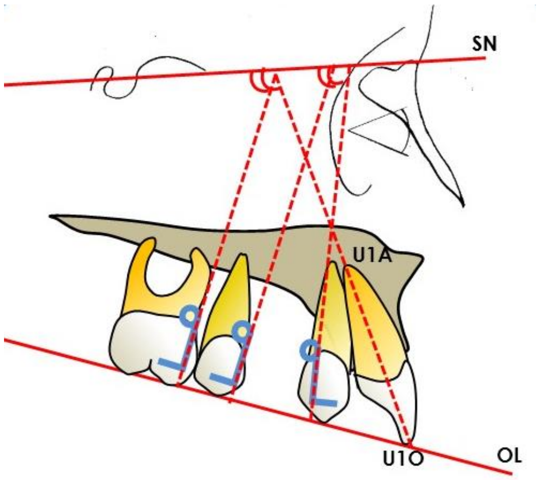

Fig. 19 Cephalometric landmarks and reference lines for the angular measurements

Digital model analysis

After taking maxillary and mandibular alginate impressions and fabrication study models, computing and fabricating three-dimensional (3D) digital models were produced on the pre-retraction (T1) and post-retraction (T2) models with a 3D digital scanner (3-Shape's R700™ Scanner, 3Shape, Copenhagen, Denmark) (Fig. 20). The 3D digital models were measured via a specific 3D software (3D Software OrthoAnalyzer™, 3-Shape, Copenhagen, Denmark). Superimposition of the digital models between T1 and T2 models was processed with contouring surface of the posterior region of the palatal vault and pointing on the medial point of the third palatal rugae bilaterally[64]. These reference area and points were used for digital model superimposition (T1 and T2 digital model). Rotational and arch width changes in the canines, the premolars, and the molars position were measured from the digital modeling[65].

Fig. 20 Generating the 3D digital model with a specific 3D scanner (3Shape R700™)

<u>Arch width measurement</u>: (Fig. 21)

- Inter molar width (IMMW): the distance between the mesiobuccal cusp tip of the right and left maxillary first molars
- Inter molar width (IMDW): the distance between the distobuccal cusp tip of the right and left maxillary first molars
- Inter premolar width (IPW): the distance between the buccal cusp tip of the right and left maxillary second premolars
- Inter canine width (ICW): the distance between the cusp tip of the right and left maxillary canines

<u>Rotational measurement</u>: (Fig. 22)

- Molar rotation (^{o}): the angle between the midpalatal raphe line and the line passing through the distobuccal and mesiopalatal cusp tips of the maxillary first molar
- Premolar rotation (^{o}): the angle between the midpalatal raphe line and the line through the second premolar axis
- Canine rotation (^{o}): the angle between the midpalatal raphe line and the line through the mesial to distal contact points of the canine

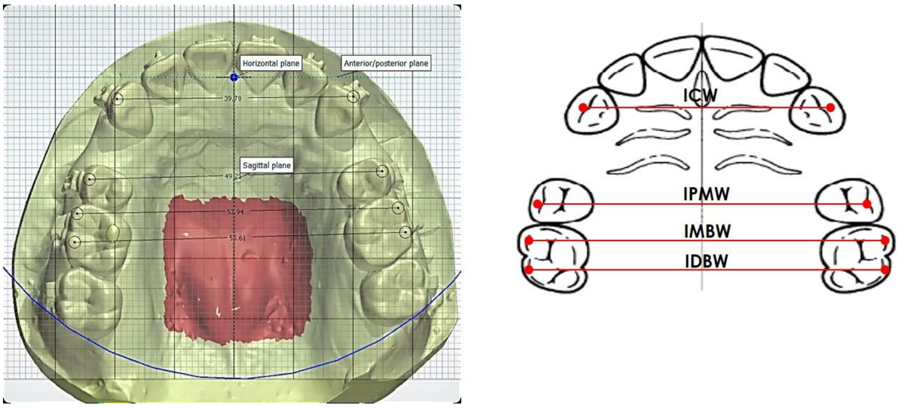

Fig. 21 The measurements of arch width on the digital model

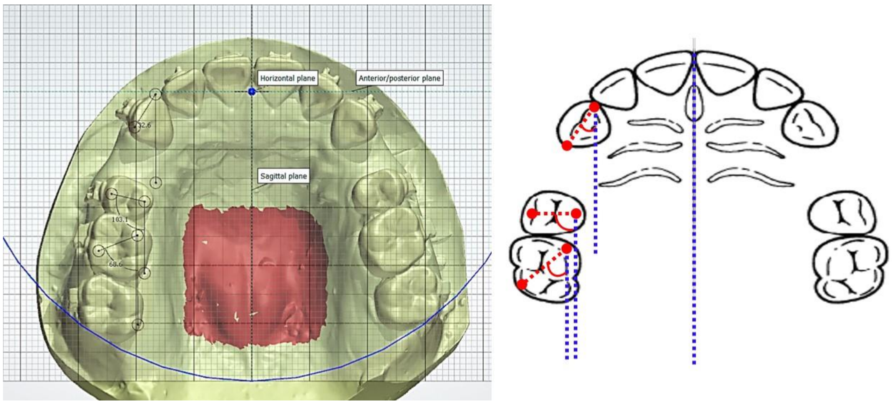

Fig. 22 The measurement of rotation on the digital model

Error of measurements

Ten lateral cephalometric radiographs and ten study models were remeasured at least 4 weeks apart. These measurements were analyzed to compare to the mean of the initial measurements using the formula of Dahlberg[59]:

$$\text{Method error} = \sqrt{\sum d^2/2n}$$

d: The difference between duplicated measurements

n: The number of double measurements

With the repeatability coefficient, the calculated The Intraclass Correlation Coefficient (ICC) also was assessed.

Statistical analysis

Data was analyzed by using the statistical software program; a predictive analytics software Statistics version 22.0 (SPSS Inc., Chicago, IL, USA). Means and standard deviations of the dental changes in all of the measurements were determined. The Shapiro-Wilk test was used to examine distribution of both cephalometric and digital model results. In this study, the data did not have normal distribution, the differences between the 2 dependent measurements was evaluated with a Wilcoxon signed-ranks test at an alpha significance level of 0.05.

CHAPTER 3

RESULTS

There were 17 subjects participated in this study which divided into 16 females and 1 male. Their average age at the start of treatment was 20.44 ± 4.75 years (Table 2). Mean of the experimental treatment time was 3.97 ± 0.10 months.

