The Influence of Gingival Biotypes on Tooth Movement and Periodontal Tissue in Anterior Retraction Phase

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ชื่อวิทยานิพนธ์ อิทธิพลของเหงือกไบโอไทป์ต่อการเคลื่อนฟันและเนื้อเยื่อปริทันต์ในการเคลื่อนฟันหน้า

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บทคัดย่อ

บทนำ: ฟันหน้าบนยื่นเป็นปัญหาที่พบบ่อยในผู้ป่วยเข้ารับการรักษา ทางทันตกรรมจัดฟันเนื่องด้วยความต้องการด้านความสวยงาม ซึ่งเหงือกไบโอไทป์เป็นตัวช่วยพยากรณ์ผลการรักษาทางทันตกรรมในแขนงต่างๆ แต่อย่างไรก็ตามในปัจจุบันนี้ยังไม่มีการศึกษาเชิงคลินิกไปข้างหน้าใดที่กล่าวถึงความสำคัญของเหงือกไบโอไทป์ในทางทันตกรรมจัดฟัน จึงเป็นที่มาสำหรับการศึกษานี้ **วัตถุประสงค์:** ส่วนที่ 1: เพื่อเปรียบเทียบความหนาของเหงือกและพารามิเตอร์ของกระดูกทั้งด้านใกล้ริมฝีปากและใกล้เพดานระหว่างกลุ่มเหงือกไบโอไทป์หนาและบางในผู้ป่วยกลุ่มฟันหน้าบนยื่น ส่วนที่ 2: เพื่อเปรียบเทียบการเปลี่ยนแปลงของความหนาของเหงือกและพารามิเตอร์ของกระดูกทั้งด้านใกล้ริมฝีปากและใกล้เพดานระหว่างกลุ่มเหงือกไบโอไทป์หนาและบางในการเคลื่อนฟันหน้าบนแบบกลุ่ม **ระเบียบวิธีวิจัย**: ส่วนที่ 1: การศึกษานี้รวมจำนวนฟันหน้าบน 240 ซี่จากผู้ป่วยที่มีสุขภาพดีจำนวน 40 คน ที่มีความผิดปกติของโครงสร้างกระดูกประเภทที่ 1 กับการยื่นของฟันและกระดูก กลุ่มเหงือกไบโอไทป์หนาจำนวน 108 ซี่ และกลุ่มเหงือกไบโอไทป์บางจำนวน 132 ซี่ ด้วยวิธีความโปร่งใสของโพรบ ทำการวัดความหนาของเหงือกและพารามิเตอร์กระดูกถุงจากภาพถ่ายรังสีสามมิติชนิดคอมพิวเตดโทโมกราฟฟี และวิเคราะห์ความแตกต่างระหว่างพารามิเตอร์ของกลุ่มเหงือกไบโอไทป์หนาและบางโดยใช้การทดสอบแมน-วิทนีย์ ส่วนที่ 2: ผู้ป่วยฟันหน้าบนยื่นจำนวน 32 ราย (กลุ่มเหงือกไบโอไทป์หนา 16 ราย, กลุ่มเหงือกไบโอไทป์บาง 16 ราย) ซึ่งถูกวางแผนด้วยการถอนฟันกรามน้อยซี่ที่หนึ่งทั้งสองข้าง โดยใช้ลวดเหล็กกล้าไร้สนิมขนาด 0.018x0.022 นิ้ว บนช่องใส่ลวดขนาด 0.018x0.025 นิ้ว สำหรับฟันหน้าและ 0.022x0.028 นิ้ว สำหรับฟันหลัง การดึงฟันหน้าแบบกลุ่ม โดยใช้คอยล์สปริงชนิดนิกเกิลไทเทเนียมส่งแรง 150 กรัมจากฟันเขี้ยวบนถึงฟันกรามซี่ที่หนึ่งทั้งสองข้างจนกระทั่งระยะเวลา 16 สัปดาห์ ภาพถ่ายรังสีศีรษะด้านข้างและแบบจำลองฟันถูกเก็บที่ระยะก่อนการดึงฟันหน้าบนและหลังการดึงฟันหน้าบน 16 สัปดาห์หลังจากนั้นรอเวลา 3 เดือนสำหรับการเปลี่ยนแปลงของกระดูก

เพื่อถ่ายภาพรังสีสามมิติชนิดคอมพิวเตดโทโมกราฟฟี การทดสอบแบบนอนพาราเมตริกถูกนำมาใช้เพื่อวิเคราะห์ข้อมูล **ผลการศึกษา:** ส่วนที่ 1: ความหนาของเหงือกและกระดูกด้านใกล้เพดานเพิ่มขึ้นทีละน้อยในบริเวณปลายยอดในขณะที่ความหนาของกระดูกด้านใกล้ริมฝีปากนั้นเกือบจะคงที่ทั้งในเหงือกไบโอไทป์สองชนิด เหงือกไบโอไทป์หนามีความหนาเหงือกและกระดูกมากกว่าเหงือกไบโอไทป์บาง ในกลุ่มเหงือกไบโอไทป์หนาความหนามีระยะจากซีเมนโตอีนาเมลจังชันถึงสันกระดูกเบ้าฟันที่สั้นกว่า และระดับกระดูกทึบด้านใกล้เพดานที่สูงกว่าเหงือกไบโอไทป์บาง และพบกระดูกโปร่งที่ด้านใกล้เพดานในทั้งสองกลุ่มเหงือกไบโอไทป์ โดยเริ่มต้นจากระดับสันกระดูกเบ้าฟันไปสู่ปลายรากฟัน ซึ่งในกลุ่มเหงือกไบโอไทป์หนาเริ่มต้นที่ระดับ 4 มิลลิเมตร และกลุ่มเหงือกไบโอไทป์บางเริ่มต้นที่ระดับ 8 มิลลิเมตร นอกจากนี้กลุ่มเหงือกไบโอไทป์หนามีกระดูกโปร่งด้านใกล้เพดานที่หนากว่ากลุ่มเหงือกไบโอไทป์บางมีนัยสำคัญ ($P < 0.01$) ส่วนที่ 2: กลุ่มเหงือกไบโอไทป์บางมีอัตราการเคลื่อนฟันที่เร็วขึ้นและมีการเปลี่ยนแปลงความเอียงของฟันหน้าบนมากกว่ากลุ่มเหงือกไบโอไทป์หนา โดยทั้งสองกลุ่มเหงือกไบโอไทป์มีความหนาของเหงือกและกระดูกด้านใกล้ริมฝีปากที่เพิ่มขึ้น และการบางลงของกระดูกใกล้เพดาน ซึ่งความสูงของกระดูกด้านใกล้เพดานปากที่ประกอบด้วยกระดูกทึบลดลงอย่างมีนัยสำคัญในกลุ่มเหงือกไบโอไทป์บาง **สรุป:** ส่วนที่ 1: ผู้ป่วยที่มีฟันหน้าบนยื่นสามารถพบได้ทั้งกลุ่มเหงือกไบโอไทป์หนาและบาง โดยที่ กลุ่มเหงือกไบโอไทป์หนามีพารามิเตอร์ของกระดูกที่ดีกว่ากลุ่มเหงือกไบโอไทป์บาง ส่วนที่ 2:กลุ่มเหงือกไบโอไทป์หนาแสดงอัตราการเคลื่อนฟันที่ช้ากว่า มีการเอียงตัวของฟันหน้าบนที่น้อยกว่า และมีการสูญเสียของกระดูกด้านใกล้เพดานที่น้อยกว่าในกลุ่มเหงือกไบโอไทป์บาง

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ABSTRACT

Introduction: Protrusion of maxillary anterior teeth was usually found in orthodontic patients with highly esthetic demands. The gingival biotypes were the outcome predictors in several dental fields. Until now, no clinical prospective studies revealed the importance of gingival biotypes in orthodontic perspective. **Objectives:** Part I: To compare gingival thicknesses and five alveolar bone parameters on the labial and palatal sides between thick and thin gingival biotypes in anterior dentoalveolar protrusion teeth Part II: To compare the changes of gingival thicknesses and five alveolar bone parameters on the labial and palatal sides between thick and thin gingival biotypes in en masse retraction phase. **Material and methods**: Part I: The study included 240 anterior teeth from 40 healthy patients with skeletal Class I malocclusion with dentoalveolar protrusion. The thick (n = 108) and thin (n = 132) gingival biotypes were assessed by probe transparency. The gingival thicknesses and five alveolar bone parameters from cone beam computed tomography were measured. The differences between the thick and thin gingival biotype parameters were statistically analyzed by Mann-Whitney U test. Part II: The 32 adult subjects with protrusion of the upper anterior teeth (thick gingival biotype = 16, thin gingival biotype = 16) who were planned with bilaterally extraction of the maxillary first premolars. An 0.018x0.022- inch stainless steel wire anterior slots 0.018x0.025 inch and posterior slots 0.022x0.028 -inch slot. The en masse retraction was used NiTi coil spring delivery force 150 grams from upper canine to upper first molars bilaterally until 16 weeks period of observation. The Lateral cephalograms, study models were taken at pre-retraction (T1) and after 16 weeks of retraction (T2). The cone-beam compute tomograms were scanned after T2 3 months for bone remodeling. Non-parametric tests were used to analyze the data. **Results**: Part I: Gingival thickness and palatal bone

gradually increased toward the apical area while the labial bone thickness was almost even in both gingival biotypes. The thick gingival biotype showed thicker gingiva and alveolar bone than in the thin gingival biotype. The thick gingival biotype showed a shorter distance from the alveolar crest to the cementoenamel junction and lower palatal cortical bone height than the thin gingival biotype. Cancellous bone was detected only at the palatal side in both gingival biotypes which started 4 mm above the crestal bone level toward the root apex in the thick gingival biotype and 8 mm in the thin gingival biotype. Additionally, the thick gingival biotype showed significantly greater palatal cancellous bone than the thin gingival biotype ($P < 0.01$). Part II: The thin gingival biotype showed faster rate of tooth movement and more upper incisors inclination change than the thick gingival biotype. Both gingival biotypes showed thickening of gingiva and labial alveolar bone and decreasing of palatal bone. The significant decreasing of palatal bone height that composed of pure cortical bone was observed in thin gingival biotype. **Conclusion**: Part I: Patients with anterior dentoalveolar protrusion teeth presented both thick and thin gingival biotypes. The thick gingival biotype showed more favorable alveolar bone parameters than the thin gingival biotype. Part II: The thick gingival biotype showed slow rate of tooth movement, less tipping movement of upper incisors and less palatal bone loss than thin gingival biotype.

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Pannapat Chanmanee

CONTENTS

LISTS OF TABLES

LISTS OF DIAGRAMS/ FIGURES

LISTS OF ABBREVIATIONS AND SYMBOLS

mm	=	Millimeter
et al	=	And others
g	=	Gram
°	=	Degree
Fig.	=	Figure
”	=	Inch (es)
/	=	Per
NiTi	=	Nickel Titanium
SS	=	Stainless steel
T1	=	Before en masse retraction
T2	=	After 16 weeks of retraction
U1	=	The maxillary central incisor
CEJ	=	Cemento-enamel junction
<	=	Less than
>	=	More than
PDL	=	Periodontal ligament
CBCT	=	Cone-beam compute tomography
GI	=	Gingival index
PI	=	Plaque index
PD	=	Periodontal pocket depth
kV	=	Kilovolts
mA	=	Miniempire
NS	=	Not significant
-	=	Not measured

CHAPTER 1

INTRODUCTION

Background and rationale

Alveolar bone is the surrounding tissue that supports the teeth to withstand a bite force and other relevant factors. Cortical bone and cancellous bone are two main structures of alveolar bone. The cortical bone serves as a limitation wall of tooth movement[1] due to its low self-remodeling[2]. Several studies reported approaches to reduce the amount of cortical bone to enhance bone remodeling and accelerate orthodontic tooth movement[3]. While cancellous bone serves as a reservoir of the progenitor cells to promote bone remodeling, a greater amount of cancellous bone tends to be more favorable for promoting bone remodeling[4].

Unfortunately, some patients with dentoalveolar protrusion present with thin layers of alveolar bone[5]. This condition probably causes a failure of bone remodeling, alveolar bone destruction, and gingival recession when pathologic forces occur[6]. Until now there is no evidence which reveals the amount of cortical bone and cancellous bone especially in cases of dentoalveolar protrusion that presents the risks of alveolar bone resorption and gingival recession.

