**The Treatment Effect of Light Force Partial Fixed Appliances**

**in Class III Growing Patients**

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**A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of**

**Master of Science in Oral Health Sciences**

**Prince of Songkla University**

**2012**

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| **Thesis Title** | The Treatment Effect of Light Force Partial Fixed Appliances in Class III Growing Patients |
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| **Major Program** | Oral Health Sciences |

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**ชื่อวิทยานิพนธ์** ผลของการใช้แรงขนาดเบาผ่านเครื่องมือจัดฟันแบบติดแน่นบางส่วนในผู้ป่วยที่มีการสบฟันผิดปกติประเภทที่ 3 ที่มีการเจริญเติบโต

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# บทคัดย่อ

**บทนำ**: ในผู้ป่วยเด็กที่มีการสบฟันผิดปกติประเภทที่ 3 และฟันหน้าล่างคร่อมฟันหน้าบนส่วนใหญ่จะได้รับการรักษาโดยการใช้เครื่องมือเฟสแมสก์ (facemask) แต่ต้องใช้ความร่วมมือของผู้ป่วยอย่างมาก ผู้ป่วยรู้สึกไม่สะดวกสบายและผลการรักษาส่วนใหญ่เกิดจากการเคลื่อนฟันมากกว่าการเคลื่อนกระดูกขากรรไกร คณะผู้วิจัยจึงได้พัฒนาเครื่องมือจัดฟันแบบติดแน่นบางส่วนด้วยแรงขนาดเบา (Easy Light Fixed technique หรือ ELF) เพื่อเป็นทางเลือกในการรักษาที่สะดวกสบายมากขึ้น อาศัยความร่วมมือผู้ป่วยน้อยลง แต่ยังมีประสิทธิภาพ และเคลื่อนฟันอย่างปลอดภัย **วัตถุประสงค์:** เพื่อศึกษาการเปลี่ยนแปลงโครงสร้างกะโหลกศีรษะและฟัน และการเปลี่ยนแปลงความหนากระดูกรอบรากฟันตัดบนจากการใช้ ELF **วัสดุและวิธีการ:** กลุ่มตัวอย่างประกอบด้วยผู้ป่วยเด็กที่มีการสบฟันผิดปกติประเภทที่ 3 และฟันหน้าล่างคร่อมฟันหน้าบนจำนวน 11 ราย อายุเฉลี่ย 9.9 ± 1.0 ปี ผู้ป่วยได้รับการรักษาด้วยวิธี ELF โดยติดเครื่องมือจัดฟันแบบติดแน่นแบบเทคนิคทูบายโฟซึ่งประกอบด้วยท่อด้านแก้มที่ฟันกรามแท้ทั้ง 2 ข้างและแบล็คเก็ตขนาด 0.022 x 0.028 นิ้ว ที่ฟันตัด 4 ซี่ ปรับระดับฟันตัดบนและล่างจนถึงลวดเหล็กกล้าไร้สนิมหน้าตัดสี่เหลี่ยมผืนผ้าขนาด 0.021 x 0.025 นิ้ว หลังจากนั้นในฟันบน ดัดลวดกลมเบตาไทเทเนียมขนาด 0.016 นิ้ว ซึ่งให้แรงขนาดเบาเป็นห่วงสำหรับดันฟัน (advancing loops) สูง 5 มิลลิเมตรและกว้าง 3 มิลลิเมตรหน้าท่อด้านแก้มของฟันกรามแท้บน และดัดเป็นห่วงกลมบริเวณกึ่งกลางฟันกรามน้อยซี่แรกสำหรับเกี่ยวยาง ยางขนาด 5/16” 2 ออนซ์ถูกใช้เกี่ยวจากห่วงกลมที่ลวดของฟันบนมาที่ด้านไกลกลางของฟันตัดแท้ล่างซี่ข้างทั้ง 2 ข้าง วิเคราะห์การเปลี่ยนแปลงของโครงสร้างกะโหลกศีรษะและฟันจากภาพถ่ายรังสีศีรษะด้านข้าง และวิเคราะห์การเปลี่ยนแปลงความหนากระดูกรอบรากฟันตัดบนจากภาพรังสีส่วนตัดอาศัยคอมพิวเตอร์ (CT scan) **ผลการศึกษา:** ฟันหน้าที่คร่อมกันถูกแก้ไขให้มีความเหลื่อมแนวระนาบและแนวดิ่งของฟันตัดบนและล่างจนเป็นปกติ และ โครงสร้างกะโหลกศีรษะเข้าใกล้ความสัมพันธ์ประเภทที่ 1 มากขึ้น กระดูกขากรรไกรบนเคลื่อนมาด้านหน้า 2.3 ± 1.4 มิลลิเมตร ฟันตัดบนเคลื่อนมาด้านหน้า 4.8 ± 1.8 มิลลิเมตรและมีความเอียงตัวฟันไปด้าน

ริมฝีปากมากขึ้น 6.6 ± 3.0 องศา โดยตำแหน่งในแนวดิ่งของกระดูกขากรรไกรบนและฟันตัดบนมีการเคลื่อนลงล่างประมาณ 2 มิลลิเมตรแต่ไม่มีนัยสำคัญทางสถิติ ส่วนการหมุนของขากรรไกรบนไม่มีการเปลี่ยนแปลงอย่างมีนัยสำคัญ กระดูกขากรรไกรล่างเคลื่อนที่ลงล่าง 3.8 ± 2.0 มิลลิเมตร แต่ไม่มีการเปลี่ยนตำแหน่งในแนวระนาบและมุมขากรรไกรล่างอย่างมีนัยสำคัญ ฟันตัดล่างไม่มีการเปลี่ยนแปลงตำแหน่งในแนวระนาบและความเอียงของตัวฟัน ความยาวใบหน้าส่วนล่างยาวขึ้น 4.1 ± 1.0 มิลลิเมตร ไม่พบการเปลี่ยนแปลงความหนากระดูกด้านใกล้ริมฝีปาก ด้านใกล้เพดานปาก และความหนาทั้งหมดรอบรากฟันตัดบนทั้ง 4 ซี่จากการเคลื่อนฟันด้วย ELF **สรุป:** การใช้ ELF สามารถรักษาผู้ป่วยเด็กที่มีการสบฟันผิดปกติประเภทที่ 3 และฟันหน้าล่างคร่อมฟันหน้าบนได้ และสามารถเคลื่อนฟันโดยความหนาของกระดูกไม่ได้ลดลง

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| **Major Program** | Oral Health Sciences |
| **Academic year** | 2011 |


## ABSTRACT

**Introduction:** Orthopedic facemask has been extensively used for the correction of skeletal Class III with anterior crossbite growing patients. However, facemask therapy needs extreme cooperation dependency, produces discomfort and predominantly generates dental effect rather than skeletal effect. The authors had developed a so-called "Easy Light Fixed (ELF) technique" which is considered to be simple, yet effective, and safe alternative treatment for Class III growing patients. **Objectives:** The aim of this study was to evaluate skeletal, dental and alveolar bone thickness changes among Class III growing patients treated with the ELF technique. **Materials and methods**: 11 patients with skeletal Class III and anterior crossbite were included in this study. The mean age was 9.9 ± 1.0 years. ELF included 2x4 fixed appliance comprised 2 buccal tubes on the first permanent molars and 4 brackets with 0.022 x 0.028 inch slot on the incisors. Upper and lower incisors were aligned until 0.021 x 0.025 inch stainless steel wire. After that, a light-force generated 0.016 inch Beta-titanium (TMA) archwire was bended into advancing loops with the height of 5 mm and the width of 3 mm, and placed right at the mesial surface of molar tubes and circular hooks at mid-buccal of first premolars areas. Short light Class III elastic 5/16" 2 oz. were crossed from the upper circular hooks of upper archwire to distal of lower lateral incisors. After crossbite correction was completed, lateral cephalogram was taken to evaluate skeletal and dental changes. CT scan of upper incisors was taken to measure alveolar bone thickness of these teeth. **Results:** With the treatment of ELF technique, anterior crossbite was corrected and skeletal relationship was improved towards Class I. The maxilla was displaced forward 2.3 ± 1.4 mm. Upper incisors were positioned forward 4.8 ± 1.8 mm and proclined $6.6 \pm 3.0^{o}$. Vertically, the maxilla and upper incisors was displaced downward about 2 mm but not significant. Maxillary rotation was not found. The mandible was moved downward 3.8 ± 2.0 mm but no changes in horizontal position and mandibular angle. Lower incisors were maintained its horizontal position and inclination. Lower facial height was increased 4.1 ± 1.0 mm. From CT scan, labial, palatal and total alveolar bone thicknesses of upper incisors were not significantly changed during advancing phase. **Conclusion:** ELF can be effective alternative treatment for skeletal Class III growing patients with anterior crossbite and can move upper incisors without alveolar bone changes.

# ACKNOWLEDGEMENT

This thesis would not have been possible unless I had got supported, guided and helped. I'm heartily thankful to my supervisor, Asst. Prof. Dr. Udom thongudomporn and Assoc. Prof. Dr. Chairat Charoemratrote, whose encouragement, supervision and support from the preliminary to the concluding level enabled me to develop an understanding of the subject.

I would like to take the opportunity to thank those people who spent their time and shared their knowledge for helping me to complete my thesis with the best possible result: Assoc. Prof. Dr. Chidchanok Leethanakul, Assoc. Prof. Supanee Suntornlohanakul, Assoc. Prof. Wipapun Ritthagol and Dr. Bancha Samraujbenchakul.

I also give gratitude to all of my patients who participated in this study. They're not only my patients, but also the great teachers. I would like to extend my thanks to my colleagues: Anongnart, Surajit and Chontira for supporting and taking care of the cases in this study.

Not forgetting also the support of the entire staff of the Orthodontic clinic, Department of Preventive Dentistry, Oral Radiology, and Dental Materials Research Unit at Faculty of Dentistry, Prince of Songkla University for their help and support through the thesis. And I would like to sincerely thank Dentalland company who support and facilitate for CBCT image.

Lastly, my deepest gratitude goes to my dad and mom for unconditioned love and tireless support. You are the only reason I was born and live my life for.

Sarayut Jearapongpakorn

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## LISTS OF DIAGRAMS/ FIGURES

## LISTS OF ABBREVIATIONS AND SYMBOLS

| | | |
|---|---|---|
| mm | = | millimeter |
| et al | = | and others |
| g | = | gram |
| $^{o}$ | = | degree |
| CBCT | = | Cone beam computed tomography |
| CT | = | computed tomography |
| Fig. | = | figure |
| % | = | percent |
| ” | = | inch (es) |
| / | = | per |
| PDL | = | periodontal ligament |
| kPa | = | kilopascal |
| $cm^2$ | = | square centimeter |
| TMA | = | Titanium Molypdenum Alloy |
| NiTi | = | Nickel Titanium |

# CHAPTER 1

# INTRODUCTION

## Background and rationale

In Class III malocclusion patients, maxillary deficiency is the most common contributing component[1] especially among Asians. A percentage of Class III patients with maxillary deficiency were as large as 75% in Chinese[2] compared with 57% in caucasian[3]. Class III malocclusion often exhibits an anterior crossbite that may lead to the inhibition of maxillary growth and unesthetically concave profile. Moreover, anterior crossbite may cause traumatized and abnormal wear of the anterior teeth, dental compensation by proclination of upper incisors and retroclination of lower incisors, resulting in thinning of the labial alveolar plate and/or gingival recession and increasing the risk of periodontal problems.[4]

According to the growth of Class III malocclusion with maxillary deficiency, the maxilla appeared to be retrusive relative to normal and does not become less retrusive with time.[5] Thus, an originally retruded maxilla cannot catch up with the growth of the mandible, leading to worsening of the negative overjet with age.[6] Class III malocclusion is not a self correcting malocclusion at either the skeletal or the occlusal level and can be the problem that leads patients search for treatment.

The early treatment that undertaken during the most active stages of dentition and craniofacial skeletal growth often be considered in mild to moderate class III malocclusion because the treatment can create a more favorable environment for dentofacial development, improved occlusal function and reduced skeletal discrepancies. In Class III growing patients, the orthopedic maxillary protraction facemask is one of the standard treatment protocols to encourage forward and downward growth of maxilla by orthopedic force. By facemask, the anterior crossbite can be corrected. Skeletal Class III and concave profile are improved.[7] But this appliance can be uncomfortable due to heavy protracted force and unacceptable by the patients because of the unpleasant look of the appliance. Consequently, the patient's cooperation may become poor which, in turn, negatively influence the treatment effect.[8]

Moreover, a greater portion of the changes from this appliance are not pure orthopedic, but are rather clockwise rotation of mandible, dentoalveolar change by proclination of upper incisors and slightly forward movement of maxilla.[1] Such proclination may be prone to labial bony resorption and, consequently, gingival recession and/or bone dehiscence. Moreover, the relative intrusion from upper incisors proclination is opposite to the normal growth direction and may lead to reduce tooth-lip relationship, resulting in poor esthetic.[9] In addition, the amount of maxillary movement following protraction was not more than normal maxillary growth, indicating the possibility of short-term relapse.[1]

From the above-mentioned facemask problems, it is probably more advantageous to use an alternative treatment which is easier to manipulate, more comfortable, and more user friendly but produce effective results. Moreover, this alternative treatment should move upper incisors forward and downward and also enhance maxillary growth in these directions. In many studies, the treatment that easy, more comfort and less cooperation in correcting crossbite is 2x4 technique which move dental only and not concern about skeletal problem.[10, 11] The commonly used archwire is stainless steel wire which is controlled to produce optimum force. However, this wire has small working range so it can produce force over the optimum and caused pain, gingival recession, root resorption and alveolar bone loss.[12] Regarding a recent concept, light forces applied to an individual tooth may affect not only the adjacent alveolar bone but also the adjacent cortical bone of the loaded area[13] resulting in displacement of both tooth and supporting alveolar bone. Hence, it is possible that by means of moving upper incisor forward and downward with light orthodontic force, the alveolar bone and maybe premaxilla region are expected to move forward and downward which minimally resemble the facemask effects.

