ปัจจัยที่มีผลต่อการเปลี่ยนแปลงของรูปหน้าด้านข้างภายหลังการจัดฟันในผู้ป่วยที่มีการสบฟันผิดปกติประเภท 2 แบบที่ 1

นางสาวสุหัชชา เมธีวรกุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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FACTORS INFLUENCING SOFT TISSUE PROFILE CHANGES
FOLLOWING ORTHODONTIC TREATMENT
IN PATIENTS WITH CLASS II DIVISION 1 MALOCCLUSION

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Orthodontics
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Thesis Title	FACTORS INFLUENCING SOFT TISSUE PROFILE CHANGES FOLLOWING ORTHODONTIC TREATMENT IN PATIENTS WITH CLASS II DIVISION 1 MALOCCLUSION
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สุหัชชา เมธีวรกุล : ปัจจัยที่มีผลต่อการเปลี่ยนแปลงของรูปหน้าด้านข้างภายหลังการจัดฟัน ในผู้ป่วยที่มีการสบฟันผิดปกติประเภท 2 แบบที่ 1 (FACTORS INFLUENCING SOFT TISSUE PROFILE CHANGES FOLLOWING ORTHODONTIC TREATMENT IN PATIENTS WITH CLASS II DIVISION 1 MALOCCLUSION) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ศ. ทญ. สมรตรี วิถีพร{, 98 หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินการเปลี่ยนแปลงของรูปหน้าด้านข้างในผู้ป่วยไทยที่มีการสบฟันผิดปกติประเภท 2 แบบที่ 1 ภายหลังการจัดฟัน และศึกษาปัจจัยที่สัมพันธ์กับการเปลี่ยนแปลงของรูปหน้าด้านข้าง กลุ่มตัวอย่างประกอบด้วยผู้ป่วยไทย 104 คน (ชาย 50 คน หญิง 54 คน) อายุเฉลี่ย 11.62±1.42 ปี ที่มีการสบฟันผิดปกติประเภท 2 แบบที่ 1 ซึ่งได้รับการจัดฟันด้วยวิธีการที่แตกต่างกัน กลุ่มที่ 1 ผู้ป่วย 30 คน (ชาย 15 คน หญิง 15 คน) อายุเฉลี่ย 10.93±1.34 ปี ได้รับการรักษาด้วยเซอร์วิคัลเฮดเกียร์ กลุ่มที่ 2 ผู้ป่วย 30 คน (ชาย 15 คน หญิง 15 คน) อายุเฉลี่ย 12.13±1.63 ปี ได้รับการรักษาด้วยการดึงยางระหว่างขากรรไกรประเภท 2 กลุ่มที่ 3 ผู้ป่วย 44 คน (ชาย 20 คน หญิง 24 คน) อายุเฉลี่ย 11.73±1.15 ปี ได้รับการจัดฟันร่วมกับการถอนฟันกรามน้อยซี่ที่หนึ่ง 4 ซี่ การเปลี่ยนแปลงของรูปหน้าด้านข้างประเมินจากภาพรังสีเซฟฟาโลเมทริกด้านข้างก่อนและหลังการรักษา ในลักษณะโคออร์ดิเนตสัมพันธ์กับแกน x และแกน y การเปลี่ยนแปลงของรูปหน้าด้านข้างอย่างมีนัยสำคัญภายในกลุ่มตัวอย่างและระหว่างกลุ่มตัวอย่างทดสอบโดยสถิติทดสอบทีแบบจับคู่ (paired t-test) และการวิเคราะห์ความแปรปรวนทางเดียว (One-way ANOVA) ที่ระดับนัยสำคัญ 0.05 ตามลำดับ ความสัมพันธ์ระหว่างการเปลี่ยนแปลงของรูปหน้าด้านข้างอย่างมีนัยสำคัญทางสถิติกับตัวแปรอิสระ ได้แก่ อายุ เพศ วิธีการรักษา โครงสร้างใบหน้า ตำแหน่งฟัน และลักษณะเนื้อเยื่ออ่อนก่อนการรักษา ประเมินด้วยสถิติวิเคราะห์การถดถอยพหุคูณแบบขั้นตอน (Stepwise multiple regression analysis) ที่ระดับนัยสำคัญ 0.05