Apart from alveolar bone, orthodontists pay close attention to periodontal health and esthetic appearance of the gingival tissue during orthodontic treatment[7]. In fact, only aligning and leveling the teeth are insufficient to enhance positive results. Since the morphologic characteristics of the gingiva are based on several factors[8], it is necessary to know these factors to determine or predict the success of treatment.

The gingival biotypes serve as a tool to determine or predict the treatment outcome[9]. In general, gingival biotypes are classified by the gingival thickness into two biotypes: thick and thin[10]. Their morphology relies on several factors such as alveolar bone profile, tooth forms, tooth inclination, and position[11]. Some evidence demonstrated that

gingival biotypes were used to determine final esthetic results[12]. The difference in gingival biotypes contributed to different responses of periodontal tissue[13].

Although there are several methods to measure gingival and alveolar bone thickness, measurements with cone beam computed tomography (CBCT) showed high accuracy in the radiographic thickness of both labial gingiva and bone compared to clinical observation[14].

To the best of our knowledge, there is no previous study which evaluated the amount of gingiva, alveolar bone, cortical bone and cancellous bone present in two gingival biotypes, especially in anterior teeth protrusion at pretreatment data and compare between before and after orthodontic treatment.

Review of literatures

Gingival biotypes

Gingival anatomy was first introduced by Ochsenbien and Ross in 1969[15] There were two main categories including flat and pronounced scalloped which affected by underlying bone contour. In 1986, Claffey and Shanley reported the relationship of gingival thickness and biotype. It was claimed that gingival thickness of thick tissue biotype was more than 2 millimeters, while less than 1.5 millimeters of gingival thickness was defined as thin tissue biotype[10]. However, the definition of biotypes was not enough to support the whole characteristics of each gingival biotype. Later in 1989, the gingival biotypes were classified more specific by Seibert and Lindhe. Alveolar bone anatomy was categorized in 3 distinct types: flat, scalloped, and pronounced-scalloped. They reported that distance from the height of interdental bone to alveolar crest were different significantly in each group. The distance was 2.1, 2.8, and 4.1 millimeters in flat, scalloped, and pronounced-scalloped alveolar bone anatomy, respectively[16].

Given crestal bone levels, Kois used the distance from apical to cementoenamel junction (CEJ) as a reference. If the distance from apical to CEJ was 3 millimeters, it is referred to normal crestal bone level[17]. If the distance of more and less than 3 millimeters was low and high crestal bone level, respectively. Olsson et al. found that

long-narrow central incisor presented diminished zone of keratinized gingiva, shallow pocket depth and pronounced-scalloped contour of gingival margin[18]. Nevertheless, there was no significant difference in free gingival thickness between long-narrow and short-wide tooth form[19]. Finally, the relationship of gingival biotype and population was reported by DeRouck. Approximately one-third of population presented thin biotype, while thick biotype was found in the rest of study population[20]. Finally, Kan and his colleague revised the definition of gingival biotypes in 2010 due to clear-cut point and clinical characteristics, which were used 1 millimeter as indicated for biotypes classification[21].

Characteristics related to thick and thin biotypes are shown in Table 1 which contains the correlation between characteristic and gingival biotypes[8].

Table 1: Characteristics related to thick and thin biotypes[8]

Characteristics	Thick gingival biotype	Thin gingival biotype
1. Keratinized tissue	Broad zone	Narrow zone
2. Gingival thickness Gingival width	> 2 mm 5-6 mm	< 1.5 mm 3.5-5 mm
3. Gingival and bony architecture	Flat	Pronounced-scalloped
4. Gingival margin location	Coronal to CEJ	Apical to CEJ (Mild gingival recession)
5. Bony plate	Thick	Dehiscence and fenestrations
6. Marginal bone	Thick	Thin
7. Risk for periodontal defects	Deep pocket and intrabony defect	Prone to gingival recession

Diagnostic tool

Several methods were introduced to classified gingival biotypes. It is believed that gingival thickness is the most reliable tissue to be a representative of gingival biotypes. The gingival thickness can be measured by the visual inspection[10], probe transparency (TRANs) method[22], direct measurement[23], ultrasonic device[23] and cone beam computed tomography (CBCT)[24].

Firstly, visual inspection, the simplest method, can be observed by individuals. This method requires no special equipment to investigate gingival tissue. Thick tissue biotype reflects in dense and fibrotic tissue but feeble and translucent tissue will be found in thin tissue biotype[15,19]. This method, however, is less reliable because it cannot measure the amount of gingival thickness and it is subjective to each clinician[25].

Secondly, probe transparency (TRANs) is the most satisfied method for gingival biotype discrimination as it serves as a minimal invasive technique by using metal periodontal probe in gingival sulcus to assess thickness of gingiva[22]. Thickness of tissue that conceals the metal probe's color is a key factor to identify each of the gingival biotypes[20]. If the probe's color is invisible through the gingiva, gingiva will be termed as thick gingival biotype. On the other hand, gingiva will be classified in terms of thin gingival biotype if the probe's color can be seen easily. However, there are some misinterpretations from color visible reported in some studies[8,20].

Thirdly, direct measurement is the most invasive technique with intensively high accuracy by using a tension-free caliper or gingival probe[21]. Direct measurement is performed by surgical approach used in periodontal surgery, but not for routine evaluation. As mentioned earlier, the gingival thickness is more than 1.5 millimeters considered as a thick biotype, while less than 1.5 millimeters of gingival thickness is referred to thin biotype[10]. Nevertheless, tissue distortion is major disadvantages of this method.

Fourthly, ultrasonic devices were introduced by Kydd et al. which is less invasive and excellent validity and reliability[26,27]. Unfortunately, this device is high-priced, unavailable commercially, arduous to set the right position and difficult to recreation[28].

Lastly, cone beam computed tomography (CBCT) is not only non-invasive technique but also outstanding diagnostic tool for determining amounts of soft and hard

tissue[24]. There is a significantly statistic correlation between CBCT and direct measurement[29,30]. Currently several researchers usually use CBCT for identifying and measuring thickness of bone and gingival tissue.

The importance of gingival biotype

Gingival biotypes are a predicting tool of several dental treatment especially on periodontics, implant surgery, orthodontics, and restoratives[22]. Based on pattern of underlying bone and keratinized tissue, gingival biotypes should be concerned before establishing treatment plan. In general, the studies reported that thick biotype shows more successful outcome of treatment than thin biotype.

In periodontal aspects, not only soft tissue is evaluated, but final soft tissue healing is required to estimate before every surgical procedure. Gingival thickness and amount of keratinized tissue play a significant role in healing after periodontal surgery including root coverage, surgical crown lengthening and ridge preservation[31]. It is obviously seen that thick biotype is prone to have a better result.

Gingival biotype is taken into consideration in implant surgery as it is used for predicting periodontium around implants especially esthetic zone[32]. Progression of gingival recession after implant placement in esthetic area is usually found in a thin tissue biotype[33]. Therefore, It can be concluded that a thick tissue biotype is more favorable esthetic outcome especially when immediate implant placement is taken.

In restorative aspects, gingival biotypes are also evaluated correctly before preparation because the selection of suitable restorative materials depends on each biotype. Thin gingival biotype is likely to have both gingival recession and metal margin visibility[34].

In orthodontic perspective, no study was associated with direct correlation between gingival biotype and orthodontic treatment; however, there were several attempts to study about this correlation in various aspects[35-37]. In previous studies, it was still controversial whether orthodontic treatment contributed to progression in gingival recession[37]. The possible explanation was loss of biological barrier, which patients with a thin biotype and small brand of keratinized tissue tend to have a higher rate of gingival recession. Furthermore, tooth proclination and severity of crowding might affect the amount of recession, but it was still controversy[11,35-37].

In conclusion, gingival biotypes, the prerequisite markers, exhibit different pathological responses which influence on treatment planning. Both evaluation and treatment plan in patient with different gingival biotypes require more attention from dentists for a successful outcome.

Orthodontic tooth movement

The achievement in orthodontic treatment affected by several factors such as periodontal status, oral health, and orthodontic forces[38-40]. The changes of dental and periodontal tissues after applying the orthodontic force encourage tooth movement. The bending of the alveolar bone and the remodeling of the periodontium are two interrelated processes in orthodontic tooth movement. When force is applied onto the tooth, it causes the compression of PDL to one side of alveolar bone, simultaneously stretch of PDL to the opposite side[41]. The stretched PDLs conduct the alveolar bone deposition, while the mechanical compression initiates the bone remodeling.

Normally, orthodontic tooth movement has no potential to induce a damage of the periodontal tissue if good periodontal tissue and oral hygiene are present. Orthodontic tooth movement, however, may cause a periodontal tissue alteration, increase rate of tooth movement and contribute to adverse effects such as root shortening, periodontal loss in cases of thin gingival biotype[42,43].

Generally, tooth movement can be divided into four basic types according to a various applied moment and force in terms of magnitude, direction, or point of application. Tipping, translation, root movement, and rotation are four basic types of tooth movement as mentioned above. Moreover, the description between the force system and the type of movement can be explained by the moment/force ratio. Moreover, the quality of the periodontal support influences on the center of resistance and the type of movement. Obviously, it can be seen that shortened root or reduced bone support alter the types of movement based on the moment/ force ratio.

Orthodontic considerations in thin gingival biotype patients

Thin gingival tissue lean to be fragile and translucent. This tissue appears the narrow zone of the keratinized gingiva. Thin or minimal bone is covered the labial surface of the roots. Not only osseous defects such as dehiscence and fenestration, but gingival recession is frequently associated with this type of gingival tissue because it is subjected to develop inflammation, trauma, and surgical insults[18].

Krishnan VA, 2006 found that an orthodontic force resulted in gingival recession in patients with thin gingival tissue[41]. Prior orthodontic treatment, to prevent gingival tissue breakdown, periodontal therapy was required to perform. Surgical periodontal therapies were including frenectomy, soft tissue augmentation, and bone grafting. The adverse effect including tissue collapse could be prevented when patients were selected properly so as to achieve high success rate in both soft tissues and bone augmentations.

Additionally, orthodontic movement to lingual side allowed alveolar bone to deposit on the labial side, thickening of the gingival tissue and coronal shift in the gingival margin resulting in the correction of the recession defect[44]. Clearly, the key of treatment success is the multidisciplinary approaches, which require teamwork to achieve the effective results.

Unfortunately, Slutzkey S, 2008 showed that when a tooth was moved bodily in a labial direction toward the cortical plate of the alveolar bone, there was no new bone formation, but bone thinning and dehiscence might occur. Especially with thin periodontal tissue, cortical plate perforation could be found during an orthodontic treatment, which was unavoidable situations[45].

Anterior retraction phase

Anterior retraction phase is an important stage for reduction of protrusion and correction of improper profiles. There are two methods to close space based on number of steps in anterior teeth retraction: the en masse retraction and the two step retraction. The first one is en masse retraction technique. From definition, en-masse retraction is the retraction of teeth together (normally the four incisors, or all six anterior teeth), as a group. The second one

is two step retraction technique is a orderly procedure including sequential steps to close the spaces; the first step is canine distalization followed by incisor retraction.

For many years, the orthodontists revealed that two step retraction is not well anchorage control than en masse retraction technique. But Heo W et al. argued that it was unnecessarily true in all instances[46]. They found no statistically significant difference between two methods similar to the study of Xu TM et al.[47] Moreover, a longer treatment time in two-step retraction had been reported.

In addition, two-step retraction leaves unaesthetic space during canines distalization, which will be maintained for long time[48]. Unlike two-step retraction, En masse retraction allows to retract all upper anterior teeth in a single step. Therefore, this technique allows dentist and patient to evaluate the maxillary incisors in aspects of the inclination and position changes as well as the lips related to facial esthetics.

En masse retraction

The control during en masse retraction is very important for function, esthetic and stability in orthodontic treatment[49]. Orthodontic tooth movement controls the forces applied on the teeth. Basically, the teeth cloud move in three ways: bodily, tipping, and combination[50]. The bodily movement, exists when a force pass through the center of resistance. So the understanding of effects of forces applied and the center location of resistance of the maxillary anterior teeth are very important.

Mechanics of anterior retraction

The space closure methods composed of two methods i.e. friction (sliding) and frictionless (loops) mechanics[51,52].