An initial morphologic characteristics of the subjects was diagnosed as skeletal class I with normodivergent pattern. The maxillary central incisor was indicated protruded and slightly proclined (Table 3).

Table 2: Sex and age at the start of treatment of all subjects

Subjects	n	mean (year)	SD
Female	16	20.26	4.84
Male	1	23.30	-
Total	17	20.44	4.75

n, number of subjects; SD, standard deviation

Table 3: Pre-treatment morphologic data

Parameter	Thai norm[66]	Pretreatment	
		Mean (year)	SD
SNA (°)	85 ± 4	84.56	3.22
SNB (°)	82 ± 4	79.85	2.94
ANB (°)	3 ± 2	4.71	1.94
SN-MP (°)	29 ± 6	34.41	4.24
Occl-SN (°)	14 ± 2	18.85	3.71
U1-NA (mm)	5 ± 2	8.24	1.11
U1-SN (°)	108 ± 6	113.94	5.91

Magnification and measurement error analysis

Ten lateral cephalometric radiographs and ten study model were re-traced, re-modeled, and finally re-measured. The random measurement error (ME) were calculated according to Dahlberg's formula. Method error for measurement of the lateral cephalogram were about 0.1 mm and 0.2 degree for the linear and the angular measurement, respectively. For measurement of the 3D digital model, the method error were 0.02 mm and 0.06 degree for the distance and the angular measurement, respectively. Intraclass correlation coefficient showed no significant difference between two series of the measurements. Consequently, the method was found to yield sufficient reliability.

Cephalometric findings

The treatment effects of the en-masse retraction system with asymmetrical V-bend were presented as descriptive statistics on movement of the maxillary central incisors, canines, second premolars and first molars. The results are as follows (Table 4-7):

1. The incisor response
   - The horizontal changes showed statistically significant in the crown movement -2.7 ± 0.50 mm (U1O-OLp) and also presented at the root movement about -1.94 ± 0.58 mm (U1A-OLp).
   - The angular changes showed statistically significant in decreasing of inclination about -3.00° ± 0.85° (U1-SN). For the quantification of incisors movement (Table 6), they were retracted by controlled tipping and partly by translation (U1A/U1O = 0.71 ± 0.12).
   - The rate of incisor retraction was 0.68 ± 0.12 mm/ month. (Table 6)
   - The vertical changes measured at the maxillary central incisor showed statistically significant. It was presented intrusion at the crown about -0.24 ± 0.31 mm (U1O-OLs) and also presented the intrusion at the root about -0.85 ± 0.49 mm (U1A-OLs).

2. The molar response
   - The horizontal changes, there were statistically significant in mesial movement of the first molars about 0.29 ± 0.27 mm (U6M-OLp).
   - The angular changes showed statistically significant in decreasing of angulation about -1.78° ± 1.15° which was distal crown tipping (U6-SN).
   - The rate of molar mesialization was 0.08 ± 0.07 mm/ month. (Table 6)
   - The vertical changes measured at mesiobuccal cusp of the maxillary first molar showed statistically significant. It was presented intrusion of the molar approximately -0.12 ± 0.65 mm (U6MB-OLs).
3. The canine response
   - The horizontal changes showed statistically significant in crown movement of -2.43 ± 0.46 mm (U3D-OLp) and root movement of -1.71 ± 0.36 mm (U3A-OLp).
   - The angular changes showed statistically significant in decreasing of angulation about -2.96° ± 1.27° (U3-SN). For the quantification of canine movement (Table 6), they were retracted by controlled tipping and partly by translation (U3A/U3O 0.76 ± 0.15).
   - The vertical changes of the maxillary canine showed statistically significant. It was presented intrusion of the canine measured at the cusp tip approximately -0.09 ± 0.15 mm (U3O-OLs) and also appeared the intrusion at the root about -0.63 ± 0.35 mm (U3A-OLs).
4. The premolar response
   - The horizontal changes, there were statistically significant in a mesial movement of the premolar about 0.31 ± 0.31mm (U5M-OLp).
   - The angular changes showed statistically significant in decreasing of angulation about -3.25° ± 1.47° which was distal crown tipping (U5-SN).
   - For changes of vertical movement, there was statistically significant in amounts of the extrusion about 0.35 ± 0.33 mm (U5O-OLs).

Table 4: Dental changes in horizontal measurement (T2-T1) on the cephalometric radiographs

Variables (n = 17)		Min. (mm.)	1st quartile (mm.)	Median (mm.)	3rd quartile (mm.)	Max. (mm.)	Mean±SD (mm.)	P-value
Horizontal measurements								
1A-OLp	T_1	68.50	72.50	74.00	75.50	81.50	74.47±3.14	
	T_2	66.50	70.50	72.50	73.50	80.00	72.53±3.11	
	T_2-T_1	-3.00	-2.50	-2.00	-1.50	-1.00	-1.94±0.58	< .001*
1O-OLp	T_1	85.00	91.75	94.00	96.50	100.50	93.97±3.68	
	T_2	82.50	88.75	91.00	94.00	97.00	91.26±3.64	
	T_2-T_1	-3.50	-3.00	-3.00	-2.25	-2.00	-2.7±0.50	< .001*
3A-OLp	T_1	65.75	68.63	72.25	73.50	76.75	71.47±3.11	
	T_2	64.00	66.88	70.75	71.88	75.50	69.75±3.12	
	T_2-T_1	-2.25	-2.00	-1.75	-1.50	-1.00	-1.71±0.36	< .001*
3D-OLp	T_1	68.00	75.38	76.75	79.13	82.75	76.84±3.47	
	T_2	66.00	72.75	74.00	76.25	80.00	74.41±3.29	
	T_2-T_1	-3.00	-2.75	-2.50	-2.25	-1.50	-2.43±0.46	< .001*
3O-OLp	T_1	75.00	82.38	83.25	84.75	90.00	83.37±3.25	
	T_2	73.00	79.63	81.00	82.50	87.50	81.10±3.13	
	T_2-T_1	-3.00	-2.63	-2.25	-1.88	-1.50	-2.26±0.44	< .001*
5M– OLp	T_1	62.50	69.00	70.25	72.25	77.50	70.19±4.00	
	T_2	63.00	69.13	70.50	72.63	77.50	70.50±4.05	
	T_2-T_1	0	0	0.25	0.50	1.00	0.31±0.31	.002*
6M–OLp	T_1	54.00	60.50	61.75	63.38	69.00	61.65±4.06	
	T_2	54.50	60.75	62.00	63.75	69.00	61.94±4.11	
	T_2-T_1	0	0	0.25	0.50	0.75	0.29±0.27	.003*