To take the advantages of 2x4 techniques and light force concept, we developed a new technique called "Easy Light Fixed technique" or "ELF". This technique could be simple, ease to manipulation, less discomfort and less patient's cooperation need but still present effectively results which bring about favorable amount and direction of upper incisors movement to correct anterior crossbite, probably move premaxilla forward, safe for dentoalveolar structures for treatment of Class III maxillary deficiency growing patients.

## Review of literatures

### Effects from the protraction facemask appliance

One of the most common appliances used to correct the Class III malocclusion with maxillary deficiecy is the orthopedic protraction facemask appliance (Fig. 1). This appliance consists of two main components[14]: the extra-oral components or the facemask with chin and forehead support connected by a heavy metal arch and horizontal bar for attachment of elastics and the intra-oral components to stabilize the maxilla as one unit by intraoral appliance such as removable acrylic plate with occlusal coverage, fixed appliance with molars headgear tube and rigid archwire or rapid maxillary expansion. Commonly intraoral appliance for facemask is bonded rapid maxillary expansion. Many studies[15, 16] have indicated that a simultaneous sutural expansion with rapid maxillary expansion at the start of protraction facemask treatment facilitates the anterior movement of the maxilla. Elastics are connected intraoral-to-extraoral and transmit the heavy force to maxilla base and midface sutural interfaces. The direction of elastic angles 30 degree to occlusal plane which assumed to pass through center of resistance of maxilla on zygomatic bone in forward and downward direction.[8] Force values from elastic are about 200-600 grams per side. Patient is instructed to use facemask 10-12 hours per day in evening and night.

**Fig. 1**: Protraction facemask with elastic that connected to rapid maxillary expansion

The treatment effects of the protraction facemask appliance are a combination of skeletal and dental changes of the maxilla and mandible. The maxilla is moved forward and downward with slightly counterclockwise rotation of palatal plane as the result of protraction force; at the same time, upper posterior teeth are extruded and upper anterior teeth are proclined. Consequently, downward and backward rotation of the mandible is occurred and improves the maxillomandibular skeletal relationship in the sagittal dimension but results in an increase in lower anterior facial height.[7]

The outcome of the early treatment is varied and depends largely on many factors such as cause of the anterior crossbites and the age of the initial intervention. There have been numerous reports about the effective of orthopedic protraction facemask appliance.[2, 9, 11, 17-21] From many of previous studies, a greater portion of the changes from this appliance were not orthopedic, but dentoalveolar changes and mandibular rotation as shown in Table 1. From the study of Gu et al[11], the skeletal changes contributed 40% and dental changes contributes 60% of overjet correction in the reverse headgear group after treatment. Similarly to the study of Lertpitayakul et al[21], the overjet was corrected by skeletal changes 40% and dental changes 60%.

From the study of Sung et al[9], the effects of protraction facemask on upper incisors were proclination that lead to relative intrusion. In protraction facemask group, upper incisor inclination was more increased and upper incisor downward movement was less than the Class I untreated patients. These indicated that treatment effect of facemask probably lead to decreased incisal show in tooth to lip relationship and low smile line.

Moreover, relapse following treatment has been seen in certain patients after growth has been completed. According to Sung and Baik[1], the direction of the forward and downward displacement resulting from the maxillary protraction was similar to that of a Class I control group while the amount of forward and downward maxillary displacement measured at A-point was significantly greater than that in the Class I control group. However, during the observation period of 1 year following protraction, the amount of maxillary growth in the protraction group was found to be less than the control group, indicating the possibility of short-term relapse.

**Table 1:** Skeletal and dental effects of maxillary protraction therapy on Class III Asian patients

| | Age | T | Maxilla | UI | Mandible | LI | ANB |
|---|---|---|---|---|---|---|---|
| Ishii et al, 1987[2, 17] | 10.7 | 15.8 | 2.7 | 5.4 | -1.0 | -4.9 | 3.2 |
| Baik, 1992[17] | 10.8 | 5.9 | 1.9 | 2.1 | -1.7 | -1.3 | 3.5 |
| Takada et al, 1993[18] | 10.0 | 14.0 | 1.5 | 1.4 | -1.2 | 0.2 | 2.8 |
| Lim, 1995[19] | 9.9 | 7.5 | 1.8 | 2.0 | -1.5 | -1.6 | 3.4 |
| Ngan et al, 1996[20] | 8.4 | 6.0 | 2.0 | 3.4 | -1.7 | -5.2 | 3.0 |
| Sung and Baik, 1998[9] | 10.0 | 8.0 | 2.2 | 3.1 | -2.3 | -1.8 | 3.1 |
| Gu et al, 2000[11] | 8.5 | 10.6 | 2.3 | 2.5 | -0.3 | -1.4 | 2.6 |
| Lertpitayakul et al, 2001[21] | 5.0 | 16.2 | 1.1 | 1.3 | -0.9 | -1.9 | 2.0 |

T, Treatment duration in months; Maxilla, change of maxillary position; UI, change of upper incisor position; Mandible, change of mandibular position; LI, change of lower incisor position; ANB, change of maxillomandibular relationship

In conclusion, although facemask has been considered as a standard treatment for skeletal class III, it produces heavy force and depends on the wearer's cooperation. Moreover, the treatment effect is mainly dental rather than skeletal.

**2x4 orthodontic appliance**

In crossbite growing patients, a simple technique using a partial fixed edgewise appliance (molar tubes and incisor brackets) to advance the incisors into a normal overjet has been advocated.[10] Incisors are first leveled and aligned with segmented archwire and followed by forward movement of the incisors with 0.016" stainless steel advancing loops. The length of vertical loop depends on the depth of the vestibule that should not higher than 8 mm. The width of the loop is usually 5 mm. The anterior segment of the wire is placed 2–3 mm labial to the incisor brackets and activated by engaging in the incisor bracket slot. After activation, the loop is constricted, anterior and posterior segment of the wire are tilted down and the V-bend effect is produced. From this application, the upper incisors are moved anteriorly by proclination and the maxillary occlusal plane is rotated downward and backward.

From the study of Gu et al[11], comparing the treatment effects between reverse pull headgear and 2x4 technique, dental changes by upper incisor proclination appeared to contribute more to the total overjet correction in 2x4 group. The anterior movement of maxilla was less than the reverse pull headgear group and the skeletal change did not contribute to crossbite correction. At the end of treatment, there was no significant difference in the position of the incisors between the two groups. So, treatment effect of 2x4 technique was dental effect only and not concerned about skeletal problems.

**Light force concept**

Regarding to the light force concept, the light force is defined as the force that is less than the optimum force but is still enough to accomplish the orthodontic tooth movement. Nevertheless, the determination of a low or a high level force applied in orthodontic movement has yet to be definitely determined. The difference between a high and a low force is relative and the terminology used varies according to the reactions of the surrounding periodontium. The response of the teeth against the force is contributed to a function of force magnitude.

The heavy force can lead to rapidly developing pain, necrosis of the cellular elements within the PDL, and undermining resorption of alveolar bone near the affected tooth. Lighter forces are compatible with survival of PDL cell that lead to frontal bone resorption of the tooth socket cell and painless. From the study of Tomizuka et al[22], the initially light and gradually increasing force from magnetic to move rat molar teeth caused less extensive hyalinization of the periodontal tissue than heavy force. On compression site, the amount of osteoclasts in light force group was more than the heavy force. The formation of resorbed lacunae on the bone surface in the initial stage may have an advantage for the recruitment of osteoclasts and continuous bone resorption, result in frontal bone resorption.

Orthodontic forces might not only influence the dentoalveolar system, but also the surrounding and adjacent cortical bone. Forces applied to teeth act as a mechanical stimulus to the underlying cortical bone and when they reach certain thresholds they influence bone remodeling patterns. The heavy force that resulting in undermining resorption can probably causes alveolar bone resorption. If the force used for proclination of upper incisors is heavy, it might be increased the risk of bone resorption at labial bone of upper incisor and, consequently, gingival recession and bone dehiscence can be occurred. With the light force, alveolar bone and root may be preserved during tooth movement. Thilander et al[23] have advocated the use of light orthodontic forces to increase the cellular activity in the surrounding tissues and reduce the risk of root resorption. From case report of Hibino et al[24], canine was distalized across a bone deficient alveolar ridge. This case report had demonstrated the effective space closure and movement of teeth into the bony defect with bony apposition to the site with the light orthodontic force from the use of a laceback ligature. Moreover, the study of Tsolakis et al[13], found that the cortical bone osteogenic reaction to lighter force in the normal rats was expressed by increased osteoblastic activity, normal lamellar orientation and normal distribution of osteocytes. In conclusion, the light force can displaces both tooth and supporting bone. So, the proclination of upper incisors with the light force will maintain the labial alveolar bone of upper incisors or decreases the risk of bone resorption.

**The light force for upper incisor protraction**

According to the pressure-tension theory, The optimal force level for tooth movement should not be over than 20-26 g/cm$^2$ of capillary pressure.[25-27] Smith and Storey[28] introduced the optimal-force theory, proposing that the optimum force related to the root surface area and pressure between 150 and 200 g would produce the maximum rate of tooth movement to distalize human maxillary canines. With the force increased beyond this optimum range, hyalinization and undermining resorption could occur. According to Quinn & Yoshikawa[29] , $7 \pm 14$ kPa ($70 \pm 140$ g/cm$^2$) would be optimal for canine retraction in humans.

In 2000, Iwasaki et al[30] compare a continuous retraction force averaging 18 g with 60 g applied to the maxillary canines. Estimated average compressive stress on the distal aspect of the canine teeth was 4 kPa or 13 kPa and the moment-to-force ratios were between 9 and 13 mm. The lag phase was eliminated and average velocities were 0.87 and 1.27 mm/month for 18 and 60 g of average retraction force, respectively. They concluded that effective tooth movement can be produced with lower forces and that because loading conditions were controlled, cell biology must account for the variability in tooth velocities measured in these subjects.

In 2009, Yee et al[31] measured the rate and the amount of orthodontically induced tooth movement under heavy (300 g) and light (50 g) continuous forces for maxillary canine retraction. They found that the heavy force increased amounts and higher rates of tooth movement, but the unwanted clinical side effects of loss of canine rotation control and anchorage were concomitantly increased. Light forces provided a greater percentage of canine retraction than heavy forces, with less strain on anchorage.

According to Lee[32], He measured the surface of the root being exposed to movement, called “the enface surface of the root”. The size of the enface root surface exposed to mesiodistal movemenfs of upper canines is 0.75 $cm^2$. By considering the lower force for maxillary canine retraction 18 g[30] and 50 g[31], the light force per a square centimeter is ranged from 18/0.75 = 24 $g/cm^2$ to 50/0.75 = 67 $g/cm^2$.

Applying the light force concept in the proclination of upper incisors, the calculated light force and upper incisors enface root surface area in labiolingual movements are used to perform the light force for proclination of upper incisors. The enface root surface of upper lateral incisor is 0.4 $cm^2$ and for upper central incisor is 0.5 $cm^2$.

- The total enface root surface area of the 4 upper incisor teeth = (0.4 x 2) + (0.5 x 2)
  = 1.8 $cm^2$

- The light force for proclination of upper incisors = 1.8 x 24 to 1.8 x 67
  = 43 to 120 g

From the study of Reitan[33], recommended force for extrusion of individual teeth should be around 25 g. Relapse of the extruded teeth was only slight because individual fiber bundles had been elongated and because newly formed osteoid layers in the apical area were not be resorbed, but will remain there until calcified. But, there has not the present study about light force for extrusion. So, the extrusion force should not over 100 g for the upper incisors. In conclusion, the calculated light force used in this study was about 43 to120 g for horizontal force and should not over than 100 g for vertical force.

**Class III elastic**

Intermaxillary Class III elastics are most helpful in orthodontic correction of Class III case. They tend to produce lower incisor retroclination, upper incisor proclination, and anteroposterior correction of the molar relationship with mesial tipping of maxillary molar. All component of the Class III elastic force can therefore be helpful in reaching treatment goals in average or low angle cases by upper molar extrusion, upward and forward rotation of maxillary plane and consequently, backward and downward rotation of mandible will be occurred and also, decreased the deep bite and Class III molar relationship. However, in high angle Class III cases with an open bite tendency, upper molar extrusion is contra-indicated.[34] The Class III elastics is commonly crossed from upper first molar hook to lower canine hook that angle to occlusal plane about 30 degree. The component of the elastic force is divided in horizontal and vertical direction. The long Class III elastic can produce more horizontal force. In order to, the more vertical force, short Class III elastics crossing from upper premolar area to lower canine that angle to occlusal plane about 60 degree can be used. With this angle, the effect on maxillary plane rotation is decreased because the line of force passes closed the center of rotation of maxillary teeth that located between first and second premolar root. In Class III patients, maxilla is also deficient in vertical direction which always shows in decreased incisal show at rest. So, using short Class III elastic may be advantageous in promoting vertical movement of upper teeth and may enhance vertical growth of maxilla.