Friction-based mechanic (Sliding mechanics)

Sliding mechanics is defined as the movement of teeth along the archwire[53,54]. Friction, a impediment to the relative bodies movement, plays a significant role in sliding mechanics. Although pros of this technique are the minimal wire-bending and increased patient comfort, there are several factors influencing friction during orthodontic tooth

movement such as size of bracket slot, bracket material, bracket width, dimension and material of archwire[52].

Optimum forces for en-masse retraction

The optimal forces for upper anterior teeth retraction are enormous. In 1989, McLaughlin and Bennett[55] stated that 150 grams was optimal for upper anterior teeth en masse retraction. In 1992, they presented that a force from 100 to 150 grams was proper during overjet reduction[56]. Additional studies by Heo[46] in 2007, Upadhyay[57] in 2008, Kumar et al[58] in 2009 and Chopra[59] in 2015 also used bilaterally 150 grams for sliding en masse retraction.

Control of mechanical side effects during space closure

McLaughlin and Bennett[55,60] suggested using the stiff and large archwire to control during en masse retraction. The square 0.019×0.025 steel wires were suitable with the 0.022 bracket slot.

Frictionless (loop) mechanics

Frictionless mechanics are the closing loop to generate the forces moving teeth. There is not created the friction between the wire and the bracket slot. Loop designs developed from simple vertical loops[61] to present more complicated loop designs, such as tear drop loops[62], T-loops[63,64], L-loops, and Gjessing's springs[65,66] to obtain more moment/ force ratio and steady force applied.

However, the several disadvantages were observed. Firstly, more chair time to adjust the wires. Secondly, soft tissue irritation and difficult to maintain the oral hygiene[67]. Therefore, the closing loop archwires are not appropriate for routine treatment.

Cone beam computed tomography (CBCT)

CBCT is an imaging method revealed 3D image of various cross sections of anatomy. Recently, 3D analyses and jaw measurement become more popular because the image is able to reveal alveolar bone morphology. Many orthodontists used CBCT for routine diagnosis and treatment planning. In dentoalveolar protrusion cases with an thin alveolar bone anatomy, CBCT provides invaluable data about underlying tooth bone, and it might reduce the

risk factor for dehiscence. So the evaluation of deficiencies of faciopalatal thickness and height of the alveolar bone should be performed before critical orthodontic tooth movement[68].

Gingival thickness assessment

The gingival thickness can be measured by direct measurement[23], ultrasonic method[69] and cone beam computed tomography (CBCT). The direct measurement is the most invasive technique and not for routine evaluation. The tissue distortion and low reliability are the disadvantages of this method.

The ultrasonic method is less invasive and excellent validity and reliability[27]. Unfortunately, this device is high-priced, unavailable commercially, arduous to set the right position and difficult to recreation[28].

The cone beam computed tomography (CBCT) is not only non-invasive technique but also outstanding diagnostic tool for determining amounts of soft and hard tissue[24]. There is a significantly statistic correlation between CBCT and direct measurement[29,30,70]. Currently several researchers usually use CBCT for identifying and measuring thickness of bone and gingival tissue.

Developing of CBCT method, from the hard tissue CBCT to soft tissue CBCT method. The clear vision of both soft and hard tissue was possible by soft tissue retraction. By retracting the the lip, cheeks, and tongue separate from the gingiva in both labial and palatal area, there is an air dark space created among these structures[14]. The difference in the density between air and soft tissue was used to locate the location of gingival tissue on the CBCT.

Alveolar bone assessment

Alveolar bone serves as remodeling area when the teeth moved within the alveolar bone. Many studied presented the measurement protocol of the alveolar bone (in term of alveolar bone thickness, alveolar bone height, cortical bone thickness, cortical bone height and cancellous bone thickness)[71-74]. However, no study revealed the cortical bone height measurement that affected on orthodontic tooth movement design. When the cortical bone is present, only an optimal force would be appropriate to desire the frontal bone resorption. So the systemic explanation of alveolar bone characteristics is required for understanding about the consequences from orthodontic tooth movement.

Conceptual framework

Part I

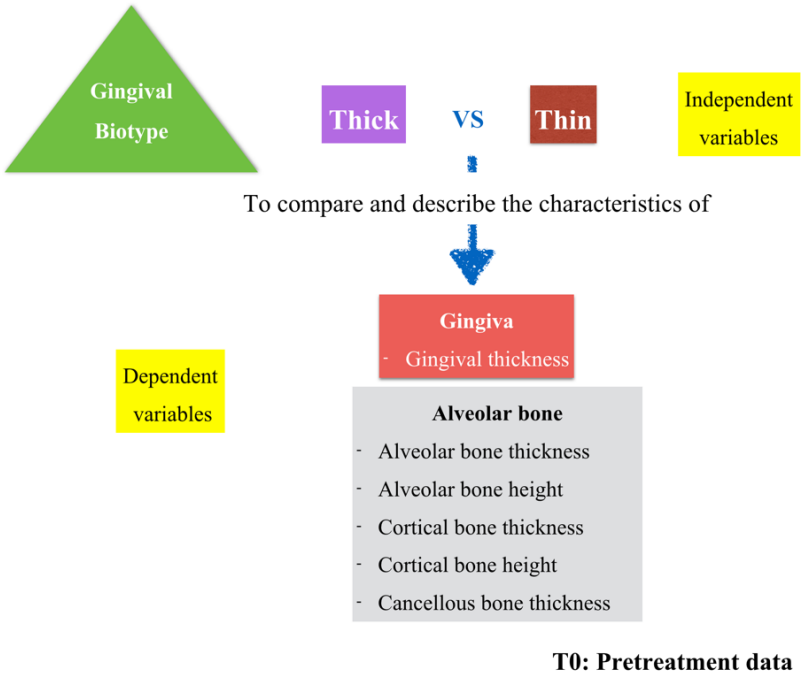

Fig. 1 Conceptual framework part I

Part II

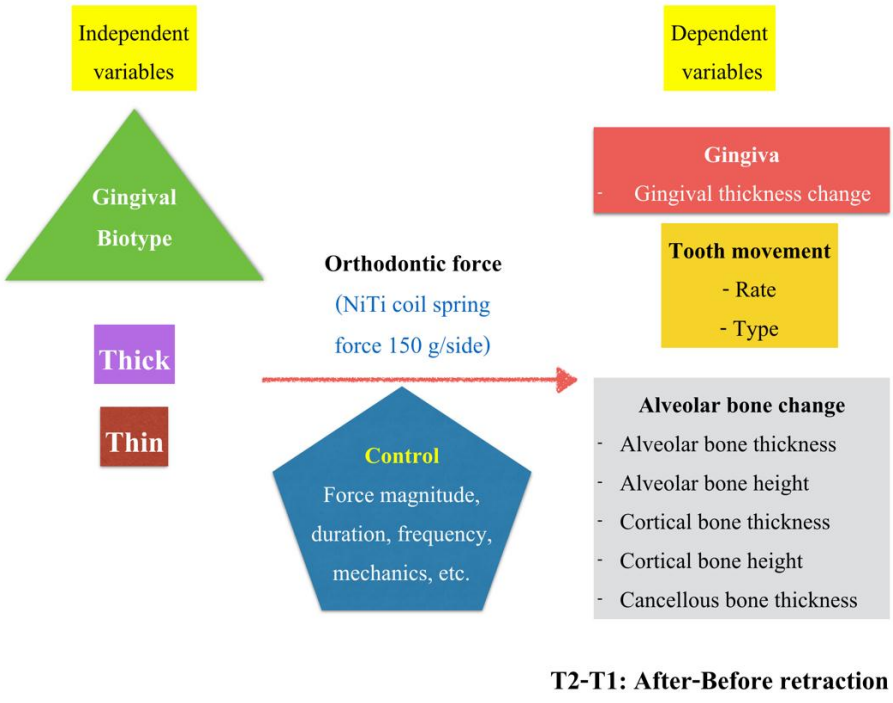

Fig. 2 Conceptual framework part II

Research questions

Part I:

1. Are there different in **gingival thickness and alveolar bone parameters** between two gingival biotypes in maxillary anterior teeth from CBCT **pretreatment data**?

Part II:

1. How does the **gingival thickness change** after anterior retraction between two gingival biotypes?
2. How does the **alveolar bone change** after anterior retraction between two gingival biotypes?

   a) How does the **alveolar bone thickness change** after anterior retraction between two gingival biotypes?

   b) How does the **alveolar bone height change** after anterior retraction between two gingival biotypes?

   c) How does the **cortical bone thickness change** after anterior retraction between two gingival biotypes?

   d) How does the **cortical bone height change** after anterior retraction between two gingival biotypes?

   e) How does the **cancellous bone thickness change** after anterior retraction between two gingival biotypes?
3. Is **tooth movement different** during anterior retraction between two gingival biotypes?

   a) Is **type of tooth movement** different during anterior retraction between two gingival biotypes?

   b) Is **rate of tooth movement** different during anterior retraction between two gingival biotypes?

Research hypotheses:

Part I:

1.1 There is no difference in **gingival thickness and alveolar bone parameters** between two gingival biotypes in maxillary anterior teeth from CBCT **pretreatment data.**

Part II:

1.1 There is no difference in **the change of gingival thickness** after anterior retraction between two gingival biotypes.

2.1 There is no difference in **the change of alveolar bone thickness** after anterior retraction between two gingival biotypes.

2.2 There is no difference in **the change of alveolar bone height** after anterior retraction between two gingival biotypes.

2.3 There is no difference in **the change of cortical bone thickness** after anterior retraction between two gingival biotypes.

2.4 There is no difference in **the change of cortical bone height** after anterior retraction between two gingival biotypes.

2.5 There is no difference in **the change of cancellous bone thickness** after anterior retraction between two gingival biotypes.

3.1 There is no difference in **type of tooth movement** during anterior retraction between two gingival biotypes.

3.2 There is no difference in **rate of tooth movement** during anterior retraction between two gingival biotypes.

Research objectives

General objectives:

Part I:

1. To compare **the gingival thickness and alveolar bone parameters** between two gingival biotypes in maxillary anterior teeth from CBCT **pretreatment data.**

Part II:

1. To compare **the change of gingival thickness** after anterior retraction between two gingival biotypes.
2. To compare **the changes of alveolar bone** after anterior retraction between two gingival biotypes.
3. To compare **the tooth movement** during anterior retraction between two gingival biotypes.

Specific objectives:

Part I:

1.1 To compare **the gingival thickness and alveolar bone parameters** between two gingival biotypes in maxillary anterior teeth from CBCT **pretreatment data** in term of gingival thickness, alveolar bone thickness, alveolar bone height, cortical bone thickness, cortical bone height and cancellous bone thickness.

Part II:

1.1 To compare **the change of gingival thickness** after anterior retraction between two gingival biotypes.

2.1 To compare **the change of alveolar bone thickness** after anterior retraction between two gingival biotypes.

2.2 To compare **the change of alveolar bone height** after anterior retraction between two gingival biotypes. .

2.3 To compare **the change of cortical bone thickness** after anterior retraction between two gingival biotypes.

2.4 To compare **the change of cortical bone height** after anterior retraction between two gingival biotypes.

2.5 To compare **the change of cancellous bone thickness** after anterior retraction between two gingival biotypes.

3.1 To compare **the type of tooth movement** during anterior retraction between two gingival biotypes.

3.2 To compare **the rate of tooth movement** during anterior retraction between two gingival biotypes.

Significance of the study

This prospective study was divided into two parts. The first part showed the gingival thickness and alveolar bone characteristics between thick and thin gingival biotypes in the adult maxillary dentoalveolar protrusion patients at baseline data. This information was so important to help orthodontists for orthodontic treatment planning before the operation. The second part showed the responses of the gingiva, the alveolar bone following the maxillary anterior en masse retraction between thick and thin gingival biotypes. Overall of this study answered the question is the gingival biotypes cloud be used for treatment outcome predictor in orthodontic perspective.

CHAPTER 2

RESEARCH METHODOLOGY

Samples

This study was approved by Human Ethics Committee of Faculty of Dentistry, Prince of Songkla University.

The parameters following the study of Frost et al. 2015[75] as follow:

Mean alveolar bone thickness in thick gingival biotype was 0.805.

Mean alveolar bone thickness in thick gingival biotype was 0.593.