SD, standard deviation

*Significance difference compared to T1

$p < .05$

Table 5: Dental changes in angular measurement (T2-T1) on the cephalometric radiographs

Variables (n = 17)		Min. (degree)	1st quartile (degree)	Median (degree)	3rd quartile (degree)	Max. (degree)	Mean±SD (degree)	P-value
Angular measurements								
1-SN	T_1	100.50	107.75	111.50	116.75	125.00	112.21±6.05	
	T_2	98.00	105.50	108.00	113.25	122.50	110.40±5.85	< .001*
	T_2-T_1	-5.00	-3.50	-3.00	-2.50	-2.00	-1.76±1.17	
3-SN	T_1	88.25	96.25	98.00	101.00	104.25	98.16±4.05	
	T_2	85.00	93.13	95.25	98.50	102.00	96.69±4.17	.001*
	T_2-T_1	-5.00	-4.00	-3.00	-2.25	0.50	-1.47±1.26	
5-SN	T_1	68.00	71.38	74.75	80.50	84.25	75.62±5.21	
	T_2	64.50	67.25	72.25	76.13	82.00	72.37±5.56	< .001*
	T_2-T_1	-5.00	-4.63	-3.50	-2.50	0.25	-3.25±1.47	
6-SN	T_1	62.75	63.88	71.00	75.00	78.50	70.40±5.44	
	T_2	59.75	62.63	69.50	73.88	77.25	68.62±5.79	.001*
	T_2-T_1	-4.50	-2.38	-1.75	-1.25	0	-1.78±1.15	

SD, standard deviation

*Significance difference compared to T1

$p < .05$

Table 6: Quantification of tooth movement in the maxillary central incisors, canines, and molars

	Rate of tooth movement (mm/month)	Tipping (degree)	Quantification of tooth movement
Incisors	0.68 ± 0.12	-1.76 ± 1.17	0.71 ± 0.12
Canines	0.62 ± 0.11	-1.47 ± 1.26	0.76 ± 0.15
Molars	0.08 ± 0.07	-1.78 ± -1.78	-

Table 7: Dental changes in vertical measurement (T2-T1) on the cephalometric radiographs

Variables (n = 17)		**Min. (mm.)**	**1st quartile (mm.)**	**Median (mm.)**	**3rd quartile (mm.)**	**Max. (mm.)**	**Mean±SD (mm.)**	**P-value**
Vertical measurements								
1A-OLs	T1	32.00	35.75	40.50	43.50	51.50	39.79±5.20	
	T2	31.00	34.75	39.50	42.75	51.00	38.94±5.24	
	T2-T1	-2.00	-1.00	-1.00	-0.50	0	-0.85±0.49	< .001*
1O–OLs	T1	55.50	58.00	62.00	66.25	75.00	62.35±5.11	
	T2	55.00	57.75	62.00	66.25	75.00	62.12±5.23	
	T2-T1	-1.00	-0.50	0	0	0	-0.24±0.31	.011*
3A-OLs	T1	31.00	33.63	37.00	42.00	50.25	38.00±5.12	
	T2	30.50	32.50	36.25	41.25	50.00	37.37±5.25	
	T2-T1	-1.25	-1.00	-0.50	-0.50	0	-0.63±0.35	< .001*
3O–OLs	T1	54.75	58.13	61.75	66.38	75.00	62.26±5.24	
	T2	54.75	58.00	61.50	66.38	75.00	62.18±5.29	
	T2-T1	-0.25	-0.25	0	.0000	0.25	-0.09±0.15	.034*
5O–OLs	T1	57.25	58.38	61.50	65.63	73.00	62.44±4.54	
	T2	58.00	58.86	61.50	66.13	73.50	62.79±4.50	
	T2-T1	0	0	0.25	0.63	1.00	0.35±0.33	.003*
6MB – OLs	T1	56.75	58.75	61.00	65.63	74.00	62.38±4.67	
	T2	57.00	59.00	61.00	65.88	74.50	62.26±4.66	
	T2-T1	0	0.13	0.25	0.25	0.75	-0.12±0.18	.021*

SD, standard deviation

*Significance difference compared to T1

$p < .05$

Digital model findings

From digital model analysis, there were statistically significant in increasing of dental arch width on all the measurements (Table 8). About rotational changes, there were statistically significant in mesiopalatal rotation that presented on the premolars and the molars (Table 9).

Table 8: Dental arch width changes (T2-T1) measured on the digital models

Variables (n = 17)		**Min. (mm.)**	**1st quartile (mm.)**	**Median (mm.)**	**3rd quartile (mm.)**	**Max. (mm.)**	**Mean±SD (mm.)**	**P-value**
Arch width measurements								
ICW	T1	33.49	37.08	38.16	41.00	41.94	38.43±2.35	
	T2	34.25	37.56	38.46	41.41	42.13	38.94±2.23	
	T2-T1	0.07	0.29	0.43	0.70	1.03	0.50±0.27	< .001*
IPMW	T1	44.47	46.71	49.38	50.03	54.21	48.90±2.64	
	T2	44.53	47.06	49.69	50.59	55.20	49.29±2.72	
	T2-T1	0.03	0.18	0.33	0.57	0.99	0.34±0.25	< .001*
IMBW	T1	47.82	50.61	53.51	55.23	56.83	52.99±2.64	
	T2	48.35	50.91	53.90	55.75	58.34	53.61±2.77	
	T2-T1	0.17	0.32	0.45	0.81	1.70	0.62±0.43	< .001*
IDBW	T1	50.92	53.32	55.18	56.87	59.19	55.06±2.52	
	T2	52.11	54.72	56.11	58.00	60.87	56.19±2.51	
	T2-T1	0.55	0.83	1.12	1.34	1.94	1.13±0.37	< .001*

SD, standard deviation

*Significance difference compared to T1

$p < .05$

Table 9: Rotational changes (T2-T1) measured on the digital models

Variables (n = 17)		**Min. (degree)**	**1st quartile (degree)**	**Median (degree)**	**3rd quartile (degree)**	**Max. (degree)**	**Mean±SD (degree)**	**P-value**
Rotational measurements								
Canines	T1	31.15	35.85	38.95	43.28	48.20	39.43±4.44	
	T2	29.85	34.70	37.45	42.25	46.95	38.30±4.47	
	T2-T1	-1.50	-1.30	-1.10	-1.00	-0.90	-1.13±0.18	< .001*
Premolars	T1	92.90	102.75	104.95	108.85	114.10	105.39±5.14	
	T2	94.70	104.05	106.65	110.55	115.75	106.93±5.09	
	T2-T1	1.00	1.25	1.55	1.78	2.10	1.54±0.33	< .001*
Molars	T1	69.30	73.13	77.15	80.08	87.95	77.20±4.73	
	T2	70.75	75.10	79.25	81.83	89.30	78.83±4.68	
	T2-T1	1.10	1.35	1.65	1.90	2.10	1.63±0.29	< .001*