**Pilot study for the light force**

This study designed the new technique for forward and downward movement of upper incisors by 2x4 appliance with advancing loops to proclined upper incisors combined with short light Class III elastics. The light force for the upper incisors was ranged about 43-120 g of horizontal force and not over 100 g of vertical force as described previously. To achieve this light force level, pilot study was done to test the force that produced from advancing loops by universal testing machine as show in Fig. 2. In addition, Class III elastics were measured the force and the angulation.

According to short light Class III elastics, the lightest elastics in PSU orthodontic clinic or 5/16” (8 mm) 2 oz (Ormco) were used to produce vertical force component for downward movement of upper dentition and maybe maxilla and also produce horizontal force component. This Class III elastic was crossed from middle of buccal surface of upper first premolar or upper first primary molar to distal of lower lateral incisor to produce the forward and downward force for upper incisors. The 10 elastics were used to test angulation and produced force. As result, short light Class III elastic angled 30-45 degree to occlusal plane. With these range of angles, the force produced from the elastic was 25-40 g. Regarding to the angle 30 degree, the horizontal force was ranged from 22-34 g (cos(30$^o$) x 25 to cos(30$^o$) x 40) and the vertical force was ranged from 13-20 g (sin(30$^o$) x 25 to sin(30$^o$) x 40). About the angle 45 degree, either horizontal or vertical force was ranged from 18-28 g. In conclusion, the short light Class III elastic produced 18-34 g of horizontal force and 13-28 g of vertical force. If the elastics were crossed both right and left side, the total force from the elastics for upper incisors were 36-68 g in horizontal and 26-56 g in vertical.

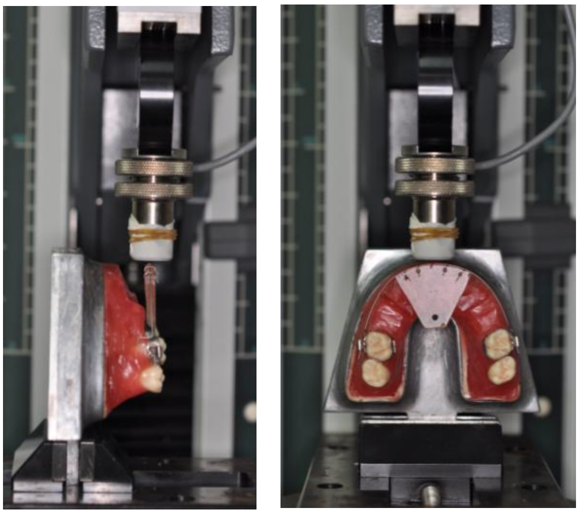

**Fig. 2:** Show universal testing machine and testing method

The horizontal force of upper incisors was a combination of advancing loops and short light Class III elastics. If the 36-68 g of the elastics force was subtracted from the 43-120 g of total horizontal light force, the force from archwire should be within 7-52 g. So, the wires with various type and preparation were tested for the appropriate archwire that can produce the light force. The included various types of archwires were 0.016” stainless steel wire with advancing loops, 0.016” Beta-titanium wire or TMA with advancing loops, 0.016” NiTi with crimpable stops, 0.016” x 0.016” NiTi with crimpable stops. The size of advancing loops was designed in height 5 mm to avoid irritating vestibules and width 3 mm.[10] Each types of archwire consisted of 10 wires. Each archwires was inserted in buccal tube of molars teeth in typodont. Anterior segment of the archwire was coligated 4 points to acrylic pad with ligature wire to represent the four upper incisor bracket positions. And then, cylindrical metal head of universal testing machine was used to push at labial most of archwire with 1 mm activation of the wire. Force was measured 3 times per wire. From the force test (Table 2), the archwire that produced appropriated horizontal force within 7-52 g was 0.016” TMA with 5 x 3 mm advancing loops. This archwire produced force about 38 g. When combined the horizontal force from the Class III elastics (36-68 g) and advancing loops (38 g), the total horizontal force was 74-106 g. In conclusion, ELF technique which was the application of 2x4 appliance, 0.016” TMA wire with advancing loops and 5/16” 2 oz. short light Class III elastics produced 74-106 g of horizontal force and 26-56 g of vertical force.

**Table 2:** Average force from 1 mm activation of the various type and preparation archwires

| Wire types | Preparation method | Average force (g)<br>Mean ± SD |
|---|---|---|
| 0.016” SS<br>(Highland) | 5x3 mm advancing loops | 82.24 ± 20.80 |
| 0.016” TMA<br>(Ormco) | 5x3 mm advancing loops | 38.44 ± 4.04 |
| 0.016” TMA<br>(Ormco) | 5x3 mm advancing loops | 63.36 ± 6.59 |
| 0.016” NT<br>(Highland) | Crimpable stops | 83.07 ± 7.72 |
| 0.016” x 0.016” NT<br>(Highland) | Crimpable stops | 126.53 ± 11.36 |

**Conceptual framework**

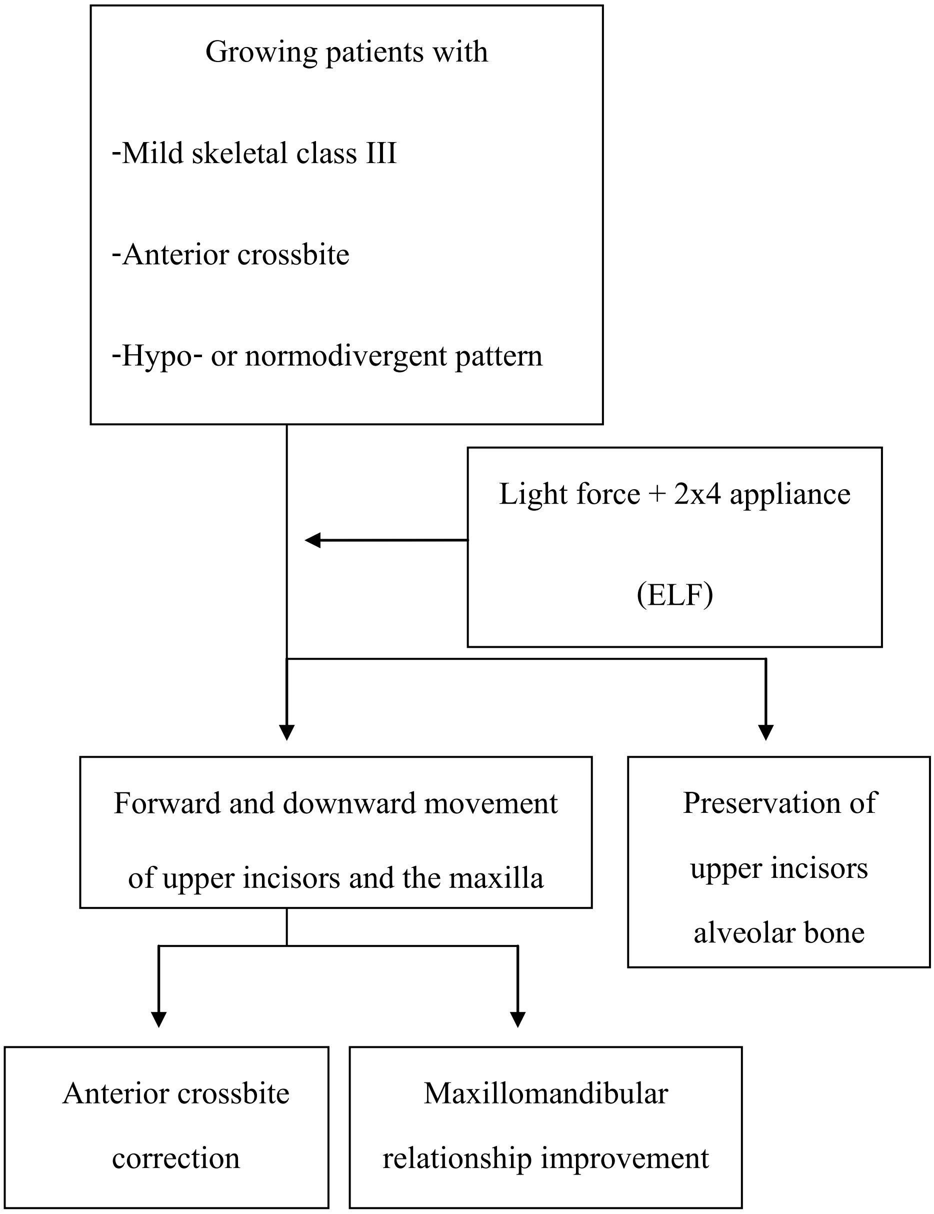


**Fig. 3:** Conceptual framework

## Objectives

1. To investigate skeletal and dental changes after the application of ELF in Class III growing patients.
2. To examine the change of the alveolar bone quantity of the upper incisors dentoalveolar area after the application of ELF in Class III growing patients.

## Hypothesis

1. Forward and downward movement of upper incisors and the anterior maxillary dentoalveolar structures or premaxilla can be achieved by the use of ELF.
2. ELF can maintain the alveolar bone thickness of the upper incisors.

## Significance of the study

This new approach will be able to move the upper incisors and the premaxilla forward and downward with favorable amount and direction, safe for dentoalveolar structures, simple and commonly used in clinic, less discomfort, and less need for patient co-operation.

# CHAPTER 2

# RESEARCH METHODOLOGY

## Subjects

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 from the formula of Kittika[35]

$$\text{Sample size (n)} = \frac{(Z_{(1-\alpha)} + Z_{(1-ß)})^2 \sigma^2 \text{diff}}{(\overline{x}_2 - \overline{x}_1)^2}$$

The values of parameters are taken from the study of Gu et al[11] as follow:

$\overline{x}_2 - \overline{x}_1$ (difference of mean between before and after treatment) is 2.6.

$\sigma$ diff (standard deviation of total change) is 3.0.

The level of significance of the change is established at 95% ($Z_{(1-\alpha)} = 1.96$).

The power of the test in this study is established at 80% ($Z_{(1-ß)} = 0.84$).

So sample size in the study is 11 patients.

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

1. Class III malocclusion patients
2. Anterior crossbite or edge to edge incisor relationship in centric occlusion
3. Mild skeletal Class III with hypodivergent or normodivergent pattern or $-2 \leq \text{ANB} \leq 1$ degree and SN-MP < $35^o$ when assessed from lateral cephalogram.
4. During pre-pubertal growth spurt or between stage 1-5 of skeletal maturation[36] assessed by hand & wrist radiographic examination according to method of Björk[37] and Grave and Brown[38].

5. From treatment plan, upper incisors were moved forward and downward to correct anterior crossbite.
6. No underlying disease.
7. No sign and symptoms of periodontal disease.
8. No oral habits that include thumb sucking, nail biting, tongue thrusting, lip biting.

All of patients were informed about step of treatment and willing to participate. When a patient sample was satisfied the inclusion criteria attended the orthodontic clinic, parent and patient were invited to enter the trial. Then, the orthodontist provided the patient and parent both oral and written information of detail to study.

## Material and method

### Easy Light Fixed (ELF) design and treatment sequence

Patients were treated with 2x4 preadjusted edgewise fixed appliances (Ormco, 3M) that consist of 4 permanent upper incisor brackets with 0.022” x 0.028” slot and 2 permanent first molar buccal tubes with 0.022” slot. Upper incisors were aligned until 0.021” x 0.025” stainless steel wire which used as main archwire and were co-ligated with ligature wire as one unit. Lower incisors were also aligned until 0.021” x 0.025” stainless steel wire. In patients who had overbite of anterior crossbite 2-3 mm, the posterior raised bites by light cured compomer (Bandlok, Unitek, 3M) were added at occlusal surface of lower molars to open the bite and unlock upper incisors for forward movement (Fig. 4).

Then, the rigid lower archwire, 0.021” x 0.025” stainless steel wire, was inserted both lower incisors and lower molars for supporting short light Class III elastics and maintaining lower incisor position. The crimpable hooks or Kobayashi hooks were attached at distal of lower lateral permanent incisors. After that, the U-shaped advancing loops were bent in 0.016” (0.4mm) diameter TMA round wire (Ormco, 3M). The length of the loop was about 5 mm and the width of the loops was 3 mm. Circular hooks in 2 mm diameter for elastics were bent anterior to advancing loops. When inserted the wire in upper buccal tubes, distal portion of the advancing loops were laid against the mesial end of the molar tubes and circular hooks position must be placed at middle of buccal primary first molars or first premolars area. Anterior segment of TMA wire was placed 1 mm labially to main archwire of upper incisors.[10] Then, the TMA wire was push to contact the main archwire and ligated with elastomeric ring in upper incisor brackets. To support the vertical force for downward displacement of upper incisors, short light Class III elastics (5/16" 2oz or 56 g) were used. The short light Class III elastics were designed to cross from the circular hooks of the TMA wire to the hooks at distal of lower lateral permanent incisors. The elastics were angled about 30-45$^{o}$ to occlusal plane (Fig. 5).