Standard deviation in thick gingival biotypes was 0.364.

Standard deviation in thin gingival biotypes was 0.291.

The level of significance was set at 95%.

The power of the test was set at 80%.

From the sample size calculation, 16 patients were required per group. The estimate dropout rate were about 20 percent so the sample in this study at least 20 patients per group would be.

The samples were enrolled from patients in orthodontic clinic, Faculty of Dentistry, Prince of Songkla University. The inclusion criteria were:

1. Adult males or females, age range between 18-30 years
2. Angle Class I or Angle Class II division 1 malocclusion with maxillary dentoalveolar protrusion (UI-NA >8 mm)
3. Skeletal Class I (ANB = 0-5 degrees)
4. Normodivergent facial pattern (MPA= 23-35 degrees)
5. Bilaterally extraction of the upper first bicuspids was planned.
6. No periodontal diseases
7. No significant systemic diseases related to bone metabolism
8. No history of trauma to the upper anterior teeth region

The exclusion criteria were:

1. Pregnancy
2. Probing depth >4 mm
3. Previous orthodontic treatment
4. Previous upper anterior surgery
5. Past or present use of drugs known to increase the risk for gingival overgrowth (phenytoin, nifedipine, cyclosporine, amlodipine)
6. Gingival overgrowth
7. Taking NSAIDs during study period

All of samples were given detailed about treatment procedures and willing to participate. Then, the orthodontist advised the patients in details about the treatment plan and aims of this study and the consent form was signed before commencement the study. The patients received oral hygiene instruction i.e. toothbrush, dental floss, and proxabrush, etc.

Material and method

Data collection and treatment sequences

1. Patients will be divided into two groups according to thick and thin gingival biotypes by probe transparency method (TRANs). The thick biotype was defined as when the probe color could not be seen through the gingiva while the thin biotype was defined when the probe could be seen through the gingiva[22].

2. Initial record (T0) will be taken including:

- Clinical periodontal parameters records (standardization with periodontist)

The following clinical measurements will be evaluated:

(1) plaque index (Pl), Quigley and Hein[76],

(2) gingival index (GI), Silness and Loe

(3) probing pocket depth (PD)

(4) the amount of keratinized tissue, to the nearest 0.01 millimeter with 15 UNC color-coded probe, Hu-Friedy®.

(5) the amount of gingival recession, to the nearest 0.01 millimeter with 15 UNC color-coded probe, Hu-Friedy®.

The PD score, the amount of keratinized tissue, the amount of gingival recession in each site will be evaluated twice. Then mean values will be calculated. One operator will perform in all measurements.

- Baseline orthodontic treatment records (Lateral cephalometric radiograph, photograph taken, the impression of upper and lower teeth)
- 1st CBCT record (To evaluate the gingival thickness and alveolar bone characteristics between thick and thin gingival biotypes)

3. Give oral hygiene instruction protocol until participants can control their oral hygiene under these parameters: plaque index (Quigley and Hein)[76] less than 1, Gingival index (Silness and Loe) less than 1, and no pocket formation

4. The first premolars will be extracted and two weeks after extraction, the patients will be recalled to follow-up wound healing.

5. Orthodontic treatments will be commenced with placement conventional brackets (pre-adjusted edgewise appliances; Roth™ system) with 0.018” slot (upper anterior teeth), 0.022” slot (posterior teeth) with vertical slot. Alignment and leveling of the arches will be performed by using from 0.012-inch NiTi until 0.018 x 0.022-inch stainless steel archwires. The molars and second premolars will be tied together with SS 0.010-inch ligatures.

6. The following data will be recorded when a well alignment is obtained. (Before retraction data; T1)

- The 2nd CBCT
- Lateral cephalometric radiograph
- Impression

- Clinical periodontal parameters records

7. Upper anterior teeth will be retracted with NiTi coil spring delivered force of 150 grams per side (checked with a dynamometer).

8. Patients will be evaluated after 4 weeks, 8 weeks, 12 weeks, 16 weeks of anterior retraction. (retraction time about 4 months)

9. After 16 weeks of anterior retraction (T2)

The following data will be recorded.

- Lateral cephalometric radiograph
- Impression
- Clinical periodontal parameters records

10. After T2 for 3 months for alveolar bone remodeling

The following data will be recorded.

- Clinical periodontal records
- The 3rd CBCT

11. For intraoperative reliability defined as method error, intraclass correlation coefficients will be calculated by the measurement of 10 randomly selected dental casts, 10 randomly selected lateral cephalometric radiograph, and 10 randomly selected CBCT samples. The measurements from 2 weeks different will be analyzed.

Cephalometric analysis

The natural head position was established for the standard of the lateral cephalometric radiographs taken. The lateral cephalometric radiographs were scanned before maxillary anterior teeth retraction (T_1) and after anterior teeth retraction 16 weeks (T_2).

Reference points :

- S (sella): the center of the cavity of sella turcica

- N (nasion): the most anterior point of the frontonasal suture in the midsagittal plane
- U1: the most incisal point on the crown of the maxillary central incisor
- A (point A; subnasale): the deepest midline point on the anterior outer contour of the maxillary alveolar process
- B (point B; supramentale): the deepest point on the outer contour of the mandible

Reference lines:

- Sella-Nasion plane (SN): the plane from the sella (S) to the Nasion (N) point
- Mandibular plane (MP): the plane from the Gonion (Go) to the Menton (Me) point
- Palatal plane (PP): the plane from anterior nasal spine (ANS) to posterior nasal spine (PNS)
- Long axis of the upper central incisor (U1axis): the plane from U1 incisal to U1 apex

Linear measurements:

- Horizontal linear measurements:
    - U1-NA distance (mm): the angle from the tooth long axis of the upper incisor (U1 axis) and the SN plane
- Vertical linear measurements:
    - Extent of Upper incisor extrusion: The difference U1 incisal to palatal plane of upper incisor between before and after anterior retraction

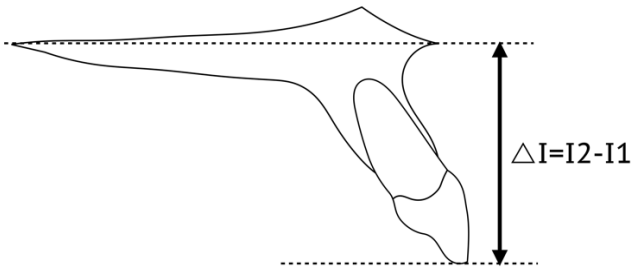

Fig. 3 The difference of U1 incisal to palatal plane

Angular measurements:

- U1-PP: the angle formed from the long axis of the upper incisor (U1 axis) and the palatal plane (PP)
- U1-NA angle: the angle formed from the tooth long axis of the upper incisor (U1axis) and the Nasion-point A plane (NA)
- MPA angle: the angle between the SN plane and the mandibular plane (MP)
- ANB angle: the angle from point A to Nasion and to point B
- SNA angle: the angle from Sella to Nasion and to point A

Digital model analysis

After taking maxillary impression and fabrication study model, the digital models were scanned before retraction (T1) and after retraction (T2) models with a 3D digital scanner (3-Shape's R700™ Scanner, 3Shape, Copenhagen, Denmark). The 3D digital models were calculated via a OrthoAnalyzer (3D Software, 3-Shape, Copenhagen, Denmark). Models superimposition between T1 and T2 was constructed on the medial point of the third palatal rugae bilaterally[77].

Distance of incisor retraction:

- Distance of incisor retraction: the different distance between the incisal edge of maxillary incisors before and after retraction.

Cone-beam computed tomography (CBCT) analysis

Before the CBCT images were taken into the soft tissue, the lip retractor and the cotton roll were inserted. The difference in density between air and soft tissue was used to determine the amount of gingival tissue in CBCT.

Upper anterior teeth were scanned using CBCT (80 kV, 5 mA, 9.2 sec exposure time, 0.125 mm voxel resolution, 80 x 80 mm field of view; Veraviewepocs J Morita MPG, Fushimi, Kyoto, Japan). CBCT data were reconstructed every 0.125 mm. Images were evaluated for gingival thickness and five alveolar bone parameters. Thickness and height measurements were in millimeters for the two closest two numbers with i-Dixel One Volume Viewer software (J Morita MPG, Fushimi-ku, Kyoto, Japan).

Gingival thickness measurements

Each CBCT image was followed along the tooth long axis of the root and the sagittal plane running transversely through the midpoint of the tooth axis. The vertical levels of the maxillary teeth were measured from 3 mm, 6 mm, and 9 mm apical to the CEJ (the crestal level, midroot level and apical level)[71]. The gingival thickness was measured from the most outer surface of the gingiva to the cortical bone perpendicular to the tooth long axis on both the labial and palatal sides.

Alveolar bone measurements

The five parameters were measured on the same level based on measurements of the alveolar bone thickness, cortical bone thickness, cancellous bone thickness, alveolar bone height, and cortical bone height.

Alveolar bone thickness

The thickness of the alveolar bone was measured from the outer surface of the alveolar bone to the inner surface of the alveolar bone on both the labial and palatal sides perpendicular to the long axis of the teeth.

Cortical bone thickness

The thickness of the cortical bone was measured from the outer surface of the cortical bone to the inner surface of the cortical bone on both the labial and the palatal sides perpendicular to the long axis of the teeth.

Cancellous bone thickness

The thickness of the Cancellous bone was measured from the outer surface of the laminate to the inner surface of the cortical bone on both the labial and palatable sides perpendicular to the long axis of the teeth.

Alveolar bone height

The height of the alveolar bone was the vertical distance parallel to the tooth axis from the cementoenamel junction (CEJ) to the alveolar bone crest.

Cortical bone height

The height of the cortical bone was the vertical distance of the cortical bone parallel to the tooth axis from the alveolar bone crest to the interface of the cortical bone and the cancellous bone.

Error of measurements

Ten lateral cephalometric radiographs, ten study models and ten CBCT samples were remeasured at least 2 weeks apart using the formula of Dahlberg:

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

d: The difference of two set of measurements

n: Number of two measurements

The Intraclass Correlation Coefficient (ICC) was evaluated.

Statistical analysis

Data were analyzed by using the statistical software program; SPSS version 17.0 (Inc., Chicago, IL, USA). Means and standard deviations of all of the variables were calculated. The Shapiro-Wilk test was used to assess the distribution of data. In this study, not all variables were presented normal distribution, the differences between the two independent variables was assessed with a Mann Whitney U test at a 95 % confident interval.

CHAPTER 3

RESULTS

The results were divided into 2 parts: First part was the pretreatment data (baseline data, T0) and comparison between before and after anterior retraction (T1 and T2 respectively).

Part I: Pretreatment data (Baseline data, T0)

Six of the anterior teeth were analyzed separately according to the gingival biotype. On the right, the central incisor, lateral incisor and canine were compared to the left. Since there were no statistically significant differences between them, measurements from both left and right were combined into one group. In addition, the comparison of the tooth type parameters was analyzed by the Kruskal-Wallis test. Because there were no statistically significant differences between the tooth types, all the anteior teeth were combined into one group for each biotype. Finally, the thick gingival biotype sample size was 108 teeth, while the 132 teeth were thin in the gingival biotype. Mean values and standard deviations of gingival thickness, alveolar bone thickness, and cortical bone thickness were calculated and compared between the thick and thin gingival biotype using the Mann-Whitney U test.

1. Descriptive data assessment

Two hundred and forty anterior teeth were composed of 108 teeth of the thick gingival biotype (18 subjects) and 132 teeth of the thin gingival biotype group (22 subjects). The initial cephalometric data of the subjects showed a skeletal Class I relationship (ANB = 2.51 ± 1.22 degrees) with normal vertical pattern (MPA = 28.14 ± 4.56 degree). There were no significant differences in the upper incisor inclinations (i.e., Upper incisor to palatal plane (UIPP) angle and UI-NA angle) and upper incisor position (i.e., UI-NA distance) between the two gingival biotypes (Table 2).