ผลการศึกษาพบว่า ภายหลังการรักษา กลุ่มที่ได้รับการรักษาด้วยเซอร์วิคัลเฮดเกียร์ มีริมฝีปากบนเคลื่อนลงล่างและถอยหลัง ในขณะที่ริมฝีปากล่างเคลื่อนลงล่าง และลูกคางมีการเคลื่อนลงล่างมาทางด้านหน้า กลุ่มที่ใช้ยางดึงระหว่างขากรรไกรประเภท 2 มีริมฝีปากบนเคลื่อนลงล่าง ริมฝีปากล่างเคลื่อนลงล่างมาทางด้านหน้า และลูกคางเคลื่อนลงล่าง กลุ่มที่ถอนฟันกรามน้อยซี่ที่หนึ่ง 4 ซี่ มีริมฝีปากบนและล่างเคลื่อนลงล่างและถอยหลัง และลูกคางเคลื่อนลงล่างมาทางด้านหน้า การวิเคราะห์การถดถอยพหุคูณพบว่า นอกจากวิธีการรักษาที่แตกต่างกัน ยังมีปัจจัยอื่น ได้แก่ อายุ เพศ ลักษณะโครงสร้างใบหน้า ตำแหน่งฟัน และลักษณะเนื้อเยื่ออ่อนก่อนการรักษา ที่มีความสัมพันธ์กับการเปลี่ยนแปลงรูปหน้าด้านข้าง โดยอำนาจในการพยากรณ์ของปัจจัยเหล่านี้ต่อการเปลี่ยนแปลงของรูปหน้าด้านข้างคิดเป็นร้อยละ 9.9 - 40.3 สรุปว่า การจัดฟันด้วยวิธีที่แตกต่างกันร่วมกับการเจริญเติบโตของใบหน้า ทำให้เกิดการเปลี่ยนแปลงของรูปหน้าด้านข้างที่แตกต่างกันในผู้ป่วยที่มีการสบฟันผิดปกติประเภท 2 แบบที่ 1 สมการทำนายการเปลี่ยนแปลงของรูปหน้าด้านข้างภายหลังการรักษาจากการศึกษานี้ ควรเป็นประโยชน์ในการเลือกวิธีการรักษาที่เหมาะสมในผู้ป่วยแต่ละราย

ภาควิชา	ทันตกรรมจัดฟัน	ลายมือชื่อนิสิต	....
สาขาวิชา	ทันตกรรมจัดฟัน	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2557		

5675824132 : MAJOR ORTHODONTICS
KEYWORDS: CERVICAL HEADGEAR / CLASS II DIVISION 1 MALOCCLUSION / CLASS II TRACTION / EXTRACTION FOUR PREMOLARS / FACTORS / ORTHODONTIC TREATMENT / SOFT TISSUE PROFILE CHANGES

SUHATCHA MAETEVORAKUL: FACTORS INFLUENCING SOFT TISSUE PROFILE CHANGES FOLLOWING ORTHODONTIC TREATMENT IN PATIENTS WITH CLASS II DIVISION 1 MALOCCLUSION. ADVISOR: PROF. SMORNTREE VITEPORN{, 98 pp.

The purposes of this study were to evaluate soft tissue profile changes of Thai patients with Class II Division 1 malocclusion following orthodontic treatment and study the factors influencing the soft tissue profile changes. The subjects comprised 104 Thai patients (50 boys, 54 girls) mean age 11.62±1.42 years old who presented Class II Division 1 malocclusion and were treated with different orthodontic modalities. Group I: 30 patients (15 boys, 15 girls) mean age 10.93±1.34 years old were treated with cervical headgear. Group II: 30 patients (15 boys, 15 girls) mean age 12.13±1.63 years old were treated with Class II traction. Group III: 44 patients (20 boys, 24 girls) mean age 11.73±1.15 years old were treated as an extraction of the four first premolars case. The profile changes were scrutinized from the lateral cephalograms before and after treatments by means of the x-y coordinate system. Significant differences of the profile changes within and between treatment groups were tested by paired-t test and one-way ANOVA at 0.05 significant level, respectively. The correlations between significantly soft tissue changes and independent variables comprising age, sex, treatment modality, pretreatment skeletal, dental and soft tissue morphology were evaluated by stepwise multiple regression analysis at 0.05 significant level.