SD, standard deviation

*Significance difference compared to T1

$p < .05$

CHAPTER 4

DISCUSSION

This study was undertaken to develop and investigate the effects of an en-masse retraction system with asymmetrical V-bend placed in the sliding archwire. With this system, the six maxillary anterior teeth would be en-masse retracted without excessive retroclination and no extrusion of the incisors and also provided the molar anchorage as maximum control. These issues were important concerns specifically in the patients with the maxillary anterior teeth protrusion and exposed in maximal maxillary incisal display at rest. En-masse retracting to the goal were required: 1) a marked amount of the maxillary anterior en-masse retraction; 2) not producing excessively incisor retroclination; 3) not incisor extruding; 4) maximum anchorage control; and 5) an effective rate of the maxillary anterior en-masse retraction. To achieve these objectives, the asymmetrical V-bend[67, 68], was modified to locate between one-third to one-half of the interbracket span of the maxillary second premolar bracket and the canine bracket. Consequently, the short segment was placed closer to the premolars. As shown in Fig. 23, this design of the asymmetrical V-bend could provide a considerably counterclockwise moment at the premolar which was an effective moment against mesial tipping at the premolar and lead to control the premolar anchorage, meanwhile, a reciprocal intrusive force at the canines resulted from two different moments could resist the canine extrusion that was a potentially continuing effect on the incisors.

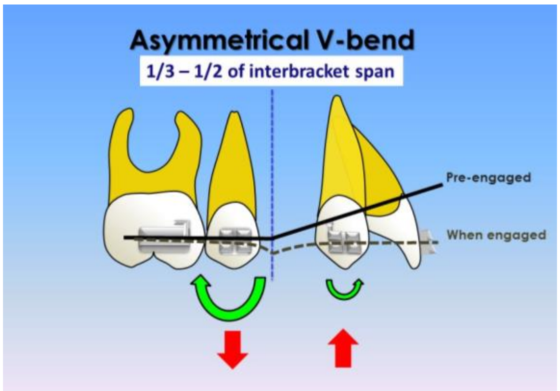

Fig. 23 The effect of the asymmetrical V-bend

The V-bend using in this study was modified from the law of statically indeterminate system as presented by Burstone and Koenig (1988)[68]. Their force system developed in a two-tooth segment when connected by a bending 0.016" stainless steel wire in the imposing condition. During an activation, the brackets and the wires could not move or rotate so that the required force system could produce a wanted tooth movement. However, the mechanics applied in this study was a dynamic movement of the en-masse sliding system with a continuous archwire. For that situation, it should consider the moments and forces only occurred in the canines and the second premolars. These two-tooth in the continuous archwire could be produced the desired force system in the correct direction as followed the force system from the asymmetrical V-bend showed in the study of Burstone and Koenig (1988)[68]. Furthermore, the stainless steel archwire using in this study was taken off and adjusted the position of the asymmetrical V-bend placement and the degree of the bend every visit to maintain the direction of the moment and force.

Anterior en-masse retraction response

From this study, the incisal tip and the root apex of the maxillary incisors were used to clarify the manner of tooth movement occurred in anteroposterior directions. The incisor showed statistically significant retraction with palatal movement of the incisal tip about 2.7 ± 0.50 mm and also presented at the root apex approximately 1.94 ± 0.58 mm within 4-months of the observation period. The ratio of the root apex-to-incisal tip movement was 0.7. It indicated that the incisor was retracted palatally in response to controlled tipping and partly translation. On the part of altering this inclination, retroclination of the incisor was appeared about 3 degrees. However, the reduction of the incisor inclination was found, when comparing between the initial values (U1-SN= 113.94°) and after 4 months of retraction values (U1_SN= 109.21°), it was revealed that the incisors were retroclined adequately and nearly achieved in a normal inclination followed by cephalometric analysis (Thai norm of U1-SN[66]= 107±6°). Consequently, our en-masse retraction system could accomplish in marked retraction of the maxillary anterior teeth without producing excessive incisor retroclination. Focusing on the inclination change of the incisors and the angulation change of the canines, it was noticed that a close relationship existed between the degree of palatal tipping of the incisors and the distal tipping of the canines. Moreover, the type of the incisor and the canine movement has been nearly similar as the control tipping and partly translation. Lastly, on the point intent to control vertical, our system could reach the goal which showed no incisor extrusion during anterior teeth retraction. On the other hand, it showed a small amount of the incisor intrusion that the incisal tip was intruded 0.24± 0.31 mm and the root apex was intruded 0.85± 0.49 mm. Comparing between the incisors and the canines in amount of the vertical movement, it revealed that the canines showed amount of intrusion lesser than the incisors presented.

The key to successful these treatment goals was based on placement the bend location of the asymmetrical V-bend on the extraction site. Take a look at our design, the asymmetrical V-bend was applied between one-third and one-half of interbracket span between the premolars and the canines and placed the short segment closer to the premolars. Furthermore, at every follow-up visit, the asymmetrical V-bend was adjusted to remain in the same relation with the interbracket span. Therefore, it could ensure that the moment and the force was provided in the same direction. With this mechanic of the asymmetrical V-bend, there were three main components to provide these outcomes. First, the counter clockwise moment occurred at the canines; although its size was quite small, this moment could resist and lead to minimize degree of the canine tipped distally when the retraction force was applied. Second, forming the V-shape on large sized archwire (0.018 × 0.022-inch) and heat-treating, as well as inserting the wire into 0.018-inch slot of anterior bracket, this raising upward of the wire combined with full-sized fit of the wire into the canine bracket could hold the tooth along with the wire and lead to reduce the canine tipped distally during en-masse retraction. Moreover, the incisor brackets were allowed to express their pre-torque and lead to decrease the incisor tipped palatally. About the heat treatment performed in this study, all V-bend archwire were treated by passing their entire archwire continually through flame of an alcohol lamp until observed a reddish-brown color[56]. However, this procedure did not follow temperature standards, it was convenient for clinicians to use an alcohol lamp for an attempt to preserve the formation of the V-bend archwire during space closure. Lastly, for presence of a mild amount of canine and incisor intrusion, an intrusive force at the canines resulted from subtracting the smaller counter clockwise moments that occurred at the canines from the larger clockwise moment that presented at the premolars could intrude and lead to resist the relative extrusion of the canines during en-masse retraction. For a mild amount of incisor intrusion, it could be explained from the forming of V-bend archwire as mentioned before that the anterior segment of the archwire was bent upward and could maintain its form until the next treatment visit, so the incisor intrusion was likely to be influenced by the shape effect of the archwire.