Table 2: Differences of tooth inclination (UIPP and UI-NA (angles)), and tooth position (UI-NA (distance)) between thick and thin gingival biotypes

	Thick	**Thin**	**Differences (Δ)**	**Significant difference**
UIPP (degree)	127.4 ± 3.1	128.8 ± 2.2	1.4	NS
UI-NA (degree)	31.3 ± 3.7	31.7 ± 3.9	0.4	NS
UI-NA (mm)	8.3 ± 1.0	8.8 ± 1.5	0.5	NS

2. Gingival thickness

In both gingival biotypes, the thickness of the labial and palatal gingiva gradually increased to the apical region (Table 3). Measurements are made only with attached gingiva. On the labial side, the thickness of the alveolar mucosa over 4 mm was measured by 4 mm. On the palatal side, the measurements were to 10 mm. Differences of about 0.23 to 0.33 mm. On the palatal side, the thick gingival biotype was statistically significantly thicker than the thin gingival biotype at the crestal bone and coronal to 2 mm. When the differences were between about 0.48 to 0.52 mm, the remaining level was not different.

Table 3: Comparisons of gingival thickness between thick and thin gingival biotypes

Maxillary teeth (n=240)	**Thick**	**Thin**	**Δ**	**Significant difference**
Labial gingival thickness				
- At crestal bone	0.72 ± 0.13	0.45 ± 0.11	0.27	< 0.01
- 2 mm apical to crestal bone	0.94 ± 0.09	0.61 ± 0.11	0.33	< 0.01
- 4 mm apical to crestal bone	1.24 ± 0.13	1.01 ± 0.08	0.23	0.01
- 6 mm apical to crestal bone	-	-	-	-
- 8 mm apical to crestal bone	-	-	-	-
- 10 mm apical to crestal bone	-	-	-	-
Palatal gingival thickness				
- At crestal bone	2.36 ± 0.26	1.87 ± 0.35	0.48	0.03
- 2 mm apical to crestal bone	2.76 ± 0.21	2.24 ± 0.08	0.52	0.01
- 4 mm apical to crestal bone	2.90 ± 0.32	2.55 ± 0.26	0.35	NS
- 6 mm apical to crestal bone	3.12 ± 0.45	2.82 ± 0.31	0.30	NS
- 8 mm apical to crestal bone	3.46 ± 0.34	3.14 ± 0.31	0.32	NS
- 10 mm apical to crestal bone	3.66 ± 0.31	3.22 ± 0.31	0.44	NS

3. Alveolar bone thickness and height

The thickness of the labial bone was almost equal in both gingival biotypes (Table 4). Thickness was 0.41-0.54 mm thick gingival biotype and 0.32-0.46 mm in thin gingival biotype. The palatal bone thickness gradually increased to the apical area in both gingival biotypes. On the labial side, the thick gingival biotype showed a statistically significantly thicker alveolar bone, except for 10 mm. The differences were 0.09 - 0.13 mm. The thick gingival biotype on the palatal side showed a significantly thicker thickness than thin gingival biotype. The differences were 0.75 to 1.74 mm. The distance between the alveolar bone and the CEJ at the thick gingival biotype was significantly lower than the thin gingival biotype ($P < 0.01$) on both the labial and palatal sides.

4. Cortical bone thickness and height

The thickness of the labial cortical bone was almost homogeneous from the teeth to the apical levels from the crestal in both gingival biotypes, while the thickness of the palatal bone increased gradually to the apical region (Table 4). On the labial side, the thick gingival biotype showed significantly thicker cortical bone than thin gingival biotype except for a 10 mm level. On the palatal side, the thick gingival biotype showed significantly thicker cortical bone than the thinner one. The differences were between 0.29 and 0.82 mm. Although there was no difference in the height of the labial cortical bone between two gingival biotypes, it was found that the palatal cortical bone height in the thick gingival biotype was significantly more coronal than the thin gingival biotype ($P < 0.01$).

5. Cancellous bone thickness

No cancellous bone was found in the labial bone at levels measured in both gingival biotypes (Table 4). Cancellous bone was observed to have a 4 mm in thick and a thin gingival biotype detected at 8 mm distance from the cretal bone. The amount of palatal cancellous bone in thick gingival biotype was significantly higher than in the thin gingival biotype at all measured levels ($P < 0.01$).

Table 4: Comparisons of alveolar bone parameters between thick and thin gingival biotypes (on labial side)

Maxillary teeth (n=240)	Labial			
	Thick	**Thin**	**Δ**	**Significant difference**
1. Alveolar Bone Thickness				
- At crestal bone	0.41 ± 0.08	0.32 ± 0.03	0.09	0.02
- 2 mm apical to crestal bone	0.43 ± 0.09	0.33 ± 0.03	0.10	0.03
- 4 mm apical to crestal bone	0.45 ± 0.09	0.32 ± 0.05	0.13	0.05
- 6 mm apical to crestal bone	0.48 ± 0.07	0.37 ± 0.06	0.11	0.04
- 8 mm apical to crestal bone	0.51 ± 0.06	0.39 ± 0.07	0.12	<0.01
- 10 mm apical to crestal bone	0.54 ± 0.05	0.46 ± 0.12	0.08	NS
2. Alveolar bone height (CEJ to alveolar crest)	1.69 ± 0.26	3.02 ± 0.57	1.33	< 0.01
3. Cortical Bone Thickness				
- At crestal bone	0.41 ± 0.08	0.32 ± 0.03	0.09	0.02
- 2 mm apical to crestal bone	0.43 ± 0.09	0.33 ± 0.03	0.10	0.03
- 4 mm apical to crestal bone	0.45 ± 0.09	0.32 ± 0.05	0.13	0.05
- 6 mm apical to crestal bone	0.48 ± 0.07	0.37 ± 0.06	0.11	0.04
- 8 mm apical to crestal bone	0.51 ± 0.06	0.39 ± 0.07	0.12	<0.01
- 10 mm apical to crestal bone	0.54 ± 0.05	0.46 ± 0.12	0.08	NS
4. Cortical Bone Height	11.62 ± 1.37	10.39 ± 0.22	1.23	NS
5. Cancellous Bone Thickness				
- At crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 2 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 4 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 6 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 8 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 10 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS

Table 4: (cont.)

Maxillary teeth (n=240)	Palatal			
	Thick	**Thin**	**Δ**	**Significant difference**
1. Alveolar Bone Thickness				
- At crestal bone	1.12 ± 0.27	0.37 ± 0.10	0.75	< 0.01
- 2 mm apical to crestal bone	1.30 ± 0.25	0.48 ± 0.13	0.82	< 0.01
- 4 mm apical to crestal bone	2.08 ± 0.11	0.90 ± 0.16	1.18	< 0.01
- 6 mm apical to crestal bone	2.45 ± 0.14	1.25 ± 0.21	1.20	< 0.01
- 8 mm apical to crestal bone	3.28 ± 0.25	2.06 ± 0.18	1.23	< 0.01
- 10 mm apical to crestal bone	4.28 ± 0.39	2.54 ± 0.35	1.74	< 0.01
2. Alveolar bone height (CEJ to alveolar crest)	1.11 ± 0.25	2.17 ± 0.31	1.06	< 0.01
3. Cortical Bone Thickness				
- At crestal bone	1.12 ± 0.27	0.37 ± 0.10	0.75	< 0.01
- 2 mm apical to crestal bone	1.30 ± 0.25	0.48 ± 0.13	0.82	< 0.01
- 4 mm apical to crestal bone	1.36 ± 0.10	0.90 ± 0.16	0.46	< 0.01
- 6 mm apical to crestal bone	1.67 ± 0.20	1.25 ± 0.21	0.42	0.02
- 8 mm apical to crestal bone	1.62 ± 0.17	1.32 ± 0.09	0.29	0.03
- 10 mm apical to crestal bone	1.89 ± 0.36	1.26 ± 0.2	0.63	0.03
4. Cortical Bone Height	3.82 ± 0.14	7.73 ± 0.16	3.91	< 0.01
5. Cancellous Bone Thickness				
- At crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 2 mm apical to crestal bone	0.00 ± 0.00	0.00 ± 0.00	0	NS
- 4 mm apical to crestal bone	0.72 ± 0.10	0.00 ± 0.00	0.72	<0.01
- 6 mm apical to crestal bone	0.79 ± 0.18	0.00 ± 0.00	0.79	<0.01
- 8 mm apical to crestal bone	1.67 ± 0.34	0.73 ± 0.16	0.94	<0.01
- 10 mm apical to crestal bone	2.39 ± 0.39	1.28 ± 0.21	1.11	<0.01

Part II: The Comparisons between before and after anterior retraction (T1 and T2)

1. Descriptive data assessment

One hundred and ninety-two anterior teeth were composed of 96 teeth from 16 subjects of each gingival biotype. The initial cephalometric data of the subjects showed a skeletal Class I relationship (ANB = 2.55 ± 1.19 degrees) with normal vertical pattern (MPA = 28.66 ± 3.87 degrees).

2. Comparison of skeletal and dental variables between thick and thin gingival biotype at T1

The means and standard deviations of skeletal and dental variables between two gingival biotypes at T1 were shown in table 5. There were no significant differences in the skeletal pattern (i.e., SNA, ANB and MPA angle) and upper incisor position and inclination (i.e., UI-NA distance, UI-NA degree and UIPP degree) between the two gingival biotype groups.

Table 5: Comparison of skeletal and dental variables between thick and thin gingival biotype at T1 (Before retraction)

	Thick		**Thin**		**Differences (Δ)**	**Significance**
	Mean	**SD**	**Mean**	**SD**		
Skeletal variables						
SNA (degree)	83.66	1.70	83.47	2.40	0.19	NS
ANB (degree)	2.50	1.30	2.59	1.10	0.09	NS
MPA (degree)	28.84	3.43	28.47	4.37	0.37	NS
Dental variables						
UIPP (degree)	126.13	1.74	127.66	1.33	1.53	NS
UI-NA (degree)	29.78	2.45	30.97	2.46	1.19	NS
UI-NA (mm)	8.22	0.63	8.56	0.63	0.34	NS

3. Rate of tooth movement and upper incisor changes after en masse retraction

The thin gingival biotype showed significantly more distance (0.76 mm) , faster rate of tooth movement (0.19 mm/month) and more upper incisors inclination change than the thick. However, there were no significant differences in the extent of upper incisor intrusion between the two gingival biotype groups. (Table 6)

Table 6: Rate of tooth movement and upper incisor changes between thick and thin gingival biotype after en masse retraction

	Thick		**Thin**		**Differences (Δ)**	**Significance**
	Mean	**SD**	**Mean**	**SD**		
Distance (mm)	3.36	0.53	4.12	0.42	0.76	< 0.01
Rate of tooth movement (mm/month)	0.84	0.13	1.03	0.10	0.19	< 0.01
Upper incisors inclination change (UI-PP of T2-T1) (degree)	8.22	1.32	10.44	0.46	2.22	< 0.01
Extent of Upper incisor extrusion (mm)	0.26	0.96	0.65	1.23	0.39	NS

4. The changes of the gingival thickness between thick and thin gingival biotypes after en masse retraction

The labial gingival thickness in both thick and thin gingival biotypes showed the thickening at all vertical levels (crestal, middle and apical level) but the statistically significant thickening ($P<0.01$) was found only at crestal level (0.15 mm for the thick and 0.10 mm for the thin). The thick and thin gingival biotypes showed no difference of increasing in labial gingivalthickness.

The palatal gingival thickness in both thick and thin gingival biotypes showed the thickening at all vertical levels but the statistically significant thickening ($P<0.01$) was found

only at crestal level (0.40 mm for the thick and 0.52 mm for the thin). The thick and thin gingival biotypes showed no difference of increasing in palatal gingival thickness.