The result indicated that after treatment the headgear group presented downward and backward movements of the upper lip whereas the lower lip only moved downward and the chin moved downward and forward. In the Class II traction group, the upper lip moved downward, the lower lip moved downward and forward and the chin moved downward. In the four first premolar extraction group, the upper and lower lips moved downward and backward whereas the chin moved downward and forward. The multiple regression analysis indicated that not only different treatment modalities but also other factors comprising age, sex, pretreatment skeletal, dental and soft tissue morphology seemed to be related to the profile changes. The predictive power of these variables on the soft tissue profile changes ranged from 9.9% to 40.3%. In conclusion different treatment modalities and facial growth produce different soft tissue profile responses in Class II Division 1 patients. The prediction equation of profile change after treatment obtained from this study should be beneficial for selection of the treatment modalities for the individual patient.

Department:	Orthodontics	Student's Signature	....
Field of Study:	Orthodontics	Advisor's Signature	....
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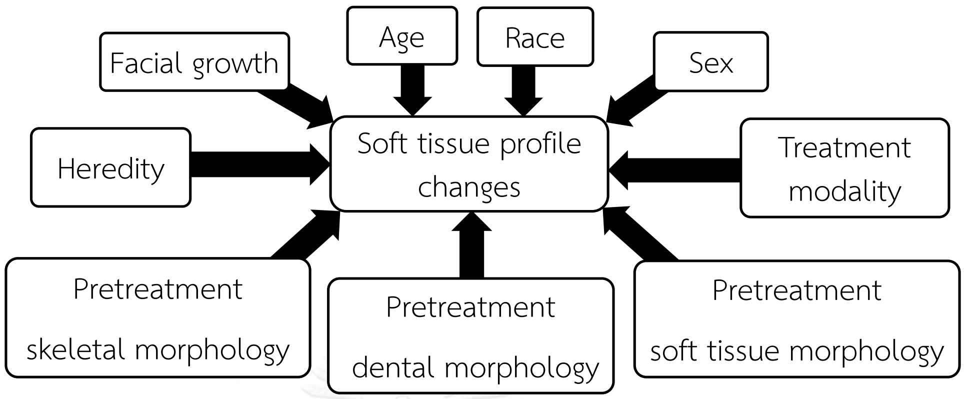
CHAPTER 1
INTRODUCTION

Background and Rationale

Facial esthetics is an important goal of treatment for contemporary orthodontics and it is one of the patient main reasons for seeking orthodontic treatment. The soft tissue coverage plays an important role in facial esthetics and the orthodontist is frequently questioned about facial changes after treatment. Thus, it is recognized by most orthodontists that success of orthodontic treatment is closely related to improvement of the soft tissue profile.

Class II Division 1 malocclusion is characterized by upper anterior teeth protrusion resulting in upper lip protrusion and convex facial profile, which are considered esthetically unfavorable (1). Although several studies (1-14) have showed soft tissue profile changes after orthodontic treatment in Class II Division 1 patients, a few studies (15-19) described factors influencing the soft tissue changes. Moreover, most of the studies are based on the Caucasian groups. Therefore, the objectives of this study are to study the soft tissue profile changes following orthodontic treatment in Thai patients with Class II Division 1 malocclusion and investigate the factors that relate to the soft tissue changes. Conclusions of the study should enhance prediction of the soft tissue profile changes following orthodontic treatment and suggest the proper treatment modalities for the individual patient.

Conceptual Framework



Research Questions

1. Are there any changes of the soft tissue profile of Class II Division 1 patients after treatment?

2. Which factors: age, sex, treatment modality, pretreatment dento-skeleton and soft tissue morphology play an important role on the soft tissue profile changes of Class II Division 1 patients?

Research Objectives

1. To evaluate soft tissue profile changes of Thai patients with Class II Division 1 malocclusion following different orthodontic treatment modalities.

2. To study the correlations between age, sex, treatment modality, patient morphology and soft tissue profile changes.

Benefits

1. This study will prevail the factors that relate to the soft tissue changes following orthodontic treatment in Class II Division 1 Thai patients.

2. This study will enhance prediction of the soft tissue profile changes following orthodontic treatment and suggest proper treatment modalities for the individual patient.

Research Hypothesis

1. H_0: Patients with Class II Division 1 malocclusion present non-significantly soft tissue profile changes after orthodontic treatment.

   H_a: Patients with Class II Division 1 malocclusion present significantly soft tissue profile changes after orthodontic treatment.

2. H_0: There are no correlations between soft tissue profile changes with the factors comprising age, sex, treatment modality, pretreatment dento-skeleton and soft tissue morphology.

   H_a: There are significant correlations between soft tissue profile changes with some factors such as age, sex, treatment modality, pretreatment dento-skeleton and soft tissue morphology.