**Fig. 4**: Aligning upper and lower incisors and raising the bite by compomer at lower first permanent molars

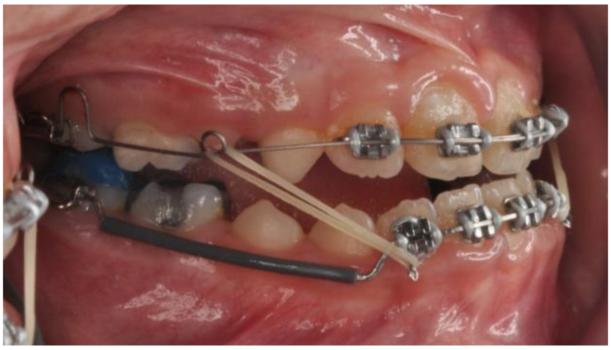

**Fig. 5**: Easy Light Fixed (ELF) technique: 2x4 fixed appliance, 0.016" TMA wire with advancing loops and circular hooks and short light Class III elastics

Patients and parent were instructed to use short light Class III elastics all the time except eating and tooth brushing time. The timecard was given to patients and parent to record the use of the elastics. Reminding for using elastics was done by phone. Moreover, agility of crossing elastics was test to evaluate the cooperation. After achieving normal overjet and overbite, 0.016" stainless steel wire with passive stops at mesial to molar tubes was used to maintain upper incisors position and discontinued the short light Class III elastics and removed the compomer on lower molars (Fig. 6). The first permanent molars were allow to extrude until obtained the seated molar occlusion for maintaining the vertical dimension after anterior crossbite correction. Lateral cephalograms were taken to evaluate changes of dental and skeletal. Upper incisors were maintained for 4 months before performing CT scan to evaluate alveolar bone. Between maintenance of upper incisor position period, patients were examed for stability of overjet and overbite every month.

**Fig. 6**: Maintaining upper incisors with 0.016” stainless steel wire with passive stops and discontinued the elastics after obtain normal overjet and overbite

## Records and data analysis

### Cephalometric analysis

Lateral cephalometric films were taken from natural head position which the patient was in the cephalostat and look straight ahead into a mirror. The patient was observed from the side to ensure that the pupil is in the middle of the eye, and the head was repositioned if there is even a slight discrepancy. The patient was instructed to comfortable and relax and not to tilt or tip the head.[39] Lateral cephalographs were done before the beginning of treatment ($T_0$) and after achieved normal overjet, overbite and seated molar occlusion ($T_1$). All lateral cephalometric radiographs used in this study were taken in the same cephalostat and cephalometric X-ray machine. Cephalometric tracing was done on acetate paper and then, reference points and lines were marked with 0.3 mm in diameter of mechanical pencil by one observer to avoid interoperate errors. Linear and angular measurements were measured by same protractor. All cephalograms were retraced and remeasured independently on 2 separate occasions with 4 week intervals. Method error (ME) in locating and measuring the changes of each landmarks were calculated by Dahlberg's formula[40]. Total error about 0.59 mm was acceptable levels of accuracy.[41] References and measurements that used in lateral cephalometric analysis are as follow (Fig. 7):

Reference points:

- S (sella): the midpoint of the cavity of sella turcica.
- N (nasion): the anterior point of the intersection between the nasal and frontal bones.
- MnI (incision inferius): the incisal tip of the most prominent mandibular incisor
- MxI (incision superius): the incisal tip of the most prominent maxillary incisor
- Pog (pogonion): the most anterior point on the bony chin.
- Go(gonion): the midpoint of the contour connecting the ramus and body of the mandible
- Me (menton): the most inferior point on the mandibular symphysis.
- Point A: the innermost point on the contour of the premaxilla between anterior nasal spine and the incisor tooth.
- Point B: the innermost point on the contour of the mandible between the incisor tooth and the bony chin.
- ANS (anterior nasal spine): the tip of the anterior nasal spine of the process of the maxilla forming the most anterior projection of the floor of the nasal cavity.
- PNS (posterior nasal spine): the tip of the posterior spine of the palatine bone, at the junction of the hard and soft palates

Reference lines:[42]

- Horizontal reference line (X): the 6 degree downward line from sella-nasion (SN) line at sella.
- Vertical reference line (Y): the line that perpendicular to the horizontal reference line at sella
- SN plane: the line connecting the sella(S) to the N point
- Palatal plane(PP): the line connecting the anterior nasal spine (ANS) to the posterior nasal spine (PNS)
- Mandibular plane (MP): the line connecting gonion (Go) to menton (Me)

- UI axis (long axis of upper incisor): the line connecting MxI to apical most of upper incisor root
- LI axis (long axis of upper incisor): the line connecting MnI to apical most of lower incisor root

Angular measurements:

- SNA: the angle designed to evaluate the anteroposterior position of the maxilla relative to the anterior cranial base
- SNB: the angle designed to evaluate the anteroposterior position of the mandible relative to the anterior cranial base
- ANB: the difference between SNA and SNB indicates the magnitude of the skeletal jaw discrepancy
- UI axis-PP: the angle formed from the long axis of the upper incisor (UI axis) and the palatal plane
- LI axis-MP: the angle formed from the long axis of the lower incisor (LI axis) and the mandibular plane
- Palatal plane angle: the angle formed by SN plane to palatal plane
- Mandibular plane angle: the angle formed by SN plane to mandibular plane

Linear measurements:

- Horizontal and vertical linear measurements: the measured by the distance from X-axis and Y-axis to Point-A, point-B, ANS, MxI, MnI, and Pog to evaluate the skeletal and dentoalveolar changes
- Overbite: the measured by distance along Y-axis between MxI and MnI
- Overjet : the measured by distance along X-axis between MxI and MnI
- LFH (lower facial height): the measured by distance from subnasale point to soft tissue menton

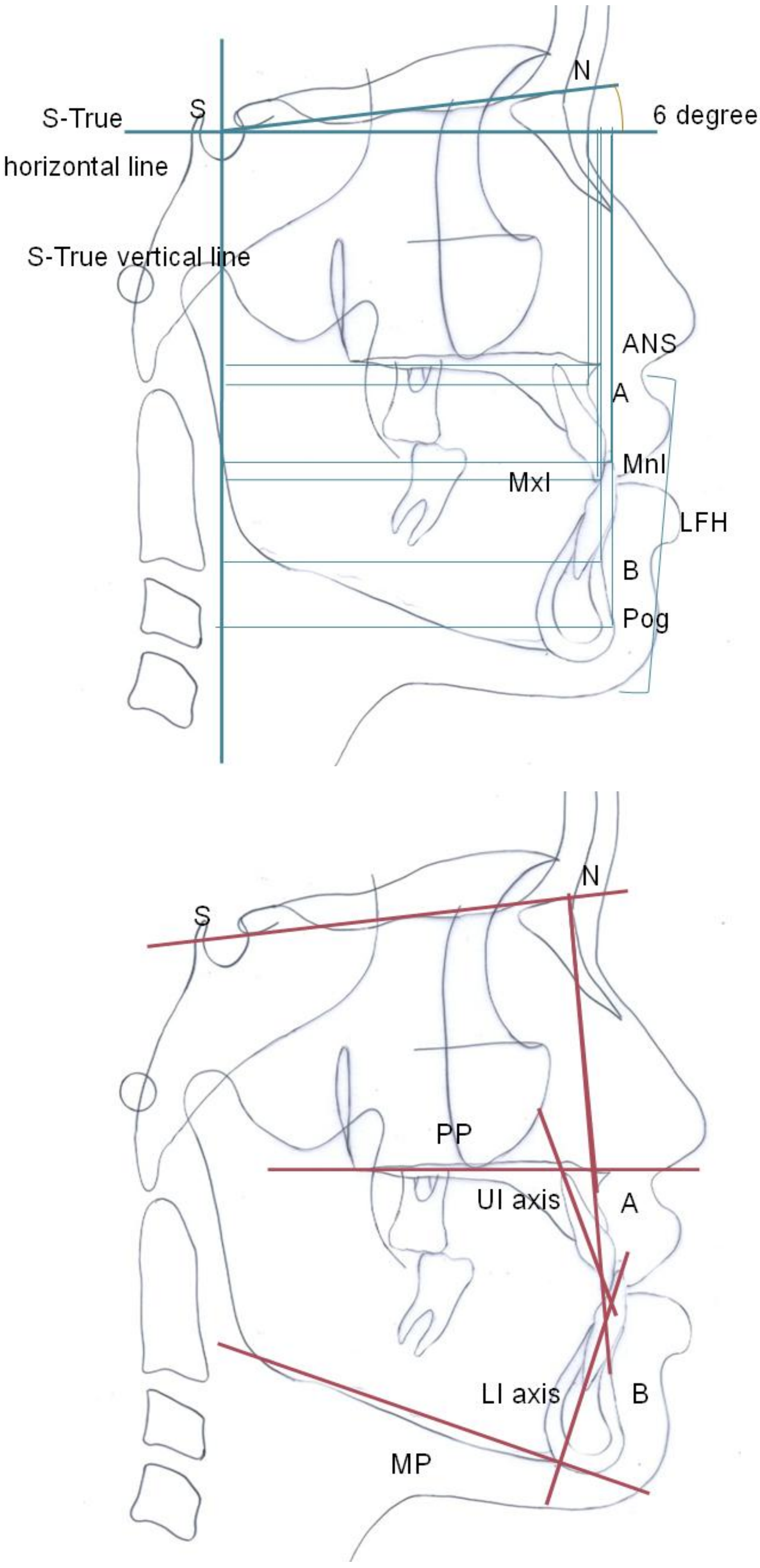


**Fig. 7**: The cephalometric reference points and lines, angular and linear measurements

Lateral cephalometric measurements in this study were performed by X-Y coordination in 6 degree down from S-N plane as horizontal reference line and perpendicular to horizontal line at Sella turtica as vertical reference line. With distance measuring, we could ensure before and after difference from the same reference without confounding from the change of reference point. From the study of Pancherz et al[43], S-N plane was rarely changed with short-term growth and easy to construct when compare to another reference line such as Frankfort plane or occlusal plane. In addition, Horizontal reference line was constructed by 6 degree down from S-N plane to simulate natural head position.[44] Outcome measures to be assessed in the cephalometric results were sagittal and vertical position changes of skeletal and dental. The mean and standard deviation of cephalometric values were calculated and compared the result at $T_1$ with $T_0$.

**Dental CT scan**

The bone thickness of upper incisors was evaluated by CBCT scan. The linear and angular measuring in CBCT produced a 1-to-1 image-to-reality ratio.[45] CBCT findings have proven to be statistically similar to histologic measurements. Moreover accuracy and reliability of CBCT measurements are not affected by changing the skull orientation.[46, 47] So, this study was designed to use CT measurements to more accurately evaluate bone thickness changes.

CT scan was done at upper incisors region with 80 kV, 3-5 mA (depend on the patient body proportion) from dental CT scanning (Veraviewepocs, J.Morita, Tokyo, Japan). And this region was determined by setting the panoramic radiograph. CT scan images were taken before the application of advancing loops and elastics, ($CT_0$) and 4 months after achieving normal overjet and overbite ($CT_1$) for completing the bone remodeling process. For each tooth, the labial, palatal and total thickness of alveolar plates was measured by OneVolumeViewer ™ software. Bone thickness was measured in 3 levels of the root, crestal level (S1), mid root level (S2), and apical level (S3). These levels were specified along the long axis of the tooth and located every 3 mm above cementoenamel junction (CEJ) level (Fig. 8). Measurements were taken at the site adjacent to the widest point of the labio-lingual root surface in cross sectional image of each level (Fig. 9).