Table 7: The changes of the gingival thickness between thick and thin gingival biotypes (T2-T1) after en masse retraction

Maxillary teeth (n=192)		**Labial**			
		T1	**T2**	**T2-T1**	**Significant difference**
3 mm apical to CEJ	Thick	0.75 ± 0.14	0.90 ± 0.16	0.15	<0.01
	Thin	0.56 ± 0.15	0.66 ± 0.19	0.10	<0.01
	Δ	**0.19**	**0.24**	**0.05**	**NS**
6 mm apical to CEJ	Thick	0.89 ± 0.13	0.90 ± 0.19	0.01	NS
	Thin	0.78 ± 0.12	0.81 ± 0.13	0.03	NS
	Δ	**0.11**	**0.09**	**0.02**	**NS**
9 mm apical to CEJ	Thick	-	-	-	-
	Thin	-	-	-	-
	Δ	-	-	-	-
Maxillary teeth (n=192)		**Palatal**			
		T1	**T2**	**T2-T1**	**Significant difference**
3 mm apical to CEJ	Thick	2.21 ± 0.55	2.61 ± 0.51	0.40	<0.01
	Thin	2.08 ± 0.49	2.60 ± 0.62	0.52	<0.01
	Δ	**0.13**	**0.01**	**0.12**	**NS**
6 mm apical to CEJ	Thick	2.60 ± 0.57	2.64 ± 0.61	0.04	NS
	Thin	2.48 ± 0.59	2.56 ± 0.66	0.08	NS
	Δ	**0.12**	**0.08**	**0.04**	**NS**
9 mm apical to CEJ	Thick	3.01± 0.34	3.03 ± 0.40	0.02	NS
	Thin	2.65 ± 0.47	2.70 ± 0.53	0.05	NS
	Δ	**0.36**	**0.33**	**0.03**	**NS**

5. The changes of the alveolar bone thickness and height between thick and thin gingival biotypes after en masse retraction

Alveolar bone thickness change

The labial alveolar bone thickness in both thick and thin gingival biotypes showed the thickening at all vertical levels but the statistically significant thickening ($P<0.01$) was found only at crestal level (0.26 mm for the thick and 0.25 mm for the thin). The thick and thin gingival biotypes showed no difference of increasing in labial alveolar bone thickness.

The palatal alveolar bone thickness in both thick and thin gingival biotypes decreased at all vertical levels but the statistically significantly thin ($P<0.01$) was found only at crestal and middle level (0.24-0.35 mm). The thick and thin gingival biotypes showed no difference of decreasing in palatal alveolar bone thickness.

Alveolar bone height change

The distance from labial bone crest to CEJ in both thick and thin gingival biotypes showed the statistically significant shortening or the labial alveolar bone height moved more coronal to CEJ (0.40mm for the thick and 0.39 mm for the thin). The thick and thin gingival biotypes showed no different change in labial alveolar bone height.

The distance from palatal bone crest to CEJ in both thick and thin gingival biotypes showed the statistically significant increasing ($p<0.01$) or the palatal alveolar bone height moved more apical to CEJ (0.79 mm for the thick and 1.75 mm for the thin).The thin gingival biotype showed more apically moved palatal alveolar bone height ($p< 0.01$) was 0.96 mm.

Table 8: The changes of alveolar bone between thick and thin gingival biotypes (T2-T1) after en masse retraction (on labial side)

Maxillary teeth (n=192)			**Labial**			
			T1	**T2**	**T2-T1**	**Significant difference**
1. Alveolar bone thickness	3 mm apical to CEJ	Thick	0.45 ± 0.26	0.71 ± 0.37	0.26	<0.01
		Thin	0.35 ± 0.20	0.60 ± 0.26	0.25	<0.01
		Δ	**0.10**	**0.11**	**0.01**	**NS**
	6 mm apical to CEJ	Thick	0.38 ± 0.31	0.52 ± 0.40	0.14	NS
		Thin	0.25 ± 0.20	0.31 ± 0.28	0.06	NS
		Δ	**0.13**	**0.21**	**0.08**	**NS**
	9 mm apical to CEJ	Thick	0.29 ± 0.26	0.31 ± 0.29	0.02	NS
		Thin	0.31± 0.15	0.32 ± 0.19	0.01	NS
		Δ	**0.02**	**0.01**	**0.01**	**NS**
2. Alveolar bone height (CEJ to alveolar crest)		Thick	2.04 ± 0.48	1.64 ± 0.52	-0.40	<0.01
		Thin	3.14 ± 2.24	2.75 ± 1.88	-0.39	0.03
		Δ	**1.10**	**1.11**	**0.01**	**NS**

Table 8: (cont.)

Maxillary teeth (n=192)			**Palatal**			
			T1	**T2**	**T2-T1**	**Significant difference**
1. Alveolar bone thickness	3 mm apical to CEJ	Thick	1.21 ± 0.36	0.90 ± 0.40	-0.31	<0.01
		Thin	0.75 ± 0.16	0.40 ± 0.19	-0.35	<0.01
		Δ	**0.46**	**0.50**	**0.04**	**NS**
	6 mm apical to CEJ	Thick	2.30 ± 1.06	1.95 ± 0.87	-0.35	0.01
		Thin	1.25 ± 0.47	1.01 ± 0.54	-0.24	<0.01
		Δ	**1.05**	**0.94**	**0.11**	**NS**
	9 mm apical to CEJ	Thick	2.94 ± 1.63	2.89 ± 1.26	-0.05	NS
		Thin	2.22 ± 0.78	2.14 ± 0.83	-0.08	NS
		Δ	**0.72**	**0.75**	**0.03**	**NS**
2. Alveolar bone height (CEJ to alveolar crest)		Thick	1.72 ± 0.95	2.51 ± 1.34	0.79	<0.01
		Thin	2.23 ± 1.09	3.98 ± 1.72	1.75	<0.01
		Δ	**0.51**	**1.47**	**0.96**	**<0.01**

6. The changes of the cortical bone thickness and height between thick and thin gingival biotypes after en masse retraction

Cortical bone thickness change

The labial cortical bone thickness in both thick and thin gingival biotypes showed the thickening at all vertical levels but the statistically significant thickening ($P<0.01$) was found only at crestal level (0.26 mm for the thick and 0.25 mm for the thin). The thick and thin gingival biotypes showed no difference of increasing in labial cortical bone thickness.

The palatal cortical bone thickness in thick gingival biotype showed the statistically significant decreasing only at crestal level (-0.31mm) but almost consonant at middle and apical levels. Apart from the thin gingival biotype showed the statistically significant decreasing only at crestal and middle levels (-0.35 mm and -0.24 mm respectively) but almost consonant at apical level. The Thin gingival biotype showed the more statistically significant decreasing ($p< 0.01$) in palatal cortical bone than the thick gingival biotype at middle level (0.21 mm).

Cortical bone height change

The labial cortical bone height in both thick and thin gingival biotypes increased or moved more coronal to CEJ or shorter distance from CEJ (0.35 mm for the thick and 0.31 mm for the thin). The thick and thin gingival biotypes showed no different change in labial cortical bone height.

The palatal cortical bone height in both thick and thin gingival biotypes decreased or moved more apicall to CEJ or longer distance from CEJ (0.85 mm for the thick and 1.75 mm for the thin). The thin gingival biotype showed more decreasing in palatal cortical bone height more than thick gingival biotype (0.95 mm).

Table 9: The changes of cortical bone between thick and thin gingival biotypes (T2-T1) after enmass retraction (on labial side)

Maxillary teeth (n=192)			**Labial**			
			T1	**T2**	**T2-T1**	**Significant difference**
1. Cortical bone thickness	3 mm apical to CEJ	Thick	0.45 ± 0.26	0.71 ± 0.37	0.26	<0.01
		Thin	0.35 ± 0.20	0.60 ± 0.26	0.25	<0.01
		Δ	**0.10**	**0.11**	**0.01**	**NS**
	6 mm apical to CEJ	Thick	0.38 ± 0.31	0.52 ± 0.40	0.14	NS
		Thin	0.25 ± 0.20	0.31 ± 0.28	0.06	NS
		Δ	**0.13**	**0.21**	**0.08**	**NS**
	9 mm apical to CEJ	Thick	0.29 ± 0.26	0.31 ± 0.29	0.02	NS
		Thin	0.31± 0.15	0.32 ± 0.19	0.01	NS
		Δ	**0.02**	**0.01**	**0.01**	**NS**
2. Cortical Bone Height		Thick	9.02 ± 0.89	9.37 ± 1.19	0.35	NS
		Thin	7.81 ± 1.72	8.12 ± 2.58	0.31	NS
		Δ	**1.21**	**1.25**	**0.04**	**NS**

Table 9: (cont.)

Maxillary teeth (n=192)			Palatal			
			T1	**T2**	**T2-T1**	**Significant difference**
1. Cortical bone thickness	3 mm apical to CEJ	Thick	1.21 ± 0.36	0.90 ± 0.40	-0.31	<0.01
		Thin	0.75 ± 0.16	0.40 ± 0.19	-0.35	<0.01
		Δ	**0.46**	**0.50**	**0.04**	**NS**
	6 mm apical to CEJ	Thick	1.45 ± 0.44	1.42 ± 0.48	-0.03	NS
		Thin	1.25 ± 0.47	1.01 ± 0.54	-0.24	<0.01
		Δ	**0.20**	**0.41**	**0.21**	**<0.01**
	9 mm apical to CEJ	Thick	1.61 ± 0.42	1.64 ± 0.37	0.03	NS
		Thin	1.42 ± 0.31	1.47 ± 0.52	0.05	NS
		Δ	**0.19**	**0.17**	**0.02**	**NS**
2. Cortical Bone Height		Thick	3.45 ± 0.66	2.65 ± 0.72	-0.80	<0.01
		Thin	6.89 ± 2.33	5.14 ± 1.29	-1.75	<0.01
		Δ	**3.44**	**2.49**	**0.95**	<0.01

7. The changes of the cancellous bone thickness and height between thick and thin gingival biotypes after en masse retraction

No cancellous bone was detected in labial bone at all measured vertical level and crestal level of palatal bone in both gingival biotypes (table 10)

The palatal cancellous bone in thick gingival biotype statistically significantly decreased (P<0.01) at middle level (0.32 mm) but almost consonant at apical level.

In thin gingival biotype, the palatal cancellous bone was detected only at apical level and statistically insignificantly decreased (-0.13 mm). The thick and thin gingival biotypes showed no difference of decreasing in labial cortical bone thickness at apical level.

Table 10: The changes of cancellous bone thickness between thick and thin gingival biotypes (T2-T1) after en masse retraction

Maxillary teeth (n=192)		**Labial**				**Palatal**			
		T1	**T2**	**T2-T1**	**Significant difference**	**T1**	**T2**	**T2-T1**	**Significant difference**
3 mm apical to CEJ	Thick	0	0	0	NS	0	0	0	NS
	Thin	0	0	0	NS	0	0	0	NS
	Δ	**0**	**0**	**0**	**NS**	**0**	**0**	**0**	**NS**
6 mm apical to CEJ	Thick	0	0	0	NS	0.85±0.78	0.53±0.49	-0.32	<0.01
	Thin	0	0	0	NS	0	0	0	NS
	Δ	**0**	**0**	**0**	**NS**	**0.85**	**0.53**	**-0.32**	**<0.01**
9 mm apical to CEJ	Thick	0	0	0	NS	1.33±1.04	1.25±1.16	-0.08	NS
	Thin	0	0	0	NS	0.80±0.59	0.67±0.51	-0.13	NS
	Δ	**0**	**0**	**0**	**NS**	**0.53**	**0.58**	**0.05**	**NS**

CHAPTER 4

DISCUSSION

Part I: Pretreatment data

Upper anterior protruded teeth are usually treated by lingual retraction. These protruding teeth are generally associated with thin, surrounding, alveolar bone exposed to damage when used as heavy force. [78]. Identifying the patient's gingival biotype is important because the movement of the teeth towards the gingival may lead to a gingival recession, especially in gingival biotype[79]. For this reason, this study was conducted to determine the thickness of the liver and the alveolar bone thickness in the dentoalveolar protruding teeth. The probe transparency method was chosen as a method for identifying gingival biotypes because the method is accurate and reliable for separating the gingival biotype and is clinically easy to perform[21].

The thick gingival biotype gingival thickness was significantly thicker than the thin gingival biotype. This corresponded to the results of the previous studies[73,80] where they investigated facial gingival dimension in maxillary anterior teeth region. Although a significant difference was found in this study, the differences were 0.23-0.33 mm and this may be clinically insignificant. The thicknesses increased apically from 0.72 to 1.24 mm and 0.45 to 1.01 mm in thin and thick gingival biotypes. In most studies, gingival thickness was not reported in palatal areas because they were considered to be insignificant[24]. In addition, on the palatal side the differences are also small (0.30-0.52 mm), suggesting questionable clinical significance.