CHAPTER 2
LITERATURE REVIEW

Class II Division 1 malocclusion occurs when the mesiobuccal cusp of the upper first molar is anterior to the mesiobuccal groove of the lower first molar and the upper anterior teeth protrusion (20). Most of the patients have narrow intercanine and intermolar widths with excessive overjet (21). Deep bite or open bite can be found. This malooclusion is caused by maxillary protrusion, upper anterior teeth protrusion, mandibular retrusion, mandibular deficiency, lower anterior teeth retrusion, or multifactorial factors (22).

Previous studies have described factors influencing soft tissue profile changes after orthodontic treatment in Class II Division 1 malocclusion for instance: patient morphology comprising skeleton, dental and soft tissue morphology, sex (23), lip morphology (16, 24), treatment modalities (10), extraction or non-extraction (12), lip tonus (16), lip thickness and length, facial growth pattern, race (13, 25) and individual difference (11, 14, 26).

Facial growth, age and sexual dimorphism

Hoffelder et al (27) evaluated soft tissue behavior of nose, lips, and chin during the growth process in Canadian subjects of both sexes with skeletal Class II malocclusions from 6 to 16 years of age. The result indicated that the nose showed the greatest increases in thickness and length in both sexes. The average increase in height was 8.65 mm and the boy had higher value than the girl. The average increase in length was 13.71 mm with no sexual dimorphism. The average upper lip thickness increase was 0.67 mm with higher values for the boy at 6, 9, 14, and 16 years. Thickness of the base had a mean increase of 4.85 mm with higher value for the boy only at 16 years of age. The length had a mean increase of 2.6 mm with no sexual dimorphism. The lower lip had a mean increase in thickness of 3.14 mm with sexual dimorphism at 9, 14, and 16 years, and was higher in the boy. Thickness of the base and length of the lower lip had mean increases of 3.42 and 3.46 mm, respectively, with no sexual dimorphism. The chin had mean increases of 2.38 mm in thickness and 1.02 mm in length with no sexual dimorphism. The effect of extraction therapy on the facial profile is greater for the girl than for the boy.

Treatment modality

The treatment of Class II Division 1 malocclusion comprises growth modification in growing patients by orthopedic appliances such as headgear or functional appliance, orthodontic treatment with or without extraction to camouflage in patients with mild to moderate skeletal discrepancies and orthognathic surgery in adult patients with severe skeletal discrepancies (28).

Difference of treatment modalities is one of the factors influencing the profile change. Kirjavainen et al (1) studied the effect of cervical headgear in the first phase of treatment of Class II Division 1 malocclusion when compared to the control and concluded that the cervical headgear restricted the forward growth of the A-point, and decreased the SNA angle 1.4 ° ±1.2 ° per year. However at the end of treatment, the SNA angles of the two groups were similar. Decreased maxillary prognathism was associated with decreased facial convexity. The upper lip protrusion was decreased while the nasolabial angle was increased. The treatment significantly decreased the gap between the lips in their relaxed position but did not significantly affect lip thickness and depth of chin recess. Nose depth was similar between groups and was unaffected by the treatment.

Battagel (5) compared the hard and soft tissue changes following the non-extraction treatment by Fränkel appliances, standard edgewise technique with extra-oral traction and extraction in 62 children with moderately severe Class II Division 1 malocclusion. In the edgewise group, the upper lip and upper incisor retractions were greater with a positive correlation. There was an inverse correlation between lip thickness and the upper lip retraction. In the Fränkel group, there was increasing of the upper lip length.

Looi et al (7) compared the treatment effects between the four first premolar extraction with Begg technique as well as non-extraction case with activator. The upper incisors were retracted more in the Begg group than in the activator group, but there was only a slight difference between groups in the upper lip response. There was more retraction of the lower incisors in the Begg group that resulted in a significantly greater lower lip retraction.

Siqueira et al (6) compared changes after orthodontic treatment between the cervical headgear and the mandibular protraction appliance followed by fixed appliances. Both appliances produced similar increases in the nasolabial angle due to palatal tipping and retrusion of the maxillary incisors. The cervical headgear produced greater restriction of anterior displacement of the maxilla and distalization of the maxillary molars whereas the mandibular protraction appliance produced greater mandibular molar mesialization and labial displacement of the mandibular incisors that resulted in greater lower lip protrusion.