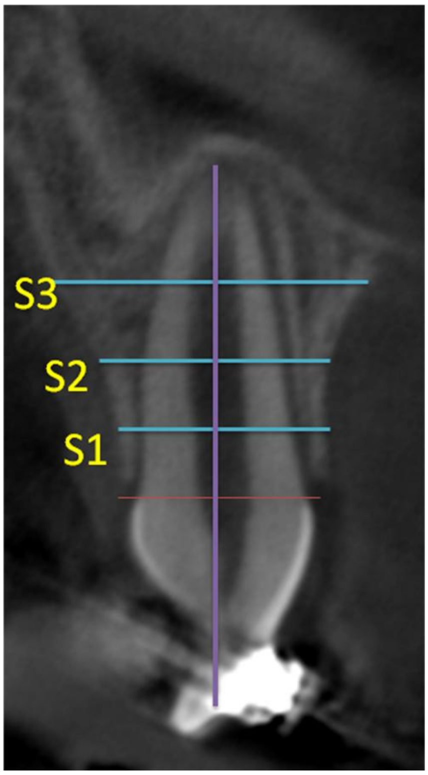


**Fig. 8**: Measurements of bone thickness from CT scan images

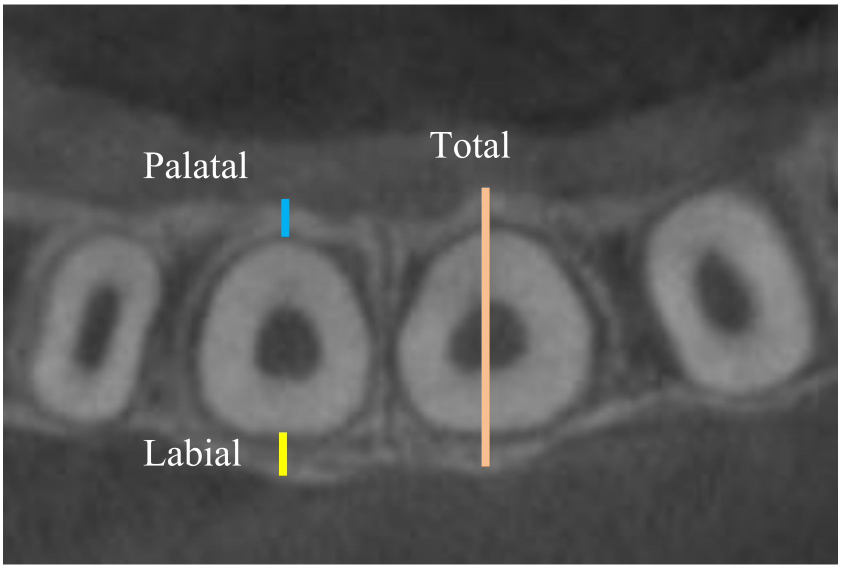


**Fig. 9**: Measurements of maxillary teeth bone plate thickness

All CT images at $CT_0$ and $CT_1$ were taken 9 measurements for each tooth: 3 on the labial side, 3 on the palatal side, and 3 for the total thickness. $CT_1$ measurements took at the same slice levels as those at $CT_0$, using CEJ level of the tooth as a reference. All measurements on CT scans were traced by same investigator. Alveolar bone thickness measurements that were used in computed tomography analysis are as follow:

The thickness of the labial alveolar plate was measured as a line passing from the outer surface of the labial plate to the mid labial root.

L1: labial alveolar bone thickness at crestal level (S1)

L2: labial alveolar bone thickness at mid root level (S2)

L3: labial alveolar bone thickness at apical level (S3)

The thickness of the palatal alveolar plate was measured as a line passing from the outer surface of the palatal plate to the mid palatal root.

P1: Palatal alveolar bone thickness at crestal level (S1)

P2: Palatal alveolar bone thickness at mid root level (S2)

P3: Palatal alveolar bone thickness at apical level (S3)

The thickness of the total alveolar plate was measured as a line passing through the center of the pulp from the outer surface of the palatal plate to the outer surface of the labial plate.

T1: Total alveolar bone thickness at crestal level (S1)

T2: Total alveolar bone thickness at mid root level (S2)

T3: Total alveolar bone thickness at apical level (S3)

## Statistic analysis

Shapiro-Wilk test was used to test normality of cephalometric and CT scan data. The measurements of all samples were presented by mean and standard deviation. Paired t-test was used to compare the skeletal and dental changes between $T_0$ and $T_1$ and used to compare the upper incisors bone thickness changes between $CT_0$ and $CT_1$. The acceptable alpha level for significance was usually 0.05. But in this study, there are multiple outcome measures and there was concern about the possibility that the results might be perceived as being a fishing expedition. This obviously makes it harder to claim a significant result and so doing decreases the chance of making a Type I error to every acceptable levels. So, a Bonferroni adjustment[48] to calculate an adjusted alpha level was used by dividing the original alpha level (0.05) with the number of outcome measures. The measured parameters for cephalometric changes were 24 parameters. And those for CT image changes were 9 parameters of each upper incisor. So, the adjusted significant level for cephalometric and CT image changes were $p \leq .002$ and $p \leq .005$ respectively.

The reproducibility of skeletal, dental and bone thickness measurements was assessed by calculating method error from the difference between two measurements taken at least 4 weeks apart. The measurement error was calculated from the formula of Dahlberg[40]:

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

d: The difference between duplicated measurements

n: The number of double measurements

Intraobserver reliability of the measurement was calculated by Paired t-test with significant level at $p < 0.05$.

# CHAPTER 3

# RESULTS

At the beginning, there were 13 subjects participated in this study. Because the anterior crossbite was corrected during leveling phase, 2 cases were excluded. The remaining 11 samples comprised 9 females and 2 males. Sex and age of all subjects at the start of treatment were summarized in Table 3. Their mean age at the start of the treatment was 9.9 ± 1.0 years. Treatment duration of each subjects were showed in Table 4 and average total treatment time was 10.6 ± 3.5 months. At pre-treatment, subjects were mild skeletal Class III (ANB, -1.2 ± 2.3$^{o}$) with normodivergent pattern (SN-MP, 31.2 ± 2.3$^{o}$) and had anterior crossbite (OJ, -3.1 ± 1.1$^{o}$).

**Table 3:** Sex and age at the start of treatment of all subjects

| Subjects | n | mean (year) | SD |
|---|---|---|---|
| Female | 9 | 9.8 | 1.1 |
| Male | 2 | 10.5 | 0.6 |
| Total | 11 | 9.9 | 1.0 |

n, number of subjects; SD, standard deviation

**Table 4:** Treatment duration (month) of the treatment

| | mean | SD |
|---|---|---|
| Leveling phase | 5.6 | 1.7 |
| Advancing phase | 5.0 | 3.6 |
| Total ($T_1 - T_0$) | 10.6 | 3.5 |

## Magnification and measurement error analysis

Method error for lateral cephalometric measures were 0.1 mm., ranging from 0 to 0.4 mm, for the distance measurement and 0.3°, ranging from 0° to 0.8° , for the angular measurement. Method error for the bone thickness measurement from computed tomography was 0.33 mm, ranging from 0.00 to 0.49 mm. Paired t-test showed no significant difference between two series of measurements. So, the method was found to yield sufficient reliability.

## Lateral cephalometric analysis

Shapiro-Wilk test was used to test normality, and found means of cephalometric measures normally distributed. Paired t-test was used to compare the mean differences of pretreatment and after achieving normal OJ, OB and seated molar occlusion ($T_1$ - $T_0$). Means and standard deviations of each cephalometric measure at $T_0$ and $T_1$ and the changes were shown in Table 5.

### Maxillary measurements

### Maxilla

Maxillary skeletal measurements (premaxilla area) showed significant forward changes about 2 mm (ANS and A to S vert., $p$ < .002). SNA was also increased 1.2$^{o}$ but not significance. Vertically, A point (A to S hor., $p$ = .002) showed significant downward changed 2.5 mm. ANS point (ANS to S hor.) displaced downward 1.8 mm but not significant. In addition, maxillary plane (SN-PP) remained unchanged.

**Upper incisors**

Upper incisors were significantly moved forward about 5 mm (MxI to S vert., $p < .002$) and proclined 6.6$^{o}$ (UI axis-PP, $p < .002$). In vertical, upper incisors were moved downward 1.9 mm (MxI to S hor.) that nearly the downward movement of ANS point but not significant.

**Mandibular measurements**

**Mandible**

The mandible significantly moved downward about 4 mm (B and Pog to S hor., $p < .002$) and lower facial height showed significant increases 4 mm (LFH, $p < .002$). There were not significant changed of mandibular angle (SN-MP). The horizontal measurements (B and Pog to S Vert. and SNB) of mandible were not significant changed.

**Lower incisors**

Lower incisors were significantly moved downward about 4 mm (MnI to S hor., $p < .002$) similar to mandibular movement but showed no horizontal change (MnI to S vert.). Inclination of lower incisors (LI axis - MP) was decreased about 2$^{o}$ but not significant.

**Maxillomandibular relationship measurements**

Overjet was significantly increased from negative to normal about 5 mm which mainly resulted from forward movement of upper incisors. Overbite was significantly decreased about 2 mm (from 3.7 mm in crossbite to 2 mm in normal overjet). Forward movement of the maxilla led to a significant improvement in intermaxillary sagittal relationship. ANB was significantly increased 2$^{o}$. The distances between A and B points in horizontal (A-B hor.) was also increased 2 mm and in vertical (A-B vert.) 1 mm but not significant in both direction.

**Table 5:** Measurement values at $T_0$ and $T_1$ in each variable and the differences

| Variables | $T_0$ | | $T_1$ | | $T_1$-$T_0$ | | |
|---|---|---|---|---|---|---|---|
| | mean | SD | mean | SD | mean | SD | P value |
| **Horizontal measurements** | | | | | | | |
| Overjet | -3.1 | 1.1 | 2.0 | 1.0 | 5.2 | 1.6 | < .001* |
| A-B hor. | -0.7 | 5.0 | 0.9 | 4.2 | 1.9 | 2.3 | .031 |
| ANS–S vert. | 68.4 | 5.5 | 70.4 | 5.6 | 2.0 | 1.2 | < .001* |
| A-S vert. | 64.8 | 5.8 | 67.0 | 6.1 | 2.3 | 1.4 | < .001* |
| MxI–S vert. | 67.4 | 7.8 | 72.5 | 8.5 | 4.8 | 1.8 | < .001* |
| MnI–S vert. | 70.5 | 8.3 | 70.5 | 8.5 | -0.4 | 2.7 | 1.000 |
| B–S vert. | 65.5 | 9.9 | 66.1 | 9.5 | 0.4 | 3.4 | .486 |
| Pog–S vert. | 66.4 | 11.4 | 67.2 | 10.9 | 0.6 | 3.8 | .422 |
| **Vertical measurements** | | | | | | | |
| Overbite | 3.7 | 1.4 | 1.7 | 0.8 | -1.9 | 1.9 | .002* |
| A-B vert. | 36.9 | 3.1 | 38.4 | 4.5 | 1.3 | 2.4 | .053 |
| ANS-S hor. | 43.5 | 3.0 | 45.0 | 3.3 | 1.8 | 1.7 | .012 |
| A-S hor. | 47.5 | 3.4 | 49.5 | 3.3 | 2.5 | 1.6 | .002* |
| MxI–S hor. | 67.8 | 4.5 | 69.5 | 4.4 | 1.9 | 2.1 | .009 |
| MnI–S hor. | 64.1 | 4.8 | 67.8 | 4.6 | 3.9 | 1.9 | < .001* |
| B–S hor. | 84.4 | 5.7 | 87.9 | 5.8 | 3.8 | 2.0 | < .001* |
| Pog-S hor. | 94.3 | 7.0 | 99.1 | 8.2 | 5.3 | 2.4 | < .001* |
| LAFH | 60.4 | 4.5 | 64.9 | 4.9 | 4.1 | 1.0 | < .001* |
| **Angular measurements** | | | | | | | |
| SNA | 81.7 | 4.6 | 83.0 | 4.3 | 1.2 | 1.1 | .003 |
| SNB | 83.0 | 5.1 | 82.5 | 4.7 | -0.6 | 1.8 | .378 |
| ANB | -1.2 | 2.3 | 0.5 | 1.6 | 1.8 | 1.0 | .001* |
| UI axis-PP | 117. | 7.7 | 124. | 7.3 | 6.6 | 3.0 | < .001* |
| LI axis-MP | 90.5 | 5.0 | 89.1 | 5.4 | -2.3 | 4.1 | .297 |
| SN-PP | 9.9 | 2.9 | 10.1 | 3.4 | 0.3 | 2.0 | .690 |
| SN-MP | 31.2 | 2.3 | 31.9 | 5.2 | 0.6 | 1.6 | .147 |

*$p \leq .002$; NS, not significant; SD, standard deviation; S vert., S vertical reference line; S hor., S horizontal reference line

## Computed tomography analysis

Shapiro-Wilk test was used to test normality. It was found that mean alveolar bone thickness was normally distributed. Paired t-test was used to compare the difference of alveolar bone thickness before advancing phase and after 4 months maintaining ($CT_1$ – $CT_0$) of four upper incisors. The changes of labial bone, palatal bone and total alveolar bone thickness were showed in Table 6, 7 and 8 respectively. Labial, palatal and total bone thickness of upper incisors had no significant changes in three sections. According to total bone thickness, There were slightly decreased the thickness but no statistically significant changes.