The labial alveolar bone in the thick gingival biotype was significantly thicker than in the thin biotype which was similar to a study by Cook et al[29]; however, the measured thickness in the current study was less. This was most likely due to the fact that the current study was done with protruding teeth and increased inclination may be associated with a reduction in labial alveolar bone as found by Nahm et al. in 2012 [5]. Furthermore, the difference was also small (0.08-0.13 mm) and was unlikely to be of clinical relevance. The

alveolar bone thicknesses of 0.41-0.54 mm and 0.32-0.46 mm in the thick and thin gingival biotypes, respectively, were considered thin which Fuhrmann[81] found that this thin labial bone plate was one of anatomic risks for bone dehiscence when uncontrolled sagittal or vertical movement was introduced.

The level of labial alveolar bone (CEJ alveolar ridge) in thick gingival biotype was closer to CEJ than the thin gingival biotype accepted by Cook et al [29]. Thin gingival biotype with dentoalveolar protrusion presented more distance from CEJ to alveolar crest than without dentoalveolar protrusion[79].

The palatal alveolar bone thickness in the thick gingival biotype was also significantly thicker than in the thin gingival biotype. No previous study reported a comparison of this area. The differences between the two gingival types were 0.75 and 1.74 mm, which may be clinically significant. Thick gingiva biotypes thicknesses from 1.12 to 4.28 mm are not easily resorbable[82], whereas thicknesses of 0.37-0.48 mm in the thin gingival biotype at the crestal bone level and 2 mm apical to the crestal bone level may be of concern since they were quite thin with the risk of resorption if the roots are tipped with excessive force.

The height of the palatal alveolar bone (CEJ to alveolar crest) in the thick gingival biotype was closer to the CEJ than in the thin gingival biotype with a 1.06 mm mean difference. Compared to a normal alveolar bone height[83], this could be considered healthy for both groups.

Labial alveolar bone in both the thick and thin gingival biotypes was only cortical bone since no cancellous bone was present. When pure cortical bone is present on all alveolar plates, only an optimal application of force would be appropriate to create the desired frontal bone resorption.

The palatal alveolar bone in the thick gingival biotype had pure cortical bone from the crestal bone level to 2 mm apical to the crestal bone level, and cancellous bone that started at 4 mm apical to the crestal bone level with a total height of 3.82 mm. However, in the thin gingival biotype, the mean pure cortical bone height was 7.73 mm with cancellous bone that started at 8 mm apical to the crestal bone level. Assuming a root length of 10 mm, this means that the ratio of the height / root length of the thick gingival biotype to the pure cortical

bone is 4/10, while the thin gingival biotype is 8/10 the ratio of cortical bone / root length. This information may be useful for orthodontists when they apply force to retract the anterior teeth. If a thin gingival biotype is targeted bone loss may be as high as 8 mm because there is no cancellous bone that allows for resorption. no cancellous bone to allow undermining resorption. Root resorption is also a major concern in orthodontics, especially when the root moves against the cortical bone with excessive force[84]. The thicker cancellous bone is favored for greater root movement. Therefore, patients with thick gingival biotypes with are more likely to have thicker cancellous bone, thus providing more space to move the roots as far as 2.39 mm at 10 mm apical to the crestal bone level, while movement of only 1.28 mm would be possible in the thin gingival biotype.

Part II: Before-After en masse retraction

The gingival thickness was greater at the crestal bone level on the labial and palatal side of both gingival biotypes. However, the gingival thickness at the middle and apical level was almost consonant as a consequence of the tipping movement of the upper anterior teeth. Since the crowns were retracted palatally, the force tended to distribute to periodontium and resulted in gingiva thickening on both labial and palatal sides. This result was consistent with the previous studies which labial gingiva was thickened after tooth moved lingually[44]. According to the histological and molecular studies, an increase of the procollagen and elastin and the sizes of the collagen fibers was presented when mechanical stress was applied[85]. It possibly explained the consequence of gingival thickening on the tension side. On the contrary, the palatal gingiva was compressed and led to the accumulation of the gingiva[86].

In addition, the previous studies showed an increase of gingival thickness in the compression side after receiving orthodontic force because of the increase of the collagen fibers diameter and the gingival elasticity[87,88]. This study showed the gingival thickening after orthodontic force was introduced. It revealed that the gingival thickness at only 0.56 mm was adequate to resist the mechanical force. However, one study argued that the favorable gingival thickness should be greater than 1 mm. It revealed less post-operative gingival recession[82]. Although the palatal gingiva increased its thickness in the thin gingival biotype more than the

thick gingival biotype due to the greater tipping tooth movement, there was no statistically significant difference. (0.04-0.12 mm)

The thickness of the labial alveolar bone significantly increased at the crestal bone level in both gingival biotypes similar to a previous study by Yodthong, et al. 2013 [72]. However, the labial alveolar bone thickness in this study was lesser than the previous one. Moreover, it was not detected an undesirable labial bone protuberance.

The level of labial bone (the distance from CEJ to alveolar bone crest) decreased in both gingival biotypes. Although the study in animal model confirmed that the lingual movement contributed to an increase of the labial bone height[89], there was no study in human at all. These findings implied the crestal bone level moved coronally without clinical significance. (0.39-0.40 mm)

The palatal alveolar bone thickness statistically significantly decreased at the crestal and middle level in both gingival biotypes because the remodeling of palatal alveolar bone occurred when the controlled tipping force was applied. The decreasing rate of the palatal bone in both gingival biotypes was almost equal (the difference = 0.03-0.11 mm). Since the amount of decreasing in palatal bone thickness was slightly (0.05 - 0.35 mm), it had no clinical significance similar to previous studies[71,90].

The height of palatal bone was key to determine the center of resistance that affected on type of the tooth movement[91]. The thick and thin gingival biotypes showed a statistically significant increase in the distance from CEJ to palatal bone crest which meant that more alveolar bone loss and crestal bone moved apically. This was the consequence of the crestal bone level was the most stress applied and led to bone resorption initiated the remodeling process[92]. Although the resorption was not clinically significant in thick gingival biotype (0.75 mm), the remarkable resorption was found in thin gingival biotype (1.79 mm). The plausible explanation was that the thin gingival biotype presented more apical initial palatal crestal bone level compared to the thick; therefore, the center of resistance in thin gingival biotype possible was located apically. Possibly, after the orthodontic force was applied, the thin biotype presented more tipping tooth movement. The more tipping movement was obtained, the more alveolar bone was resorbed[93].

In this study, both gingival biotypes increased the cortical bone thickness at the crestal bone level but it was minute (0.25-0.26 mm). Interestingly, since no previous study stated about labial cortical bone following the tooth movement, the maintenance of a thin cortical bone plate when the tooth moved were challenged[94].

The labial cortical bone height in both gingival biotypes increased and almost equal to an increase of alveolar bone height (0.31-0.35 mm). These findings implied the increasing bone level was almost complete cortical bone, but there was no clinical significance.

The palatal cortical bone thickness in thick gingival biotype statistically significantly decreased only at crestal level (0.31 mm) because the complete cortical bone was detected at only crestal level. On the other hand, the thin gingival biotype presented a slight increase in palatal cortical bone thickness at the crestal and middle level because the pure cortical bone was detected at this level.

The palatal cortical bone height decreased both gingival biotypes equaled to the amount of decreasing palatal bone height. It was assumed that the bone decreasing was mainly found on cortical bone. This supported the idea that cortical bone was a low remodeling tissue[2].

The palatal cancellous bone was detected at the middle level of thick gingival biotype and at the apical level of thin gingival biotype. At the middle level, when the tooth moved palatally, bone thickness in thick biotype was mainly decreased in the cancellous bone while bone thickness in thin biotype was mainly decreased in the cortical bone. Thereby, prior moving tooth palatally, the well-controlled tooth movement should be planned to reduce risk of the root resorption.

CHAPTER 5

CONCLUSIONS

Part I

Patients with anterior dentoalveolar protrusion presented both thick and thin gingival biotypes.

Patients with thick gingival biotype presented a thicker alveolar bone, cortical bone, and cancellous bone than thin gingival biotype.

In both gingival biotypes, only the cortical bone was observed on the labial side, while the palatal bone was originally at the 4 mm in thick gingival biotype and 8 mm in thin gingival type.

The shorter distance from the crestal bone to CEJ and the shorter palatal cortical bone height were found in the thick gingival biotype.

Part II

The thin gingival biotype showed faster rate of tooth movement and more upper incisors inclination change than the thick gingival biotype.

Both gingival biotypes showed thickening of gingiva and labial alveolar bone and decreasing of palatal bone. The significant decreasing of palatal bone height that composed of pure cortical bone was observed in thin gingival biotype.

In this study, patients with different gingival biotypes can able to move the teeth with optimal forces.

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APPENDICES

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

The Project Entitled	:	The Influence of Gingival Biotypes on Tooth Movement and Periodontal Tissue in Anterior Retraction Phase
REC Project No.	:	EC6103-10-P-HR
Principal Investigator	:	Assoc. Prof. Dr. Chairat Charoemratrote
Affiliation	:	Department of Preventive Dentistry, Faculty of Dentistry, PSU
Co-Principal Investigator	:	Assoc. Prof. Dr. Chidchanok Leetanakul / Mr.Pannapat Chanmanee
Affiliation	:	Department of Preventive Dentistry, Faculty of Dentistry, PSU

Approved Documents :

- ☑ Submission Form
- ☑ Research Proposal
- ☑ Informed Consent
- ☑ Consent Form

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

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

This review is documented in the meeting minutes of the meeting 3/2018
Agenda 4.2.2 **on** 29 MARCH 2018

Please submit the Progress Report every 12 months. (Renewal must be submitted at least 30 days prior to expired date.)

(For Exemption Determination, Please submit a Final Report after study completion)

Surapong Vongvatcharanon

(Asst.Prof.Surapong Vongvatcharanon)
Acting on Behalf Chairman of Research Ethics Committee

Date of Approval : 13 JUNE 2018
Date of Expiration : 12 JUNE 2019

ใบเชิญชวน

ขอเชิญเข้าร่วมโครงการวิจัยเรื่อง
อิทธิพลของเหงือกไบโอไทด์ต่อการเคลื่อนฟันและเนื้อเยื่อปริทันต์ในการเคลื่อนฟันหน้า
เรียน ท่านผู้อ่านที่นับถือ

ข้าพเจ้า ทพ.ปัณณ์พัฒน์ จันทร์มณี นักศึกษาหลักสูตรปรัชญาดุษฎีบัณฑิต สาขาวิทยาศาสตร์สุขภาพช่องปาก (ทันตกรรมจัดฟัน) โดยมี รศ.ทพ.ดร.ไชยรัตน์ เฉลิมรัตนโรจน์ ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ เป็นหัวหน้าโครงการและข้าพเจ้าเป็นผู้ร่วมวิจัย ขอแจ้งรายละเอียดเกี่ยวกับโครงการวิจัย และขอเชิญชวนท่านผู้สนใจเข้าร่วมโครงการฯ ดังนี้

ในโครงการนี้มีวัตถุประสงค์ที่จะรวบรวมผู้ป่วยที่มีเหงือกไบโอไทป์ที่แตกต่างกันมาให้แรงจัดฟันและดูผลที่เกิดขึ้นทั้งทางคลินิกและภาพถ่ายรังสี ซึ่งการตอบสนองที่เกิดขึ้นจะทำให้มีประโยชน์ในแง่การป้องกันความเสี่ยงที่อาจจะเกิดขึ้นจากการให้แรงจัดฟันในผู้ป่วยเหงือกไบโอไทป์ที่แตกต่างกัน ทั้งนี้ผู้ป่วยจะต้องให้ความร่วมมือในการดูแลรักษาความสะอาดอย่างดี