Regarding extraction or non-extraction as part of the treatment, Janson et al (3) found that posttreatment changes of the soft tissue profile following Class II Division 1 malocclusion treatment with or without extraction of the maxillary premolars were similar. Furthermore, it was demonstrated that treatment of complete Class II malocclusion with extraction of the two maxillary premolars was more effective on greater occlusal changes in a shorter time. This corresponded with the studies of Zierhut et al (29) and Stephens et al (30) who found that at the end of treatment and long term follow up, the soft tissue profiles of the two groups were similar.

Bishara et al (4) compared the changes in subjects with Class II Division 1 malocclusions treated with or without the extraction of the four first premolars. After treatment the upper and lower lips were more retrusive in the extraction group but more protrusive in the non-extraction group. The extraction group tended to have straighter face and slightly more upright incisor. This agreed with the studies of Paquette et al (31) and Bowman et al (32).

Bishara et al (33) compared the pretreatment dento-facial characteristics of Class II, Division 1 patients treated with either extraction or non-extraction. The result indicated that the extraction group had significantly larger tooth size - arch length discrepancies in the both arches. In addition, the upper and lower lips of male subjects, and the lower lip of female subjects were significantly more protrusive. These subjects were eventually treated with the four first premolar extraction. Therefore, lip protrusion is one of the important parameters for decision of extraction.

Pretreatment skeletal and dental morphology

Kasai (17) investigated soft tissue adaptability to hard tissue change in Class II Division 1 and Class I bimaxillary protrusion groups who were susceptible for four premolar extraction. In the static state, the vertical dimension of lower facial height and the lower incisor position were associated with the thickness of the upper lip vermilion and the soft tissue B. The horizontal relations between the upper and lower jaw positions were associated with the thickness of the upper lip and soft tissue chin. In the dynamic state, the results indicated that changes of the stomion and the lower lip could be predicted and strongly reflected the changes of the hard tissue. In contrast, change of the upper lip showed a weaker correlation with the hard tissue change. Chin form was influenced by hard tissue structures such as the ANB angle and lower facial height rather than that of incisor retraction.

Mergen et al (34) evaluated pre- and post-treatment soft tissue profiles of growing Class II Division 1 patients treated with fixed orthodontic appliances and headgear. The sample was grouped according to the severity of their initial mandibular retrognathism and vertical skeletal pattern. The result indicated that there was no perceived difference in the final profiles between groups and significantly greater improvement of facial profile was detected from those with greater initial skeletal discrepancies. They concluded that treatment of Class II Division 1 malocclusion with fixed appliances at appropriate timing can improve facial profile significantly.

Talass et al (19) studied the soft tissue profile changes caused by retraction of the maxillary incisors in growing and adult females. The data suggested that growth was associated with only minimal changes of the soft tissue profile in a period not exceeding 36 months. There were three clinically significant soft tissue changes in response to orthodontic treatment. First, the upper lip retraction that related to the maxillary incisal edge retraction, subnasale before treatment, thickness of the upper lip before treatment and vertical nasal growth during the treatment. Second, the increase of nasolabial angle that related to the increase of hard tissue lower facial height due to orthodontic treatment, subnasale before treatment, amount of the maxillary incisal edge retraction, thickness of the upper lip before treatment and overjet before treatment. Third, the increase of the lower lip length that related to lower lip length before treatment, amount of the maxillary incisor crowns covered by the relaxed lower lip before treatment and increase in the hard tissue lower facial height due to orthodontic treatment. Additionally, the lower lip response to orthodontic tooth movement was more predictable than that of the upper lip because of the complex anatomy and/or dynamics of the upper lip.

Rains and Nanda (15) determined the response of the upper and lower lips to the maxillary and mandibular incisor movements in Caucasian females aged 15 - 23. A stepwise multiple regression analysis revealed a complex interaction between dentition, bony structures, and soft tissues of the perioral area. The lower lip response to upper incisor movement was more variable than the upper lip. The upper lip at labrale superius was more variable with retraction of the upper incisors. Change of sulcus superius had a more positive correlation with retraction of labrale superius and labrale inferius than with dental movement. The upper lip response was related to both upper and lower incisor movements, mandibular rotation, and the lower lip. The upper incisor position had a moderately high correlation for the alteration of labrale superius. The lower incisor movement did not correlate with changes of the lips.

Pretreatment soft tissue morphology

Oliver (16) investigated the influence of the upper lip thickness and strain on the relation between dental and soft tissue changes in orthodontically treated patients. He found that the patients with thin lips or a high lip strain displayed a significant correlation between incisor retraction and lip retraction, whereas patients with thick lips or low lip strain displayed no correlation. The soft tissue changes were significantly different between sexes, there were significantly greater in male. Uprighting of the maxillary incisors was significantly greater in female.