**Table 6:** Comparison of mean labial alveolar bone thickness of four upper incisors at $CT_0$ and $CT_1$

| Labial bone width | | $CT_0$ | | $CT_1$ | | $CT_1$- $CT_0$ | | |
|---|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD | P value |
| Maxillary right lateral | L1 | 0.55 | 0.54 | 0.40 | 0.26 | -0.16 | 0.54 | .400 |
| | L2 | 0.80 | 1.27 | 0.45 | 0.47 | -0.35 | 1.10 | .366 |
| | L3 | 1.92 | 2.19 | 1.73 | 1.58 | -0.19 | 1.38 | .694 |
| Maxillary right central | L1 | 0.88 | 0.33 | 0.82 | 0.35 | -0.06 | 0.29 | .564 |
| | L2 | 1.26 | 0.74 | 1.15 | 0.83 | -0.11 | 0.48 | .524 |
| | L3 | 2.22 | 1.55 | 2.74 | 1.62 | 0.52 | 1.08 | .183 |
| Maxillary left central | L1 | 0.89 | 0.41 | 0.78 | 0.26 | -0.10 | 0.17 | .128 |
| | L2 | 1.34 | 0.64 | 1.37 | 0.63 | 0.03 | 0.38 | .847 |
| | L3 | 2.55 | 1.34 | 2.42 | 1.08 | -0.12 | 0.55 | .554 |
| Maxillary right lateral | L1 | 0.45 | 0.48 | 0.30 | 0.28 | -0.12 | 0.32 | .300 |
| | L2 | 0.85 | 0.99 | 0.46 | 0.55 | -0.30 | 0.43 | .066 |
| | L3 | 2.03 | 2.00 | 1.66 | 1.52 | -0.29 | 0.76 | .294 |

Significant when $p \leq .005$

**Table 7:** Comparison of mean palatal alveolar bone thickness of four upper incisors at $CT_0$ and $CT_1$

| Palatal bone width | | $CT_0$ | | $CT_1$ | | $CT_1 - CT_0$ | | |
|---|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD | P value |
| Maxillary right lateral | P1 | 1.14 | 0.43 | 1.21 | 0.54 | 0.07 | 0.43 | .642 |
| | P2 | 2.39 | 0.50 | 2.08 | 0.71 | -0.31 | 0.59 | .156 |
| | P3 | 3.62 | 0.77 | 3.19 | 0.92 | -0.44 | 1.06 | .251 |
| Maxillary right central | P1 | 1.53 | 0.93 | 1.05 | 0.32 | -0.48 | 1.07 | .213 |
| | P2 | 2.37 | 0.77 | 1.88 | 0.50 | -0.48 | 0.63 | .067 |
| | P3 | 4.09 | 1.78 | 2.95 | 1.17 | -1.14 | 1.15 | .018 |
| Maxillary left central | P1 | 1.38 | 0.20 | 1.32 | 0.38 | -0.05 | 0.31 | .640 |
| | P2 | 3.03 | 1.23 | 2.59 | 1.06 | -0.40 | 0.46 | .032 |
| | P3 | 4.49 | 1.73 | 4.09 | 1.60 | -0.36 | 0.36 | .015 |
| Maxillary right lateral | P1 | 1.22 | 0.41 | 1.25 | 0.74 | 0.02 | 0.42 | .875 |
| | P2 | 2.51 | 1.17 | 2.44 | 1.41 | -0.06 | 0.39 | .671 |
| | P3 | 3.77 | 1.40 | 3.49 | 1.73 | -0.22 | 0.87 | .485 |

Significant when $p \leq .005$

**Table 8:** Comparison of mean total alveolar bone thickness of four upper incisors at $CT_0$ and $CT_1$

| Total bone width | | $CT_0$ | | $CT_1$ | | $CT_1 - CT_0$ | | |
|---|---|---|---|---|---|---|---|---|
| | | mean | SD | mean | SD | mean | SD | P value |
| Maxillary right lateral | T1 | 7.39 | 0.95 | 7.27 | 0.74 | -0.12 | 0.49 | .474 |
| | T2 | 8.05 | 1.14 | 7.58 | 1.11 | -0.47 | 0.64 | .059 |
| | T3 | 9.45 | 2.24 | 8.83 | 2.20 | -0.62 | 0.88 | .069 |
| Maxillary right central | T1 | 8.08 | 1.17 | 7.69 | 0.49 | -0.39 | 0.90 | .229 |
| | T2 | 8.25 | 1.08 | 8.02 | 0.97 | -0.24 | 0.32 | .054 |
| | T3 | 9.96 | 2.93 | 9.38 | 2.26 | -0.57 | 0.84 | .076 |
| Maxillary left central | T1 | 8.09 | 0.64 | 7.96 | 0.71 | -0.11 | 0.34 | .348 |
| | T2 | 9.26 | 2.10 | 8.96 | 1.59 | -0.27 | 0.76 | .318 |
| | T3 | 10.56 | 2.82 | 10.05 | 2.57 | -0.46 | 0.66 | .071 |
| Maxillary right lateral | T1 | 7.50 | 0.87 | 7.38 | 1.15 | -0.09 | 0.45 | .556 |
| | T2 | 8.56 | 1.97 | 8.13 | 1.95 | -0.34 | 0.53 | .093 |
| | T3 | 9.73 | 2.95 | 9.31 | 2.61 | -0.33 | 0.50 | .082 |

Significant when $p \leq .005$

# CHAPTER 4

# DISCUSSION

An initial characteristic of samples in this study was mild skeletal Class III with normodivergent pattern. Although maxillary position of the subjects was within normal range or orthognathic maxilla, treatment is necessary because the abnormality tends to worsen with age, since maxillary growth cannot catch up with the mandibular growth.[49] The mean age of samples was 9.9 ± 1.0 years and skeletal age was within pre-pubertal growth spurt. We assumed that growth between female and male in pre-pubertal stage or age below 11-12 years was not different as reported by Alexander et al[50]. Hence, the male and female data was pooled.

The results of this study demonstrate that ELF technique can effectively correct anterior crossbite and improve skeletal relationship. The maxilla measured from the premaxilla area was displaced forward with neither vertical change nor rotation. Upper incisors were proclined and positioned forward. The mandible was moved downward without change in horizontal position and mandibular angle. Lower incisors were moved downward along with the mandible but maintained its horizontal position and inclination. Lower facial height was increased. From CT scan, labial, palatal and total alveolar bone thicknesses of upper incisors did not change during treatment.

## Skeletal and dental changes

### The maxillary and upper incisor changes

### Horizontal changes

After 10.6 months of treatment time, forward movement of the premaxilla and upper incisors was about 2 mm. and 5 mm respectively, which is more than horizontal growth of the maxilla (approximately 1.2-1.4 mm/year) and the upper incisors (approximately 1.6 mm/year) among untreated Class III subjects of the same age from the study of Alexander et al.[50]

Comparing the change of SNA angle, SNA in this study was increased 1.2° more than 0.1° of untreated Class III.[50] Although the A point significantly moved forward, the increasing SNA angle showed no significant change. This may be because the change of angle is less than the change of distance when A point moved forward. The higher rate of maxillary forward movement of the study subjects may be resulted from the combination of growth of the maxilla and the effect of force from ELF technique. The light advancing force from TMA wire with short light Class III elastics probably moved both upper incisors and the premaxilla forward.

The more forward movement of the upper incisors than the maxilla, in combination with the increase of inclination, indicates tipping movement of these teeth. These may be caused by the orthodontic force that did not pass the center of resistance of the upper incisors. When combined four upper incisors as a unit, center of resistance was located mid-root level of upper incisors in vertical position[51] and between upper central and lateral incisor in anteroposterior position. The light force direction from TMA wire with advancing loops passed at the bracket below the center of resistance that lead to upper incisor proclination. Such incisal proclination was advantageous for most Class III growing patients whose upper incisors were usually retroclined. Although, the 6.6° proclination of upper incisors in this study was less than the 9.5° proclination of 2x4 technique in Rabie's study[10]. These indicated the less relatively intrusion of the upper incisors and less worsen of the low smile line and tooth-lip relationship.

From the study of Al-Abdwani et al[52], each 10° proclination of the upper incisors resulted in an average of 0.4 mm retraction of A point in the horizontal plane. Since the upper incisor proclination of the subjects in this study was as little as 6°, the point A position was less likely to be affected by the incisor proclination, but rather by the forward displacement of the premaxilla.

**Vertical changes**

As previous study of vertical growth of the maxilla and upper incisors, the maxillary vertical change was downward 1.3-1.5 mm/year. Palatal plane angle was rarely changed (-0.4° to 0.8° /year). The upper incisors were also downward 1.8-1.9 mm/year. Although the vertical changes of the premaxilla in this study, considering to ANS point, were not significance, the downward movement of ANS point and the change of palatal plane in

10.6 months were 1.8 mm and 0.3$^{o}$ respectively. And the downward movement of the upper incisors was 1.9 mm. These indicated the normal vertical growth of the premaxilla and upper incisors in this study. The force of short light Class III elastics was expected to downward move upper incisors and maybe to enhance maxillary growth in vertical. But the result did not showed the changes over the normal vertical growth may be because the TMA wire was curved down when crossed the elastics led to decrease the vertical force that not enough to stimulate the premaxilla downward. Anyhow, these downward movements improved tooth-lip relationship. The initial tooth-lip relationship of the patients in this study was -0.3 mm. After the treatment, tooth-lip relationship was increased to 1.3 mm.

The A point showed significant downward movement while ANS and upper incisor changes were not significant. From the study of Shanker et al[53], the untreated Class III patients were evaluated for the localized remodeling of A point in vertical dimension. Their results showed that A point was found to remodel downward 1.1 mm during 6 months. This indicated that the significant downward movement of A point in this study may be resulted by downward local remodeling during growth combined with downward movement of the premaxilla.

**The mandibular and lower incisor changes**

**Horizontal changes**

Although the mandible was clockwisely rotated, it was not displaced backward. This can be explained by the mandibular growth. In untreated Class III[50], sagittal movement of the mandible (Pog-Na prep, distance from pogonion to nasion perpendicular line) increased about 1 mm during 10-11 years. So, the backward displaced of the mandible from the clockwise rotation was diminished by forward growth of the mandible.

As planned, the inclination of lower incisors was not retroclined. The anterior crossbite was expected to be solely solved by forward movement of upper incisors. The use of lower large rectangular archwire to support the anchorage for short light Class III elastics can minimize retroclination effect due to the use of Class III elastics.

## Vertical changes

The mandible had significant downward because the mandible had clockwise rotation. During treatment, posterior raised bite by compomers was used to open the bite and the mandible displaced downward and backward. After that, upper incisors were advanced until obtained normal overjet and overbite. In clinical, after achieved normal overjet and overbite, compomers were removed and, then, unseated molars were allow to extruded until obtain the occlusion. These indicated that occlusal plane was changed downward. So, the new occlusion maintained vertical position of mandible. Finally, the mandible was positioned in backward and downward direction led to significantly increase of lower facial height.

From clockwise rotation of the mandible, mandibular plane angle should be increased. But in this study, this angle was not significant changed. In untreated Class III[50], mandibular plane angle (FMA, angle between Frankfort and mandibular plane) slightly decreased during 10-11 year. The forward movement of the mandible and decreased mandibular plane angle indicate anterior rotational growth pattern of the mandible which commonly occurs in normodivergent or hypodivergent growth pattern.[54] So, the mandibular plane was maintained by anterior rotation of mandibular growth.

In conclusion, downward but not forward movement and maintained angle of the mandible were resulted from anterior rotational growth of mandible that counteracted clockwise rotation of the mandible during anterior crossbite correction.

## Maxillomandibular changes

## Horizontal changes

The ANB and overjet were significantly increased. The horizontal distance from A point to B point was also increased but not significant. These changed because the premaxilla and upper incisors had forward movement while the mandible and lower incisors were unchanged the horizontal position. These changes improved skeletal Class III relationship and corrected negative overjet. So, the patients that suit to this changes were skeletal Class III with anterior crossbite that maxilla has deficiency in sagittal dimension and need to move the maxilla forward than move the mandible backward.

**Vertical changes**

Overbite was significantly decreased from deepbite in anterior crossbite to normal overbite in normal overjet. The decreased overbite was caused by downward movement of the mandible that concomitant moved the lower incisors downward. The vertical distance from A point to B point was not increased as downward movement of the mandible because A point was also moved downward along with B point. Furthermore, lower anterior facial height was increased. So, the suitable patients for these vertical changes were hypodivergent or normodivergent pattern with deepbite and short lower facial height that downward displacment of the mandible can improve deepbite and profile.

## Comparing ELF and facemask effects

In many studies[20, 55-58], the facemask effects led to the forward movement of A point about 2 mm (ranged from 1-3 mm), downward displacement of the maxilla with counterclockwise rotation of the palatal plane, downward and backward rotation of the mandible, increasing in lower anterior facial height, proclination of upper incisors due to mesial dental movement and retroclination of lower incisor due to pressure by the chincup and soft tissue. From the retrospective, yet unpublished, data of Class III patients at orthodontic clinic in the Faculty of Dentistry, Prince of Songkla University and the study of Sung and Baik[9], treatment effects with facemask with or without RPE were measured by the distance and angle changes similarly to this study method. Comparing facemask and ELF data (Table 9), the premaxilla displaced forward nearby 2 mm but ELF data showed more downward displacement of the premaxilla than the facemask. From facemask, upper incisor had less proclination and lower incisor had more retroclination than ELF technique. Both treatments also had downward movement of the mandible and increasing lower facial height. But mandibular plane angle was increased in facemask while no changed in ELF.