As compared to other studies in the positional changes of the maxillary central incisor, there were more substantial retroclination up to 10.83 degrees[69] and 13 degrees[70] than presented in our study. Although the observation period (T2-T1) of their studies were longer; with regard to the rate of incisor tipping, theirs showed much higher than the rate obtained from our study (Table 10). In the study of Kumar VV et al[70], this effect might come from using the straight archwire without any designing to withstand the archwire deformation resulted from a retraction force applied between the canine hooks and the molar tube; though the wire was larger in size, it might not adequate to resist the incisor palatal tipping[71]. Even though, Upadhyay M et al[69] attempted to apply a differential moment on an archwire to en-masse retract with maximum anchorage control, the incisors still showed a greater degree of palatal tipping. When considered in the differential moment in their study, it was undefined its mechanisms and unknown where was the bend position and how many degrees of the bend. If the position of the bend was placed less than 1/4 of the inter-bracket span and closer the premolars, the effect produced at canines was converted from a counter clockwise moment to a clockwise moment and could promote further distal crown tipping at the canines and continuing to palatal crown tipping at the incisors. Therefore, it was important to focus on the position of the bend to obtain the suitable moment and force. Furthermore, having some of clearances between archwire and bracket slots of maxillary anterior teeth as used in two previous studies that 0.022”-inch slot still had a certain clearance when the 0.017 x 0.022”[69] or the 0.019 x 0.025”[70] rectangular wires were inserted (Fig. 24). When the wires were undersized, pretorque slot for the maxillary incisor bracket and preangulated slot for the canine bracket were not fully performance and might be useless. Moreover, the canine and the incisors were more prone to distal tip and palatal tip in these clearances, respectively. Therefore, considering in relationship between archwire and slot on the maxillary anterior teeth was an important factor to control the incisor inclination and canine angulation during the anterior retraction.

Table 10: Comparison degree of the incisor tipping between different sliding methods

Authors (Year)	Bracket Slot and archwire	Duration (months)	Amount of retraction (mm.)	U1 Tipping (degree)	Rate of tipping (degree/month)
Kumar VV et al.[70] (2015)	0.022” MBT (6-6) 0.019×0.025” SS	7 months	4.2 mm	-13°	-1.86
Upadhyay M et al.[69] (2006)	0.022” Roth (7-7) 0.017×0.025” SS with differential moment	10.6 months	5.72 mm	-10.83°	-1.02
This study (2017)	0.018” Roth (3-3) 0.022” Roth (5-6) 0.018×0.022” SS with asymmetrical V- bend	4 months	2.8 mm	-3.0°	-0.75

Posterior anchorage response

The maxillary second premolars and the first molars showed statistically significant mesial movement. Nevertheless, amount of the mesial movement was too small to be of any clinical importance and also lesser than amount of the anterior teeth retraction. Consequently, the system using in our study could provide another satisfactory result that the posterior teeth could be controlled as maximum anchorage during the en-masse retraction. About the designing of the system to reach this goal, the asymmetrical V bend was highly influence in achieving this successful outcome. Because the asymmetrical V bend in our study was intentionally placed closure the premolars, it was like a tip-back bend for anchorage control. Therefore, a considerable clockwise moment in backward rotation was created and could reliably resist the mesial crown tipping at the premolars that occurred during application of retraction force. Moreover, presence of the molars tipped distally was another result of forming the V-bend on archwire that raised upward at posterior part.

Comparison to the previous studies, there were different results of anchorage loss measured as maxillary molar mesialization. Upadhyay M et al[69] retracted the maxillary anterior teeth and used the conventional molar anchorage preparation such as a differential moment, headgear, and banding the second molars. They found that the mean rate of the molar mesialization was 0.36 mm/ month. It might be considered when the differential moment was applied to control the posterior anchorage, determining the bend position on the wire was an important factor to generate the moment in suitable direction and size. The moment in clockwise rotation was essential for anchorage control because it could tip the molars backward. Moreover, using the headgear as an extraoral anchorage was required patient cooperation, so this method was unpredictable for maximum anchorage control. In the same way, a study of Kumar VV et al[70] that started the maxillary en-masse retraction without any anchorage preparation. Their result showed the rate of molar mesialization about 0.23 mm/ month and the molars tipped mesially in a high degree. It became interesting to note about the angulation changes in relation to the amount of mesial movement. The more degree of mesial tipping was presented, the more chance of mesial movement of the molars was obviously appeared (Table 11). So, if the molar control was planned to be maximum anchorage, tipping the molar backward obtained from the clockwise rotation moment was an effective mechanic to prevent the anchorage loss.

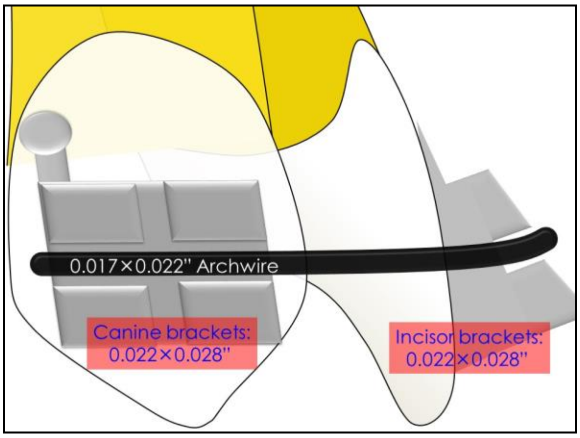

Fig. 24 Clearance of the wire in the bracket slot

Table 11: Comparison of anchorage loss between different anchorage preparation methods

Authors (Year)	Anchorage preparation	Duration (months)	Anchorage loss (mm.)	Rate of anchorage loss (mm/month)	Molar tipping (degree)
Kumar VV et al.[70] (2015)	No anchorage preparation	7 months	1.6 mm	0.23	3.2°
Upadhyay M et al.[69] (2006)	Differential moment, Headgear, Band 2nd molars	10.6 months	2.07 mm	0.36	3.7°
This study (2017)	Asymmetrical V- bend : short segment placed closer the premolars	4 months	0.29 mm	0.08	-1.78°