Tadic and Woods (2) evaluated the correlation between the upper incisal and lip changes in Class II treatment with fixed appliance treatment and two upper premolar extraction. The average increase of the nasolabial angle was 3.6 degrees and was correlated with a decrease in the upper lip thickness and curve depth. Change in the upper lip curve depth was correlated with change in the upper lip thickness, nasolabial angle and mandibular length changes. Change in the lower lip curve depth was correlated with changes in the lower lip thickness at the vermillion level and soft tissue menton. They concluded that the lip changes were most likely to be related to their preexisting morphology.

The above studies prevailed the soft tissue profile changes following orthodontic treatment in Class II Division 1 patients. Nevertheless, the factors influencing the soft tissue profile changes studied by means of correlations among age, sex, treatment modalities, initial patient morphology and soft tissue changes were still unclear. The present study aims to identify these aforementioned factors so that validity of prediction of the soft tissue profile changes following orthodontic treatment in Class II Division 1 malocclusion can be increased.

CHAPTER 3
RESEARCH METHODOLOGY

Study Design

A retrospective analytical study was undertaken from pretreatment and posttreatment lateral cephalograms of a group of Class II Division 1 Thai patients.

Population

Class II Division 1 malocclusion Thai patients

Sample Size Calculation

The sample size was calculated from the equation for testing mean of the two independent populations.

$$\text{Sample size (n)} = \frac{(\sigma_1^2 + \sigma_2^2)(z_{\alpha/2} + z_{\beta})^2}{(\mu_1 - \mu_2)^2}$$

α: significant level 0.05

1-β: power of test = 80%

From the previous study (3), the changes of nasolabial angle of the non-extraction group and the extraction group were used for the sample size calculation: μ_1 = 3.39, σ_1 = 3.66, μ_2 = 5.4, and σ_2 = 3.63. The data was calculated and the sample size in each independent group was 28.93 persons.

The Subjects

The subjects comprised 104 Class II Division 1 malocclusion Thai patients who received orthodontic treatment from a private clinic by the same orthodontist.

Inclusion Criteria

1. Patients presented Class II Division 1 malocclusion with molar Class II relationship and overjet larger than 5 mm.

2. No history of trauma that can affect facial growth and development.

3. None of the patients had congenital syndromes or defects, obvious facial asymmetry, extreme vertical disproportion and congenital missing teeth.

4. Each had complete orthodontic record indicating patient history, age, sex, type of treatment, lateral cephalograms taken before treatment (T1) and after treatment (T2) from the same radiographic machine.

5. Each was treated by one of the three treatment modalities regarding the following treatment protocols:

5.1 Group I: Orthopedic treatment with cervical headgear followed by fixed appliance edgewise technique. Each patient was in the mixed dentition with unerupted permanent maxillary second molars and well aligned lower teeth or mild crowding that could be corrected during leveling phase. Skeletal analysis indicating skeletal Class II normal or deep bite malocclusion due to maxillary protrusion with severe upper incisor protrusion. Facial profile should be improved when mandible moved forward. The patient with bimaxillary protrusion when the mandible moved forward was excluded. The facial development evaluated from the hand wrist film had not passed the peak of pubertal growth. The patients were recommended to wear the cervical headgear that delivered 500 grams per side via the permanent maxillary first molars for 12-14 hours per day for distalization of the maxillary first molar so that Class I molar relation could be acheived and there was adequate space for correction of the upper incisor protrusion without extraction. The fixed appliance edgewise technique was prescribed in the second stage to obtain Class I molar and canine relations with acceptable overbite and overjet.

5.2 Group II: Fixed appliance edgewise technique, non-extraction with Class II traction. Each patient was in the permanent dentition with fully eruption of the maxillary second molar and remarkable upper arch constriction and narrow intercanine width that inhibit forward movement of the mandible. Moreover, each patient had minor to moderate crowding that could be corrected simultaneously during arch expansion and leveling. The clinical examination indicating improvement of the soft tissue profile when the mandible moved forward to obtain Class I molar and canine relations. The fixed appliance edgewise technique was used for upper arch expansion and Class II traction force 4.5-6.5 ounces per side was prescribed for full time traction after obtaining arch compatibility.

5.2 Group III: Fixed appliance edgewise technique with extraction of the first four premolars. Each patient was in permanent dentition and cephalometric analysis indicated severe protrusion of the upper and lower incisors with less skeletal malocclusion indicating mainly dentoalveolar problem.