**Table 9:** Comparing direction and amount of skeletal and dental changes between ELF and retrospective facemask data

| Skeletal and dental changes | ELF | | Retrospective data of Facemask | | Sung and Baik[9] | |
|---|---|---|---|---|---|---|
| | Direction | Amount | Direction | Amount | Direction | Amount |
| Maxilla | Forward<br>Downward | 2.0 mm<br>1.8 mm | Forward<br>Downward | 2.3 mm<br>0.4 mm | Forward<br>Downward | 2.1 mm<br>0.9 mm |
| Upper incisors | Forward<br>Downward | 4.8 mm<br>1.9 mm | Forward<br>Downward | 4.1 mm<br>1.3 mm | Forward<br>Downward | 2.9 mm<br>1.3 mm |
| Palatal plane angle | Clockwise | $0.3^{o}$ | Counter-clockwise | $0.1^{o}$ | Counter-clockwise | $0.4^{o}$ |
| Mandible | Forward<br>Downward | 0.6 mm<br>5.3 mm | Forward<br>Downward | 1.1 mm<br>1.5 mm | Backward<br>Downward | 2.0 mm<br>2.8 mm |
| Lower incisors | Backward<br>Downward | 0.4 mm<br>3.9 mm | Forward<br>Downward | 0.2 mm<br>1.9 mm | Backward<br>Downward | 1.3 mm<br>2.4 mm |
| Mandibular plane angle | Clockwise | $0.6^{o}$ | Clockwise | $0.9^{o}$ | Clockwise | $1.7^{o}$ |
| Lower facial height | Increase | 4.1 mm | Increase | 2.9 mm | Increase | 2.0 mm |

Interesting point, the maxilla had downward displacement without counterclockwise rotation in ELF technique but, in facemask, the maxilla showed slightly downward displacement and rotated counterclockwise which opposed to growth direction and may lead to worsen upper incisors to upper lip relationship and low smile line. Although the force direction of facemask was intentional passed center of resistance of the maxilla, rotation of the maxilla still occurred because the force did not truly pass the center of resistance of the maxilla that hard to located and vary in each patient. In ELF, there was not orthopedic force that directly protracted the maxilla but enhance the movement of the premaxilla by dental movement. The direction of force form short light Class III elastics designed in forward and downward direction as the normal maxillary growth. So, the rotation of the maxilla did not occur in ELF.

Unless counterclockwise rotation of the maxilla in ELF, the unwanted facemask effects, decreased upper incisor show to upper lip relationship or low smile line, was prevented.

**Table 10:** Comparing skeletal and dental changes (mm) contributing to overjet correction

| | OJ correction | Skeletal change | Max. change | Man. change | Dental change | UI change | LI change |
|---|---|---|---|---|---|---|---|
| This study, 2012 | 5.2 | 1.9 | 2.3 | 0.4 | 3.4 | 1.7 | -0.6 |
| Percentage | 100 | 36.5 | 44.2 | -7.7 | 63.5 | 53.8 | 9.7 |
| Retrospective data, 2011 (FM) | 3.9 | 1.7 | 2.3 | 0.6 | 2.2 | 1.7 | 0.5 |
| Percentage | 100 | 43.6 | 59.0 | -15.4 | 56.4 | 43.6 | 12.8 |
| Jia, 1998[59] (FM) | 6.7 | 3.5 | 2.0 | -1.5 | 3.2 | 2.2 | -1.0 |
| Percentage | 100 | 52.2 | 29.8 | 22.4 | 47.8 | 32.8 | 15.0 |
| Gu, 2000[11] (FM) | 6.5 | 2.6 | 2.6 | -0.3 | 3.2 | 1.3 | -1.9 |
| Percentage | 100 | 40.0 | 40.0 | 4.6 | 61.5 | 25.0 | 36.5 |
| Lertpitayakun, 2001[21] (FM) | 5.2 | 2.0 | 1.1 | -0.9 | 3.9 | 2.5 | -1.4 |
| Percentage | 100 | 38.5 | 21.2 | 17.3 | 60 | 38.5 | 21.5 |
| Gu, 2000[11] (2x4) | 5.2 | -0.8 | 1.3 | 2.1 | 6.0 | 4.5 | -1.5 |
| Percentage | 100 | -15.4 | 25.0 | -40.4 | 115.4 | 86.5 | 28.9 |

In distance change, positive means forward movement and negative mean backward movement.
In percentage, positive means improving OJ and negative mean worsening OJ.
Max., Maxilla; Man., Mandible; FM, Facemask; 2x4, 2x4 partial fixed appliance;
%; percentage contribute to overjet correction

In this study, overjet correction was contributed to dental changes (63.5%) more than skeletal changes (36.5%). The main factors for overjet correction were forward movement of upper incisors and forward movement of the premaxilla. Comparing ELF to another facemask studies (Table 10), the forward movements of upper incisors and the maxilla were nearly the same as ELF, about 2 mm. But the amount of the movements of the mandible and lower incisors in each study were different. The mandible showed either forward or backward changes and lower incisor was retroclined in different degree. These may cause the difference of skeletal and dental changes between the studies. In the study of Gu et al[11], after active treatment by 2x4 appliance with stainless steel wire in Class III treatment, the average 5.2 mm of overjet correction was achieved by dental change almost 100%. When comparing ELF with Gu et al' s 2x4 techniques, ELF had more skeletal effects by more forward movement of the premaxilla and less forward movement of the mandible. So, advancing upper incisor with the lighter force compared with the higher force in common 2x4 technique may prone to more forward movement of the bone and the skeletal.

## Alveolar bone thickness of upper incisors

As principle of maxillary growth and bone remodeling, premaxilla area has surface orientation by resorption on labial cortex below A- point, deposition on inferior periosteal surface of nasal spine above A point and deposition on the lingual cortex of premaxilla. These combinations bring about a growth movement which proceeds in a predominantly downward but at the same time slightly posterior direction[60]. So, by normal growth, labial bones of upper incisors have resorption at crestal and mid-root areas and deposition at apical area while its palatal bone has deposition.

From results of CT scan in this study, labial, palatal and total bone thickness of upper incisors had no statistically significant difference although upper incisors had proclination and forward movement. Eventhough labial alveolar bone at mid-root and crestal areas of upper incisors has resorption after bone remodeling from premaxilla growth, the labial bones were still presents and the thickness was unchanged after advancing upper incisors with light force. So, the light force can move the upper incisors forward and also can preserve the alveolar bone.

## Strengths, limitations and suggestions

### Strengths

1. The skeletal and dental changes were measured from horizontal and vertical reference lines that were adjusted into natural head position. So, the changes in lateral cephalometric films can be implied to the clinical changes. Moreover, these reference lines can reduce errors from the changes of reference landmarks during treatment such as forward movement of N point, change of occlusal plane and Wits and displacement of Co point.
2. CT scan data of upper incisors can show the quantity of alveolar bone of upper incisors that cannot be evaluated from lateral cephalometric film which show 2-D of alveolar bone at midline and most anterior area.

### Limitations and suggestions

1. Because of ethical reason, growing Class III patients should receive orthodontic treatment to solve the emergency problems. So, there was no control data to evaluate the growth from untreated Class III patients. The results from ELF cannot be compared with the Class III growth and cannot distinct the ELF effects from the growth. In the next study, the Bjork and Skieller's technique of maxillary superimposition[61] that used zygomatic process as horizontal reference can be used to differentiate between skeletal changes and localized upper incisors bone remodeling during the treatment and evaluate the ELF effects. In addition, comparing the effects of ELF and facemask by randomized controlled trial can be useful data for decision on Class III treatments.
2. Evaluation of alveolar bone thickness by using the long axis of upper incisor as reference may have error. Change of upper incisor inclination may lead to change of bone measured area between before and after advancing. The measurement of bone thickness was probably done in different area after

advancing. Anyhow, this reference is easy to measure and reproducible. These problems can be corrected by using external reference that can be showed in CT image and measure the bone along with this reference plane.

3. The effects of ELF on upper permanent molars were not evaluated in this study because the position of these teeth was hard to accurately locate. For the next study, the wire jig that put in molars tubes can be the reference of molars and can be easily located in lateral cephalographic film. In addition, evaluation of profile changes from ELF should be useful data for the treatment.

## Advantages, limitations and suggestions of ELF technique

### Advantages

1. During leveling phase, upper incisors were leveled with segmented wire. So, horizontal force on upper incisors was less. Moreover, very small leveling wire in first visit and slightly increasing the size of leveling wire had still produced lighter force on upper incisors. To decrease treatment time during leveling phase, brackets can be bonded in passive position or large leveling wire can be bended passively in bracket slot.
2. Short light Class III elastics with advancing loops has benefit on forward and downward force that can simultaneously move upper incisors forward and downward as the normal growth.

### Limitations and suggestions

1. Using short light Class III elastics need patient cooperation. If patients did not use the elastics, the treatment results may different from good cooperative patients. In this study, timecards that patient marked after use elastics were used. Moreover, telephone for reminding and let the patient show wearing the elastics were done to evaluate the cooperation. In this study, patients have good

cooperation. Anyhow, new design of appliance with none patient cooperation may probably advantage and lead to more comfort.

2. Using TMA wire in 2x4 technique has increased risk of broken wire especially at distal of upper lateral incisor because, after crossing the elastics at hooks in TMA wire, the wire was deflected and curved down led to bended and fatigue point. For suggestion, to decrease a chance of broken wire, another wire that has more strength than TMA but great springiness that produces relatively constant light force should be used.
3. From the results, vertical position of upper incisors showed rarely change. Class III patients always present low smile line and less incisal show at rest. So, more downward movement of upper incisors can improve these problems. If we design the vertical force closer the upper incisors, the more downward movement of upper incisor may occur. For example, cross elastics at upper canine areas or distal of upper lateral incisors to lower incisor or maybe use anterior cross elastics. So, the appropriate elastics position for more downward movement of upper incisors should be evaluated.
4. After obtained normal overjet and overbite, posterior teeth were not occluded. The next treatments need extrusion of the upper and lower molars for proper posterior occlusion. So, it would be advantage if we develop or modify ELF technique for simultaneous molars extrusion with anterior crossbite correction, for examples, change the compomer position to primary molars and use vertical elastics to extrude first permanent molars during correcting the anterior crossbite or intrude lower incisors combine with extrude lower molars to decrease the deepbite before anterior crossbite correction.

## Clinical implication

From the ELF treatment results, forward movement of upper incisors and the premaxilla and downward movement of the mandible lead to anterior crossbite correction, improving skeletal Class III and increasing lower anterior facial height. From forward movement of the maxilla but not mandibular change, there is usefulness for using ELF in Class III patient with retrognathic maxilla but orthognathic mandible. Moreover, normodivergent or hypodivergent pattern especially with decreased lower facial height which the mandible can be moved downward and then improve the profile is the appropriate characteristic for ELF technique.

Although the facemask can treat Class III malocclusion, patient may feel discomfort from heavy force and extraoral appliance that may lead to negatively influence the treatment effects. Using ELF can be an alternative treatment that easier, more comfortable than facemask. Patients cross only the elastics that trend to high cooperation than facemask. In clinical application, treatment times in both groups were nearly the same. But after obtained normal overjet in facemask, crowding of upper incisors were not corrected. But in ELF treatment, crowding of upper incisors were simultaneously aligned and advanced. Those will safe time for next treatment. Considering in cost, ELF is less cost than the facemask, about 1,700 baht in ELF and 6,660 baht in facemask.

# CHAPTER 5

# CONCLUSION

Easy Light Fixed technique can correct anterior crossbite and improve skeletal Class III. The maxilla was displaced forward and upper incisors were proclined and positioned forward. The mandible was moved downward. Lower facial height was increased. Labial, palatal and total alveolar bone thicknesses of upper incisors were not significantly changed during advancing upper incisors. These results suggest that ELF can be the safe and effective alternative treatment for skeletal Class III hypodivergent or normodivergent pattern with anterior crossbite growing patients.

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# APPENDICES

ที่ ศธ 0521.1.03/ ๑๓๓

คณะทันตแพทยศาสตร์
มหาวิทยาลัยสงขลานครินทร์
ตู้ไปรษณีย์เลขที่ 17
ที่ทำการไปรษณีย์โทรเลขคอหงส์
อ.หาดใหญ่ จ.สงขลา 90112

**หนังสือฉบับนี้ให้ไว้เพื่อรับรองว่า**

**โครงการวิจัยเรื่อง** "ผลของการใช้แรงขนาดเบาผ่านเครื่องมือจัดฟันแบบติดแน่นบางส่วน ในผู้ป่วยที่มีโครงสร้างกะโหลกศีรษะและใบหน้าประเภทที่ 3 ที่มีการเจริญเติบโต"

**หัวหน้าโครงการ** ทันตแพทย์ศรายุทธ เจียรพงศ์ปกรณ์

**สังกัดหน่วยงาน** นักศึกษาหลังปริญญา ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์

ได้ผ่านการพิจารณาและได้รับความเห็นชอบจากคณะกรรมการจริยธรรมในการวิจัย (Ethics Committee) ซึ่งเป็นคณะกรรมการพิจารณาศึกษาการวิจัยในคนของคณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ แล้ว ในคราวประชุมครั้งที่ 1/2553 เมื่อวันที่ 29 มกราคม 2553

ให้ไว้ ณ วันที่ 15 มีนาคม 2553

(รองศาสตราจารย์ ทพ.นพ.ธงชัย นันทนรานนท์)
รองคณบดีฝ่ายวิจัย
ประธานกรรมการ

..........กรรมการ
(ผู้ช่วยศาสตราจารย์ ดร.ทพญ.สุวรรณา จิตภักดีบดินทร์)

ไม่ได้เข้าประชุม..........กรรมการ
(ผู้ช่วยศาสตราจารย์ ทพญ.สิริยา ศรีสินทร)

สุรพงษ์ วงศ์วัชรานนท์..........กรรมการ
(ผู้ช่วยศาสตราจารย์ ทพ.นพ.สุรพงษ์ วงศ์วัชรานนท์)

..........กรรมการ
(ผู้ช่วยศาสตราจารย์ นพ.พรชัย สถิรปัญญา)

..........กรรมการ
(ผู้ช่วยศาสตราจารย์ ดร.ทพญ.อังคณา เธียรมนตรี)

ไม่ได้เข้าประชุม..........กรรมการ
(อาจารย์วศิน สุวรรณรัตน์)