Rate of the maxillary anterior en-masse retraction

From the results of our study, the mean rate of maxillary anterior en-masse retraction was about 0.68 mm/month (ranging from 0.56 to 0.8 mm/ month) which was nearly similar to the rate obtained by a study of Upadhyay M et al[69] using a straight 0.017×0.025-inch SS archwire with miniscrew implants as a directed anchorage for maxillary anterior en-masse retraction (Table 12). It seemed to confirm that our system could actually produce a marked amount of the maxillary en-masse retraction. Although the archwire used in our study was larger than their study and bent as the asymmetrical V-bend, the residual retraction forces subtracted from the initial friction were sufficient and optimal to provide the effective rate of the maxillary anterior teeth retraction. However, a study of Peter G. Miles[62] was reported the rate of en-masse retraction about 1.1 mm/ month which was higher than the rate presented in our study. Although amount of the clearance between the bracket slots and the archwire seem indifferent to our study, having counter clockwise moment built at the canines from the asymmetrical V-bend; despite its relatively small moment, it could produce an anti-retracting effect as an attempt to tip the canine mesially and contribute to retard the rate of the palatal retraction of maxillary anterior teeth in our study. However, this retraction system was not invented to be a new one providing a faster acceleration of en-masse retraction, it was intentionally developed to be an en-masse retraction system which could retracted the maxillary anterior teeth with providing an effective retraction rate and simultaneously provide appropriate pattern of incisor movement without excessive retroclination and no extrusion during en-masse retraction. Moreover, it had to control the molars as maximum anchorage. With all of this, using of the asymmetrical V-bend that created one of a kind moment was fulfilled our treatment goal.

Table 12: Comparison of rate of en-masse retraction per month

Authors (Year)	Bracket slot and archwire	Rate of en-masse retraction (mm/month)
Upadhyay M et al.[69] (2006)	0.022” MBT (6-6) 0.017×0.025” SS	0.68
Peter G. Miles[70] (2007)	0.018” Roth (6-6) 0.016×0.022” SS	1.1
This study (2017)	0.022” Roth (5-6) 0.018×0.022” SS with asymmetrical V- bend	0.68

When compared rotational changes and dental arch width changes from digital study models, the rotation of the maxillary second premolars had been showed statistically significant mesiopalatal rotation in which was accompanied closely in degree of the mesiopalatal rotation of the first molar. Whereas the canines, unlike the premolars and the molars, they were presented statistically significant distopalatal rotation. Nevertheless, amount of the rotational changes about 1.6° happened at the premolar-molar and 1.1° at the canines were too small to sufficient to cause any clinical importance. About dental arch width changes, intercanines width, interpremolars width, and intermolars width were showed little expansion. We noticed on the archwire, it was expanded especially in its posterior segments. It might be due to the stiffness of the archwires were not enough to resist the optimal retraction force that was loaded at buccal side of the molar and lead to unable to keep the pre-retraction arch forms throughout treatment. However, little amount of the expansion was not clinically important.

For limitation of this study, first, the effectiveness of the asymmetrical V-bend in sliding retraction system had never been evaluated before, so we designed an experimental study to collect preliminary data and compared the data within subjects between the pre-retraction data and the post-retraction data to investigate the dental effects of using the asymmetrical V-bend in the retraction system. Second, there was no data achieved from a control group or the other experimental group, so the results from this study could not actually compare with different en-masse retraction methods and could not differentiate this study from the others.

Further a prospective randomized controlled trial will be comparing the effects between two techniques using the asymmetrical V-bend and the accentuated curve on identical archwire progressions and prescription brackets to determine and differentiate whether there are any differences in dental changes.

Clinical implication

The en-masse retraction by our retraction system would be suitable for the patients assessed as the maxillary dental protrusion and required maximum anchorage control during space closure. With this en-masse retraction system, approximately 0.7 mm of the maxillary anterior teeth could be retracted palatally per month with incisors was tipped palatally at least 0.75°. Another important issue was the reported amount of the incisor intrusion during the retraction, although the amount was relatively small about 0.06 mm/month, it might worsen the patient's overbite, especially in an anterior dental open bite patient. About anchorage control, there was a chance of anchorage loss about 0.08 mm/month during the en-masse retraction. Another important clinical implication was the need for routine appointments since the position of the asymmetrical V-bend would be moved posteriorly to closer the premolar in every month and it might hit the premolar bracket leading to produce more amount of anchorage loss.

CHAPTER 5

CONCLUSIONS

With this en-masse retraction system consisting of asymmetrical V-bend archwire based on the results obtained in 4-months period of observation, the following conclusion can be drawn.

1. En-masse retraction of the six maxillary anterior teeth occurred significantly with maximum anchorage control.
2. Reduction of incisor proclination during retraction could be controlled appropriately with altering the inclination as control tipping and partly bodily movement.
3. No extrusion of incisor and canine presented, on the other hand, the incisor was slightly intruded.
4. The rate of the en-masse retraction with this system was about 0.7 mm per month.
5. Mesial movement of the maxillary molars showed statistically significant in the degree of distal crown tipping presented.
6. The rate of molar anchorage loss was about 0.08 mm per month.

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APPENDICES

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Documentary Proof of Ethical Clearance
Research Ethics Committee (REC)
Faculty of Dentistry, Prince of Songkla University

The Project Entitled		The Treatment Effects of Sliding Mechanic System During En-masse Retraction in Adult Maxillary Dental Protrusion Patients
REC Project No.	:	EC5905-15-P-HR
Principal Investigator	:	Assoc. Prof. Dr. Chairat Charoemratrote
Co-Principal Investigator	:	Miss Aweekhun Thanasansomboon

Approved by Research Ethics Committee (REC), Faculty of Dentistry, Prince of Songkla University.

This is to certify that REC is in full Compliance with International Guidelines for Human Research Protection such as the Declaration of Helsinki, the Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP).