6. At the end of treatment, all cases had Class I molar and canine relations with overjet 2-3 mm and overbite that was not exceed 1/3 of the lower incisor crown height (35).

Variables and Measurement

The independent and dependent variables were presented in Table 1.

Table 1 The independent and dependent variables

Independent Variables	Dependent Variables
Age Sex Treatment modality - Orthopedic treatment - Headgear - Orthodontic treatment - Class II traction - Extraction Pretreatment skeletal morphology - SNA (degree) - SNB (degree) - ANB (degree) - SN-GoGn (degree) Pretreatment dental morphology - U1-NA (degree) - U1-NA (mm) - L1-NB (degree) - L1-NB (mm) Pretreatment soft tissue morphology - Nasolabial angle: NLA (degree) - Labiomental angle: LMA (degree) - Upper lip length (mm) - Lower lip length (mm) - Upper lip thickness (mm) - Lower lip thickness (mm)	Soft tissue profile change (mm) - Soft tissue nasion (N') - Pronasale (Pr) - Columella (Cm) - Subnasale (Sn) - Superior labial sulcus (Sls) - Labrale superius (Ls) - Stomion superius (Ss) - Stomion inferius (Si) - Labrale inferius (Li) - Inferior labial sulcus (Ils) - Soft tissue pogonion (Pg') - Soft tissue menton (Me')

Cephalometric Analysis

1. Both the pretreatment and posttreatment lateral cephalograms (T1 and T2) were traced on acetate papers and the reference points representing hard and soft tissue structures were located by the same researcher with black and red pencils, respectively (Figure 1). The definitions of cephalometric landmarks were described in Table 2.

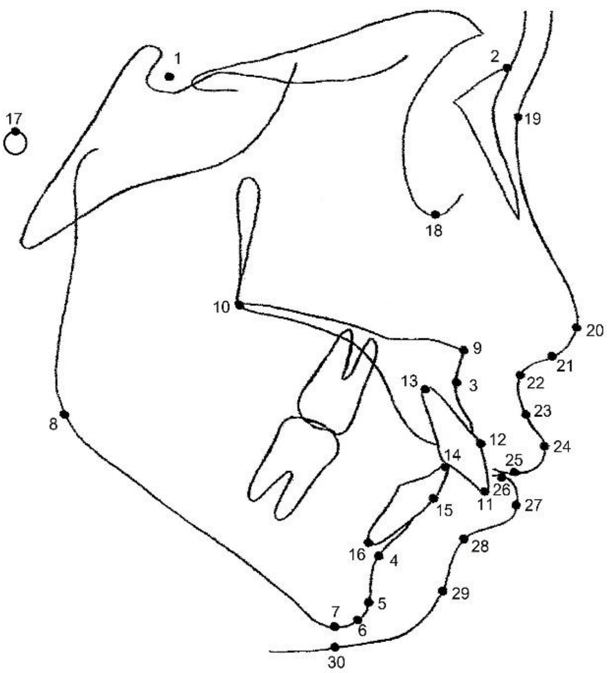


Figure 1 Cephalometric landmarks

1. S (Sella turcica), 2. N (Nasion), 3. A (Subspinale), 4. B (Supramentale), 5. Pg (Pogonion), 6. Gn (Gnathion), 7. Me (Menton), 8. Go (Gonion), 9. ANS (Anterior nasal spine), 10. PNS (Posterior nasal spine), 11. Maxillary central incisor edge, 12. The most anterior labial point of the maxillary central incisor, 13. Maxillary central incisor apex, 14. Mandibular central incisor edge, 15. The most anterior labial point of the mandibular central incisor, 16. Mandibular central incisor apex, 17. Po (Porion), 18. Or (Orbitale), 19. N’ (Soft tissue nasion), 20. Pr (Pronasale), 21. Cm (Columella), 22. Sn (Subnasale), 23. Sls (Superior labial sulcus), 24. Ls (Labrale superius), 25. Ss (Stomion superius), 26. Si (Stomion inferius), 27. Li (Labrale inferius), 28. Ils (Inferior labial sulcus), 29. Pg' (Soft tissue pogonion), 30. Me’ (Soft tissue menton)