***ใบเชิญชวน***

**ขอเชิญเข้าร่วมโครงการวิจัยเรื่อง** “ผลของการใช้แรงขนาดเบาผ่านเครื่องมือจัดฟันแบบติดแน่นบางส่วนในผู้ป่วยที่มีการสบฟันผิดปกติประเภทที่ 3 ที่มีการเจริญเติบโต”

เรียน ท่านผู้อ่านที่นับถือ

ข้าพเจ้า ทพ.ศรายุทธ เจียรพงศ์ปกรณ์ นักศึกษาหลักสูตรวิทยาศาสตร์มหาบัณฑิต สาขาทันตกรรมจัดฟัน ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ขอแจ้งรายละเอียดเกี่ยวกับโครงการวิจัยและขอเชิญชวนท่านผู้สนใจเข้าร่วมโครงการฯ ดังนี้

โครงการวิจัยนี้จัดทำขึ้นเพื่อพัฒนาวิธีการที่ใช้ในการแก้ไขปัญหาฟันหน้าสบไขว้ในผู้ป่วยเด็กที่มีลักษณะขากรรไกรบนเล็กกว่าปกติเล็กน้อยด้วยแรงขนาดเบาผ่านเครื่องมือติดแน่นบางส่วนแทนการใช้เครื่องมือนอกช่องปาก (เฟสแมสก์) ซึ่งเป็นการรักษาที่นิยมใช้ในปัจจุบัน โดยวิธีที่พัฒนาขึ้นนี้ใช้ง่ายและมีความสะดวกสบายมากกว่า ให้ผลการรักษาใกล้เคียงกับวิธีปกติ ผู้วิจัยคาดหวังว่าภายหลังการรักษาแล้วฟันตัดบนจะมีการเคลื่อนที่ออกมาด้านหน้าและลงล่างจนมีการสบฟันหน้าที่ปกติอย่างปลอดภัย ซึ่งส่งเสริมการเจริญเติบโตของขากรรไกรบนให้ใกล้เคียงปกติมากขึ้น ลดปัญหาเหงือกร่นและฟันสบกระแทก

<u>ผู้ป่วยที่เข้าร่วมวิจัยจะได้รับการรักษาทางทันตกรรมจัดฟันโดยที่ไม่ต้องเข้าคิว</u> และได้รับการตรวจและบันทึกข้อมูลซึ่งประกอบด้วยการซักประวัติเช่น ข้อมูลทั่วไป ประวัติทางทันตกรรม ประวัติทางการแพทย์ ได้รับการตรวจนอกช่องปากและภายในช่องปาก การถ่ายภาพภายนอกและภายในช่องปาก การถ่ายภาพรังสีกะโหลกศีรษะด้านข้าง (lateral cephalometric radiograph) ภาพถ่ายรังสีพานอรามิก (panoramic radiograph) และภาพถ่ายรังสีส่วนตัดอาศัยคอมพิวเตอร์ (computer tomography radiograph) โดยมีขั้นตอนในการรักษา คือ

- บันทึกข้อมูลเบื้องต้นก่อนการรักษา
- ติดเครื่องมือจัดฟันติดแน่นบางส่วน และ ปรับระดับฟันหน้า
- ทำการเคลื่อนฟันหน้าบนมาทางด้านหน้าและลงล่างจนกว่าจะมีลักษณะการสบฟันหน้าและฟันหลังที่ดี (normal overjet, overbite and seated molar occlusion)
- ใส่เครื่องมือที่ปราศจากแรงเพื่อคงสภาพตำแหน่งฟันหน้าบน 4 เดือน
- บันทึกข้อมูลหลังการใช้เครื่องมือที่ออกแบบในงานวิจัย
- ให้การรักษาความผิดปกติของการสบฟันในตำแหน่งอื่นตามแผนการรักษาจนกว่าการรักษาจะเสร็จ

ในช่วงการรักษาจัดฟันที่เป็นงานวิจัย ผู้เข้าร่วมวิจัยต้องมารับการรักษาจัดฟันเดือนละ 1 ครั้ง ตลอดระยะเวลาในงานวิจัยรวม 1 ปี โดยมาปรับระดับฟัน หลังจากนั้นเคลื่อนฟันหน้าโดยใช้เครื่องมือที่ออกแบบในงานวิจัย และเปลี่ยนยางรัดลวดติดตามผลในช่วงคงตำแหน่งฟันหน้าบน เมื่อจบช่วงเวลางานวิจัยผู้เข้าร่วมวิจัยจะได้รับการรักษาจัดฟันตามแผนการรักษาต่อเนื่องจนเสร็จซึ่งระยะเวลาในการรักษาขึ้นกับแผนการักษาในผู้ร่วมวิจัยแต่ละราย

ในกรณีที่การใช้เครื่องมือที่ออกแบบในงานวิจัยไม่สามารถเคลื่อนฟันมาด้านหน้าและลงล่างได้ในระยะเวลา 3 เดือน ทางผู้วิจัยจะเปลี่ยนวิธีการรักษาโดยการใช้แรงที่อยู่ในช่วงแรงปกติที่ใช้ในการเคลื่อนฟัน หรือ ใช้เครื่องมือเฟสแมสก์ ขึ้นอยู่กับความร่วมมือและการตัดสินใจของผู้ป่วยและผู้ปกครอง

ผู้เข้าร่วมวิจัยต้องเสียค่าใช้จ่ายในการจัดฟันตามปกติโดยมีค่าใช้จ่ายในการเก็บข้อมูล, พิมพ์ปาก, ถ่ายรูป, การจัดฟันแบบติดแน่น และ ภาพถ่ายรังสีในการรักษา ซึ่งเป็นค่ารักษาในอัตราปกติของคลินิกทันตกรรมจัดฟัน และ แผนกรังสี โรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ในกรณีที่ต้องเปลี่ยนการรักษาเพราะงานวิจัยไม่สำเร็จ จะไม่มีการเสียค่าใช้จ่ายในการักษาเพิ่ม เว้นแต่กรณีที่ผู้ป่วยต้องการใช้เครื่องมือเฟสแมสก์ต้องเสียค่าเครื่องมือชนิดนี้เอง ส่วนค่าใช้จ่ายสำหรับภาพถ่ายรังสีกะโหลกศีรษะด้านข้างหลังการแก้ไขฟันหน้าสบคร่อม และ การถ่ายภาพ Cone beam computed tomogram ที่ฟันหน้าบน 4 ซี่ 2 ครั้ง ทางคณะผู้วิจัยจะรับผิดชอบค่าใช้จ่ายในส่วนนี้ให้

ตารางสรุปค่าใช้จ่าย ต่อผู้ป่วย 1 ราย

| | รายการ | ค่าใช้จ่าย |
|---|---|---|
| ผู้ป่วย | จัดฟันแบบติดแน่นตลอดการรักษา (รวม retainer) | 24,000 บาท |
| | ค่าพิมพ์ปาก, ถ่ายรูป, เก็บข้อมูล | 600 บาท |
| | ภาพถ่ายรังสีกะโหลกศีรษะด้านข้างตลอดการรักษา | 900 บาท |
| | ภาพถ่ายรังสีกระดูกข้อมือ 1 film | 300 บาท |
| | ภาพถ่ายรังสี panoramic ตลอดการรักษา ประมาณ 3 film | 900 บาท |
| | รวม | **26,700 บาท** |
| คณะผู้วิจัย | ภาพถ่ายรังสีกะโหลกศีรษะด้านข้าง 1 film | 300 บาท |
| | การถ่ายภาพ Cone beam computed tomogram ที่ฟันหน้าบน 4 ซี่ 2 ครั้ง (ครั้งละ 2,500 บาท) | 5,000 บาท |
| | รวม | **5,300 บาท** |

ในแง่ของการควบคุมความเสี่ยงที่อาจจะเกิดขึ้น เนื่องจากปริมาณแรงที่ใช้ในการเคลื่อนฟันเป็นแรงที่น้อยกว่าแรงที่ใช้ในการเคลื่อนฟันเป็นปกติในคลินิก จึงมีความปลอดภัยในการเคลื่อนฟันไม่แตกต่างจากการเคลื่อนฟันด้วยวิธีการรักษาปกติ อย่างไรก็ดีผู้เข้าร่วมวิจัยจะได้รับการตรวจประเมินอาการและอาการแสดงที่บ่งชี้ว่ามีความผิดปกติอันเกิดจากการเคลื่อนฟัน ในทุกๆครั้งที่มาพบทันตแพทย์ผู้ให้การรักษา หากตรวจพบว่ามีความผิดปกติจะหยุดการรักษาในทันที

ถ้าท่านและบุตรหลานของท่านตัดสินใจเข้าร่วมโครงการวิจัยนี้จะมีขั้นตอนของการวิจัยที่เป็นต้องขอความร่วมมือของท่านและบุตรหลานตามที่กล่าวมาข้างต้นซึ่งจะไม่ก่อให้เกิดความเจ็บปวดและอันตรายต่อเนื้อเยื่อมากไปกว่าการใช้เครื่องมือจัดฟันติดแน่นชนิดอื่นหรือเครื่องมือเฟสแมสก์ แต่อย่างใดโดยผู้เข้าร่วมโครงการฯต้องมารับการรักษาและ ณ คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ติดตามผลตามระยะเวลาที่กำหนดอย่างเคร่งครัด

ไม่ว่าท่านจะเข้าร่วมในโครงการวิจัยนี้หรือไม่ ท่านจะยังคงได้รับการรักษาที่ดีเช่นเดียวกับผู้ป่วยอื่นๆ และถ้าท่านต้องการที่จะถอนตัวออกจากการศึกษานี้เมื่อใดท่านก็สามารถกระทำได้อย่างอิสระ ถ้าท่านมีคำถามใดๆ ก่อนที่จะตัดสินใจเข้าร่วมโครงการนี้ โปรดซักถามจากคณะผู้วิจัยได้อย่างเต็มที่

ขอบพระคุณเป็นอย่างสูง

ทพ.ศรายุทธ เจียรพงศ์ปกรณ์

หมายเหตุ : กรุณาอ่านข้อความให้เข้าใจก่อนเซ็นชื่อยินยอมเข้าร่วมโครงการ

## แบบยินยอมเข้าร่วมการศึกษา

**โครงการวิจัยเรื่อง** ผลของการใช้แรงขนาดเบาผ่านเครื่องมือจัดฟันแบบติดแน่นบางส่วนในผู้ป่วยที่มีการสบฟันผิดปกติประเภทที่ 3 ที่มีการเจริญเติบโต

วันที่_______เดือน___________________พ.ศ._______

ข้าพเจ้า_________________ผู้ปกครองของ ด.ช./ด.ญ.___________________ อายุ________ปี อาศัยอยู่บ้านเลขที่_________หมู่_______ถนน_________ ตำบล_____________ อำเภอ___________________จังหวัด________________ได้อ่าน/ได้รับการอธิบายถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตรายหรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่จะเกิด ขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

หากข้าพเจ้ามีข้อสงสัยประการใด หรือเกิดผลข้างเคียงจากการวิจัยจะสามารถติดต่อกับ ทพ.ศรายุทธ เจียรพงศ์ปกรณ์ ได้ที่ ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ หมายเลขโทรศัพท์ 074-287601 หรือ เมื่อมีปัญหาใดๆ เกิดขึ้นเนื่องจากการทำวิจัยในเรื่องนี้ ข้าพเจ้าสามารถร้องเรียนได้ที่คณบดี คณะทันตแพทยศาสตร์ มหาวิทยาลัย สงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90112 หมายเลขโทรศัพท์ 074-287510

หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งทางด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ข้าพเจ้าทราบอย่างรวดเร็วโดยไม่มีปิดบัง

ข้าพเจ้ามีสิทธิ์ที่จะของดการเข้าร่วมโครงการวิจัยโดยจะแจ้งให้ทราบล่วงหน้า โดยการงดการเข้าร่วมการวิจัยนี้จะไม่มีผลต่อการได้รับบริการหรือการรักษาที่ข้าพเจ้าจะได้รับแต่อย่างใด

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะที่เกี่ยวกับตัวข้าพเจ้าเป็นความลับ จะไม่เปิดเผยข้อมูลหรือผลการวิจัยของข้าพเจ้าเป็นรายบุคคลต่อสาธารณชน จะเปิดเผยได้ในรูปที่เป็นสรุปผลการวิจัย หรือการเปิดเผยข้อมูลต่อผู้มีหน้าที่ที่เกี่ยวข้องกับการสนับสนุนและกำกับดูแลการวิจัย

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ จึงได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ โดย ผู้วิจัยได้ให้สำเนาแบบยินยอมที่ลงนามแล้วกับข้าพเจ้าเพื่อเก็บไว้เป็นหลักฐานจำนวน 1 ชุด

ลงชื่อ.........................................ผู้ยินยอม

ลงชื่อ.........................................บิดา/ผู้ใช้อำนาจปกครอง

ลงชื่อ.........................................มารดา

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

ลงชื่อ.........................................พยาน

ลงชื่อ.........................................พยาน

# VITAE

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**Educational Attainment**

| Degree | Name of Institution | Year of Graduation |
|---|---|---|
| Doctor of Dental Surgery | Mahidol University | 2007 |

**List of Publication and Proceeding**

The 23rd National Graduate Research Conference, Rajamangala University of Technology Isan, 22-23 December 2011.