Date of Approval 22 JULY 2016 No. of Approval : MOE 0521.1.03/804

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ใบเชิญชวน

ขอเชิญเข้าร่วมโครงการวิจัยเรื่อง ผลของระบบการเคลื่อนฟันด้วยวิธีเลื่อนไถลตามลวดหลัก ขณะดึงกลุ่มฟันหน้าในผู้ป่วยผู้ใหญ่ที่มีลักษณะฟันหน้าบนยื่น

เรียน ท่านผู้อ่านที่นับถือ

ข้าพเจ้า ทพญ.อาวีคุณ ธนะสารสมบูรณ์ นักศึกษาหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาวิทยาศาสตร์สุขภาพช่องปาก (ทันตกรรมจัดฟัน) คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ใคร่ขอเล่าถึงโครงการวิจัยที่กำลังทำอยู่และขอเชิญชวนท่านเข้าร่วมโครงการดังนี้

โครงการวิจัยนี้จัดทำขึ้นเพื่อพัฒนาวิธีการที่ใช้ในการดึงกลุ่มฟันหน้าบนไปด้านหลัง ด้วยระบบการเคลื่อนฟันที่<u>เพิ่มการดัดลวดเป็นรูปตัววีบนลวดเส้นหลักที่ใช้เคลื่อนฟัน</u> ซึ่งระบบดังกล่าวจะสามารถดึงกลุ่มฟันหน้าบนและแก้ไขฟันหน้าบนยื่นจนได้ตำแหน่งฟันที่เหมาะสม

ผู้เข้าร่วมโครงการวิจัยจะได้รับการจัดฟันโดยเครื่องมือจัดฟันชนิดติดแน่นร่วมกับระบบการเคลื่อน กลุ่มฟันหน้าบนหกซี่ไปด้านหลัง ผู้เข้าร่วมวิจัยจะได้รับการตรวจและบันทึกข้อมูลซึ่งประกอบด้วยการซักประวัติ เช่น ข้อมูลทั่วไป ประวัติทางทันตกรรม ประวัติทางการแพทย์ การตรวจนอกช่องปากและในช่องปาก การถ่ายภาพภายนอกและภายในช่องปาก การถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง ภาพถ่ายรังสีพสนอรามิก และการพิมพ์ปากเพื่อทำแบบจำลองฟัน โดยมีขั้นตอนการรักษา คือ

- บันทึกข้อมูลเบื้องต้นก่อนการรักษา
- ติดเครื่องมือจัดฟันติดแน่น
- ปรับระดับฟัน
- บันทึกข้อมูลก่อนการเคลื่อนกลุ่มฟันหน้าบนหกซี่ไปด้านหลัง
- ส่งถอนฟันกรามน้อยบนซี่แรก และรอ 2 อาทิตย์สำหรับการหายของแผลถอนฟัน
- เคลื่อนกลุ่มฟันหน้าบนหกซี่ไปด้านหลัง
- บันทึกข้อมูลหลังการเคลื่อนกลุ่มฟันหน้าบนหกซี่ไปด้านหลัง

- ให้การรักษาความผิดปกติของการสบฟันในตำแหน่งอื่นตามแผนการรักษาจนรักษาเสร็จ

โครงการวิจัยนี้เป็นเพียงส่วนหนึ่งของการรักษา ในช่วงการรักษาจัดฟันที่เป็นงานวิจัย ผู้เข้าร่วมวิจัยต้องมารับการรักษาโดยประมาณ 7 ครั้ง เดือนละ 1 ครั้ง ตลอดระยะเวลาในงานวิจัยรวม 7 เดือน หลังจากสิ้นสุดงานวิจัย ผู้เข้าร่วมวิจัยจะได้รับการรักษาความผิดปกติของการสบฟันในตำแหน่งอื่นจนกว่าการรักษาจะเสร็จสิ้นตามแผนการรักษาทางทันตกรรมจัดฟัน

ในกรณีที่ระบบการเคลื่อนกลุ่มฟันหน้าบนที่ออกแบบในงานวิจัยไม่สามารถเคลื่อนกลุ่มฟันหน้าบนไปด้านหลังได้ในระยะเวลา 3 เดือน ทางผู้วิจัยจะเปลี่ยนวิธีการรักษา หรือใช้เครื่องมืออื่นที่มีความเหมาะสม

ผู้เข้าร่วมวิจัยต้องเสียค่าใช้จ่ายในการจัดฟันตามปกติ โดยมีค่าใช้จ่ายในการเก็บข้อมูล, พิมพ์ปาก, ถ่ายรูป, การจัดฟันแบบติดแน่น และ ภาพถ่ายรังสีในการรักษา ซึ่งเป็นค่ารักษาในอัตราปกติของคลินิกทันตกรรมจัดฟัน และแผนกรังสีโรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ในกรณีที่ต้องเปลี่ยนการรักษาเพราะงานวิจัยไม่สำเร็จจะไม่มีการเสียค่าใช้จ่ายในการรักษาเพิ่ม ส่วนค่าใช้จ่ายสำหรับการถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง และค่าพิมพ์ปากเพื่อทำแบบจำลองฟัน ก่อนและหลังการเคลื่อนกลุ่มฟันหน้าบน ทางคณะผู้วิจัยจะรับผิดชอบค่าใช้จ่ายในส่วนนี้ให้

ความเสี่ยงที่มีโอกาสเกิดขึ้น เมื่อเข้าร่วมการวิจัย

- ความเสี่ยงในขั้นตอนการเก็บข้อมูล: ส่วนของปริมาณรังสีเอกซเรย์ที่ได้รับ

ในงานวิจัยนี้ มีการถ่ายภาพรังสีเพิ่มเติมจากเวชปฏิบัติ มากกว่าปกติ 2 ครั้ง ได้แก่ การถ่ายภาพรังสีกะโหลกศีรษะและใบหน้าด้านข้าง ระยะก่อนและหลังการดึงกลุ่มฟันหน้าบนดังที่กล่าวมาแล้ว ซึ่งการถ่ายภาพรังสีแต่ละครั้งนั้น **มีความเสี่ยง**ที่จะเกิดอันตรายต่อผู้เข้าร่วมวิจัย**น้อยมาก** เนื่องจากปริมาณรังสีที่ได้รับในแต่ละครั้งของการถ่ายน้อยมาก และมีการสวมเสื้อตะกั่วและไทรอยด์ชีล เพื่อป้องกันรังสีให้แก่ผู้เข้าร่วมวิจัยทุกราย ร่วมกับการพยายามให้มีความผิดพลาดในการถ่ายภาพรังสีน้อยที่สุด เพื่อลดปริมาณรังสีที่ผู้เข้าร่วมวิจัยจะได้รับโดยไม่จำเป็น

- ความเสี่ยงในส่วนของการไม่ตอบสนองต่อระบบการเคลื่อนฟัน และ/หรือ การเกิดการเคลื่อนที่ของกลุ่มฟันหน้าและกลุ่มฟันหลังที่เป็นหลักยึดในทิศทางที่เกิดผลเสีย