ผู้ป่วยที่ยินยอมเข้าร่วมโครงการจะได้รับการรักษาทางทันตกรรมจัดฟัน และต้องเสียค่าใช้จ่ายในการจัดฟันตามปกติ โดยมีค่าใช้จ่ายในการเก็บข้อมูล, พิมพ์ปาก, ถ่ายรูป, การจัดฟันแบบติดแน่น และ ภาพถ่ายรังสีในการรักษา ซึ่งเป็นค่ารักษาในอัตราปกติของคลินิกทันตกรรมจัดฟัน และ แผนกรังสี โรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ส่วนค่าใช้จ่ายสำหรับการถ่ายภาพโคนบีมคอมพิวเตดโทโมกราฟ ซึ่งเป็นการถ่ายภาพเอ็กซเรย์สาม มิติ และการเก็บตัวอย่างน้ำเหลืองเหงือกทางคณะผู้วิจัยจะรับผิดชอบค่าใช้จ่ายในส่วนนี้ให้ ถ้าท่านตัดสินใจเข้าร่วมในโครงการนี้จะมีขั้นตอนของการวิจัยที่เกี่ยวข้องกับท่าน คือ บันทึกข้อมูลเบื้องต้นก่อนการรักษาด้วยถ่ายภาพรังสี 3 มิติ CBCT และเก็บน้ำเหลืองเหงือก ติดเครื่องมือจัดฟันติดแน่น ปรับระดับและการเรียงตัวของฟัน ใส่เครื่องมือปราศจากแรงเพื่อคงสภาพตำแหน่งฟันหน้าบน 3 เดือน เก็บข้อมูลก่อนการดึงฟันหน้าบนด้วยถ่ายภาพรังสี 3 มิติ CBCT และเก็บน้ำเหลืองเหงือก ทำการดึงฟันหน้าบนจนกว่าจะชิดกับฟันกรามน้อยซี่ที่สอง ใส่เครื่องมือที่ปราศจากแรงเพื่อคงสภาพตำแหน่งฟันหน้าบน 3 เดือน เก็บข้อมูลหลังการดึงฟันหน้าบนด้วยถ่ายภาพรังสี 3 มิติ CBCT และเก็บน้ำเหลืองเหงือก ให้การรักษาความผิดปกติของการสบฟันในตำแหน่งอื่นตามแผนการรักษาจนกว่าการรักษาจะเสร็จ

ในช่วงการรักษาจัดฟันที่เป็นงานวิจัย ผู้เข้าร่วมวิจัยต้องมารับการรักษาจัดฟันเดือนละ 1 ครั้ง ตลอดระยะเวลาในงานวิจัยโดยใช้เวลาโดยประมาณรวม 2-2.5 ปี โดยมาปรับระดับฟันประมาณ 4-6 ครั้ง เปลี่ยนยางรัดลวดติดตามผลในช่วงคงตำแหน่งฟันหน้าบน 3 ครั้ง เคลื่อนฟันหน้าโดยประมาณ 4 ครั้ง เปลี่ยนยางรัดลวดติดตามผลในช่วงคงตำแหน่งฟันหน้าบน 3 ครั้ง รวมเป็นประมาณ 20-28 ครั้ง หลังจากนั้นจะให้การรักษาตามแผนการรักษาต่อเนื่องจนเสร็จซึ่งระยะเวลาในการรักษาขึ้นกับแผนการรักษาในผู้เข้าร่วมวิจัยแต่ละราย

ผู้เข้าร่วมวิจัยต้องเสียค่าใช้จ่ายในการจัดฟันตามปกติโดยมีค่าใช้จ่ายในการเก็บข้อมูล, พิมพ์ปาก, ถ่ายรูป, การจัดฟันแบบติดแน่น และ ภาพถ่ายรังสีในการรักษา ซึ่งเป็นค่ารักษาในอัตราปกติของคลินิกทันตกรรมจัดฟัน และ แผนกรังสี โรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ส่วนค่าใช้จ่ายสำหรับการถ่ายภาพ Cone beam computed tomogram (FOV 80x80 cm^2) ที่ขากรรไกรบน 3 ครั้ง จำนวน 9,000 บาททางคณะผู้วิจัยจะรับผิดชอบ ตามเกณฑ์ของคณะกรรมการแห่งชาติด้านการป้องกันและการวัดรังสี (National council on radiation protection and measurements) พบว่าปริมาณรังสีที่ได้รับปลอดภัยต่อผู้เข้าร่วมวิจัย ไม่มีความเสี่ยงที่จะเกิดมะเร็ง หรือการเปลี่ยนแปลงทางพันธุกรรม ในแง่ของการควบคุมความเสี่ยงที่อาจจะเกิดขึ้นเนื่องจากปริมาณแรงที่ใช้ในการเคลื่อนฟัน เป็นแรงที่ใช้ใน การเคลื่อนฟันปกติในคลินิกจึงมีความปลอดภัยในการเคลื่อนฟัน อย่างไรก็ดีผู้เข้าร่วมวิจัยทุกคนจะได้รับการตรวจ ประเมินอาการและอาการแสดงที่บ่งชี้ว่ามีความผิดปกติอันเกิดจากการเคลื่อนฟัน ในทุกๆครั้งที่มาพบทันตแพทย์ ผู้ให้การรักษา หากตรวจพบว่ามีความผิดปกติจะหยุดการรักษาในทันที

ถ้าท่านและบุตรหลานของท่านตัดสินใจเข้าร่วมโครงการวิจัยนี้จะมีขั้นตอนของการวิจัยที่จำเป็นต้องขอความร่วมมือ ของท่านและบุตรหลานตามที่กล่าวมาข้างต้น ซึ่งจะไม่ก่อให้เกิดความเจ็บปวดและอันตรายต่อเนื้อเยื่อมากไปกว่าการใช้ เครื่องมือจัดฟันติดแน่นชนิดอื่นแต่อย่างใด โดยผู้เข้าร่วมโครงการฯต้องมารับการรักษา ณ คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ ติดตามผลตามระยะเวลาที่กำหนดอย่างเคร่งครัด

ไม่ว่าท่านจะเข้าร่วมในโครงการวิจัยนี้หรือไม่ ท่านจะยังคงได้รับการรักษา ตามมาตรฐานการรักษาปกติ เช่นเดียวกับผู้ป่วยอื่นๆ และถ้าท่านต้องการที่จะถอนตัวออกจากการศึกษานี้เมื่อใดท่านก็สามารถกระทำได้อย่างอิสระ ถ้าท่านมีคำถามใดๆ ก่อนที่จะตัดสินใจเข้าร่วมโครงการนี้ โปรดซักถามจากคณะผู้วิจัยได้อย่างเต็มที่

การเก็บตัวอย่างน้ำเหลืองเหงือกเพื่อใช้ศึกษาวิจัยทางห้องปฏิบัติการ เมื่อเสร็จสิ้นโครงการวิจัยนี้แล้ว ชิ้นส่วนชีวภาพ ดังกล่าวที่นำมาใช้ในงานวิจัยนี้จะถูกทำลายตามมาตรฐาน

ของโรงพยาบาลทันตกรรม คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ โดยปกติแล้ว การจัดฟันจะไม่เกิดปัญหาใดๆ แต่ในกรณีที่ผู้ป่วยรักษาความสะอาดได้ไม่ดีอาจจะทำให้เกิดการทำลาย ของกระดูกรอบรากฟันมากขึ้นซึ่งหากเกิดอาการนี้ขึ้นจะหยุดการรักษาทางทันตกรรมจัดฟันทันทีและส่งตัวให้ทันตแพทย์เฉพาะทางรักษาโรคเหงือกเพื่อควบคุมโรคปริทันต์ก่อนพิจารณาให้การรักษาต่อ ไม่ว่าท่านจะเข้าร่วมในโครงการวิจัยนี้หรือไม่ท่านจะยังคงได้รับการรักษาตามมาตรฐานการรักษาเช่นเดียวกับผู้ป่วย คนอื่นๆ และถ้าท่านต้องการที่จะถอนตัวออกจากการศึกษานี้เมื่อใด ท่านก็สามารถกระทำได้อย่างอิสระ หากท่านมีคำถามใดๆ ก่อนที่จะตัดสินใจเข้าร่วมโครงการนี้ โปรดซักถามคณะผู้วิจัยได้อย่างเต็มที่

ขอขอบคุณเป็นอย่างสูง

รศ.ทพ.ดร.ไชยรัตน์ เฉลิมรัตนโรจน์
อาจารย์ที่ปรึกษาโครงการ/หัวหน้าโครงการ
ทพ.ปัณณ์พัฒน์ จันทร์มณี
ผู้ร่วมวิจัย

หมายเหตุ :- กรุณาอ่านข้อความให้เข้าใจก่อนเซ็นชื่อยินยอมเข้าร่วมโครงการ

แบบยินยอมเข้าร่วมการศึกษา

โครงการวิจัยเรื่อง "อิทธิพลของเหงือกไบโอไทด์ต่อการเคลื่อนฟันและเนื้อเยื่อปริทันต์ในการเคลื่อนฟันหน้า"

วันที่.....เดือน.....พ.ศ.....

ข้าพเจ้า.....อายุ.....ปี อาศัยอยู่บ้านเลขที่.....ถนน.....ตำบล.....อำเภอ.....จังหวัด.....ได้อ่าน/ได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตรายหรืออาการที่อาจเกิดขึ้น จากการวิจัยหรือจากยาที่ใช้ รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียดและมีความเข้าใจดีแล้ว

หากผู้เข้าร่วมวิจัยได้รับผลข้างเคียงจากการวิจัย ผู้เข้าร่วมวิจัยจะได้รับการปฏิบัติ/การชดเชย โดยจะ ทำการรักษาให้สำเร็จ แม้ว่าจะล่วงเลยเวลาการทำวิจัย โดยที่ไม่มีค่าใช้จ่ายเพิ่มเติม โดยผู้รับผิดชอบ โครงการวิจัยนี้คือ ทพ.ปัณณ์พัฒน์ จันทร์มณี สถานที่ติดต่อ ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ เบอร์โทรศัพท์ 084-519-4559 โดยมี รศ.ดร.ไชยรัตน์ เฉลิมรัตนโรจน์ ภาควิชาทันตกรรมป้องกัน คณะทันตแพทยศาสตร์ มหาวิทยาลัยสงขลานครินทร์ เป็นอาจารย์ที่ปรึกษาโครงการ เบอร์โทรศัพท์ 096-887-9851 หรือเมื่อมีปัญหาใดๆ เกิดขึ้นเนื่องจากการทำวิจัยในเรื่องนี้ของข้าพเจ้า ผู้เข้าร่วมวิจัยสามารถร้องเรียนไปที่ คณะกรรมการจริยธรรมในการวิจัย หน่วยส่งเสริมและพัฒนางานวิจัย คณะทันตแพทยศาสตร์มหาวิทยาลัยสงขลานครินทร์ อ.หาดใหญ่ จ.สงขลา 90112 โทรศัพท์ 074-287-504

หากผู้วิจัยมีข้อมูลเพิ่มเติมทั้งด้านประโยชน์และโทษที่เกี่ยวข้องกับการวิจัยนี้ ผู้วิจัยจะแจ้งให้ผู้เข้าร่วมวิจัยทราบ อย่างรวดเร็ว โดยไม่ปิดบัง

ผู้เข้าร่วมวิจัยมีสิทธิที่จะของดการเข้าร่วมโครงการวิจัยโดยมิต้องแจ้งให้ทราบล่วงหน้าโดยการงดการเข้าร่วมการ วิจัยนี้ จะไม่มีผลกระทบต่อการได้รับบริการหรือการรักษาที่ข้าพเจ้าจะได้รับแต่ประการใด

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะที่เกี่ยวกับตัวผู้เข้าร่วมวิจัยเป็นความลับ จะไม่เปิดเผยข้อมูลหรือผลการวิจัย ของผู้อยู่ภายใต้การดูแลของข้าพเจ้าเป็นรายบุคคลต่อ

สาธารณชน จะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย หรือ การเปิดเผยข้อมูลต่อผู้มีหน้าที่ที่เกี่ยวข้องกับการสนับสนุนและกำกับดูแลการวิจัย

ข้าพเจ้าได้อ่าน/ได้รับการอธิบายข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการจึงได้ลงนามในใบยินยอม นี้ด้วยความเต็มใจโดยนักวิจัยได้ให้สำเนาแบบยินยอมที่ลงนามแล้วกับข้าพเจ้าเพื่อเก็บไว้เป็น หลักฐาน จำนวน 1 ชุด

ลงชื่อ.....ผู้ยินยอม

ลงชื่อ.....หัวหน้าโครงการ

ลงชื่อ.....พยาน

ลงชื่อ.....พยาน

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List of Publication and Proceeding

Chanmanee P, Charoemratrote C. Maxillary bone characteristics between thick and thin gingival biotypes with dentoalveolar protrusion. ***J World Fed Orthod*** 2019. (In Press)

Chanmanee P, Leethanakul C, Charoemratrote C. Gingival biotypes and soft tissue characteristics surrounding upper anterior protrusion.The 97th International Association for Dental Research Conference; 2019. June 19-22; Vancouver, Canada; 2019