เนื่องจากระบบการเคลื่อนฟันและปริมาณแรงที่ใช้ในการเคลื่อนฟันไม่แตกต่างจากการเคลื่อนฟันด้วยวิธีการรักษาปกติ จึง**มีความปลอดภัยในการเคลื่อนฟัน** อย่างไรก็ดี ผู้เข้าร่วมวิจัยจะได้รับการตรวจ ประเมินอาการและอาการแสดงที่บ่งชี้ว่ามีความผิดปกติอันเกิดจากการเคลื่อนฟันในทุกๆครั้งที่มาพบทันตแพทย์ผู้ให้การรักษา

ในกรณีผู้เข้าร่วมจัยไม่ตอบสนองต่อระบบการเคลื่อนฟัน หรือเกิดผลข้างเคียงที่ทำให้ผู้เข้าร่วมวิจัยได้รับความเสียหาย ภายในระยะเวลา 3 เดือน นับจากครั้งที่เริ่มให้แรงดึงกลุ่มฟันหน้าบน นักวิจัยจะหยุดการรักษา, ผู้เข้าร่วมการวิจัยจะถูกคัดออกจากงานวิจัย, และผู้วิจัยจะเปลี่ยนวิธีการรักษา หรือใช้เครื่องมืออื่นที่มีความเหมาะสมทันที

ถ้าท่านตัดสินใจเข้าร่วมโครงการวิจัยนี้ จะมีขั้นตอนของการวิจัยที่จำเป็นต้องขอความร่วมมือของท่านตามที่กล่าวมาข้างต้น โดย**ผู้เข้าร่วมโครงการวิจัย ต้องมารับการรักษาเดือนละ 1 ครั้ง** (ตามระบบนัดปกติ) ณ คลินิกทันต- กรรมจัดฟัน โรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์

หากท่านตัดสินใจไม่เข้าร่วมโครงการวิจัยนี้ ท่านก็จะได้รับการตรวจเพื่อการวินิจฉัยและรักษาทางทันต-กรรมจัดฟันตามวิธีการที่เป็นมาตรฐานและเหมาะสมเช่นเดียวกับผู้ป่วยท่านอื่นๆ

ท่านมีสิทธิ์ที่จะขอยกเลิกการเข้าร่วมโครงการวิจัย โดยจะแจ้งให้ทราบล่วงหน้า ซึ่งการยกเลิกนี้จะไม่มีผลต่อการได้รับบริการ หรือการรักษาที่ท่านจะได้รับแต่อย่างใด

หากท่านมีข้อสงสัยหรือคำถามใดๆ ก่อนที่จะตัดสินใจเข้าร่วมโครงการนี้ โปรดซักถามคณะผู้วิจัยได้อย่างเต็มที่

ขอขอบคุณเป็นอย่างสูง
ทพญ. อาวีคุณ ธนะสารสมบูรณ์
ผู้ร่วมวิจัย

หมายเหตุ :- กรุณาอ่านข้อความให้เข้าใจก่อนเซ็นชื่อยินยอมเข้าร่วมโครงกา

แบบยินยอมเข้าร่วมการศึกษา

โครงการวิจัยเรื่อง ผลของระบบการเคลื่อนฟันด้วยวิธีเลื่อนไถลตามลวดหลัก ขณะดึงกลุ่มฟันหน้าในผู้ป่วยผู้ใหญ่ที่มีลักษณะฟันหน้าบนยื่น

วันที่………....เดือน…………..……………พ.ศ……………...……

ข้าพเจ้า…………………………………………………อายุ………..……….ปี อาศัยอยู่บ้านเลขที่……………...…..………………..….ถนน……………………..………… ตำบล…………………อำเภอ……………………...…...………จังหวัด………………………….. ได้อ่าน/ได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตรายหรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียดและมีความเข้าใจดีแล้ว

หากข้าพเจ้าได้รับผลข้างเคียงจากการวิจัย ข้าพเจ้าจะได้รับการปฏิบัติ/การชดเชย ดังนี้ ข้าพเจ้าจะได้รับการยกเลิกวิธีการรักษาที่ใช้ในงานวิจัยและได้รับการรักษาทางทันตกรรมจัดฟันด้วยวิธีการรักษาปกติจนสิ้นสุดการรักษาต่อไป โดยผู้รับผิดชอบโครงการวิจัยนี้คือ รศ.ดร.ทพ. ไชยรัตน์ เฉลิมรัตนโรจน์ และผู้ร่วมวิจัยคือ ทพญ. อาวีคุณ ธนะสารสมบูรณ์ สถานที่ติดต่อ ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์. เบอร์โทรศัพท์ 0-7442-9875, 089-1776568 หรือเมื่อมีปัญหาใดๆ เกิดขึ้นเนื่องจากการทำวิจัยในเรื่องนี้ข้าพเจ้าสามารถร้องเรียนไปที่คณบดีคณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90112 โทรศัพท์ 0-7428-7500

หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็ว โดยไม่ปิดบัง

ข้าพเจ้ามีสิทธิที่จะของดการเข้าร่วมโครงการวิจัยโดยมิต้องแจ้งให้ทราบล่วงหน้า โดยการงดการเข้าร่วมการวิจัยนี้ จะไม่มีผลกระทบต่อการได้รับบริการหรือการรักษาที่ข้าพเจ้าจะได้รับแต่ประการใด

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะที่เกี่ยวกับตัวข้าพเจ้าเป็นความลับ จะไม่เปิดเผยข้อมูลหรือผลการวิจัยของข้าพเจ้าเป็นรายบุคคลต่อสาธารณชน จะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย หรือการเปิดเผยข้อมูลต่อผู้มีหน้าที่ที่เกี่ยวข้องกับการสนับสนุนและกำกับดูแลการวิจัย

ข้าพเจ้าได้อ่าน/ได้รับการอธิบายข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ จึงได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจโดยนักวิจัยได้ให้สำเนาแบบยินยอมที่ลงนามแล้วกับข้าพเจ้าเพื่อเก็บไว้เป็นหลักฐาน จำนวน 1 ชุด

ลงชื่อ..ผู้ยินยอม

ลงชื่อ......................................หัวหน้าโครงการ

ลงชื่อ..พยาน

ลงชื่อ..พยาน

VITAE

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List of Publication and Proceeding

Thanasansomboon A, and Charoemratrote C. The deflective distance on asymmetrical V-bend in archwire at different inter-bracket distances *in vitro* study. Proceedings of the 7th Conference on the topic CREATIVE SCHOOLS; 2017 February 24; Nakhon Si Thammarat, Thailand. Southern College of Technology; 2017.