Table 2 Definitions of cephalometric landmarks

Measure	Definition
Hard tissue landmarks	
S, Sella turcica	The midpoint of the cavity of sella turcica
N, Nasion	The frontal margin of the fronto-nasal suture
A, Subspinale	The innermost point on the contour of the premaxilla between anterior nasal spine and the incisor tooth
B, Supramentale	The innermost point on the contour of the mandible between the incisor tooth and the bony chin
Pg, Pogonion	The most anterior point on the contour of the chin
Gn, Gnathion	The most inferior and anterior point on the chin
Me, Menton	The most inferior point on the mandibular symphysis
Go, Gonion	The midpoint of the contour connecting the ramus and body of the mandible
ANS, Anterior nasal spine	The most anterior point on the maxilla at the nasal base
PNS, Posterior nasal spine	The tip of the posterior nasal spine of the palatine bone
Po, Porion	Superior point of external auditory meatus
Or, Orbitale	The lowest point on the inferior margin of the orbit

Table 2 Definitions of cephalometric landmarks (Cont.)

Measure	Definition
<u>Soft tissue landmarks</u>	
N’, Soft tissue nasion	The point of deepest concavity of the soft tissue contour of the root of the nose
Pr, Pronasale	The most prominent or anterior point of the nose tip
Cm, Columella	The most anterior point of the columella of the nose
Sn, Subnasale	The point at which the lower border of the nose meets the outer contour of the upper lip
Sls, Superior labial sulcus	The point of the greatest concavity between labrale superior and subnasale
Ls, Labrale superius	The point located at the maximum convexity of the vermilion border most prominent in the midsagittal plane
Ss, Stomion superius	The lowermost point on the vermilion of the upper lip
Si, Stomion inferius	The uppermost point on the vermilion of the lower lip
Li, Labrale inferius	The most prominent point on the vermilion border of the lower lip in the midsagittal plane
Ils, Inferior labial sulcus	The point of the greatest concavity between labrale inferior and soft tissue pogonion
Pg', Soft tissue pogonion	The most anterior point on soft tissue chin
Me’, Soft tissue menton	The most inferior point on soft tissue chin

2. Determined reference planes (36) for evaluating the soft tissue changes on the T1 film (Figure 2).

x-axis: Frankfort horizontal plane of the T1 film

y-axis: The perpendicular line to the x-axis at the nasion point of the T1 film

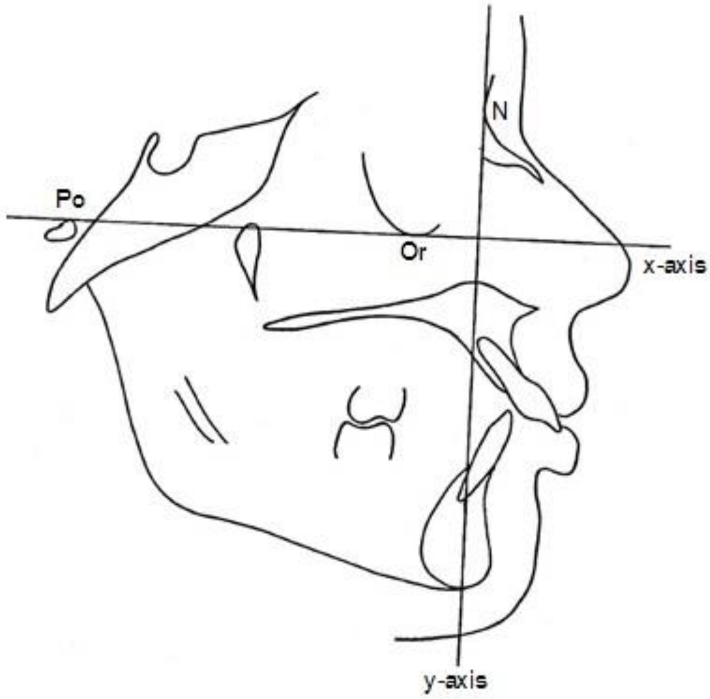


Figure 2 Reference points and reference planes of the T1 film utilized for evaluation of the soft tissue profile changes

3. Soft tissue profile changes were evaluated by superimposition of the T2 film to T1 film on the stable structures of the anterior cranial base as described by Björk and Skieller (37). (Figure 3)

1. The contour of the anterior wall of sella turcica
2. The mean intersection point of the lower contours of the anterior clinoid processes and the contour of the anterior wall of the sella
3. The anterior contour of the median cranial fossa
4. The contour of the cribriform plate
5. The details in the trabecular system in the anterior cranial base

6. The contours of the bilateral frontoethmoidal crests

7. The cerebral surfaces of the orbital roofs

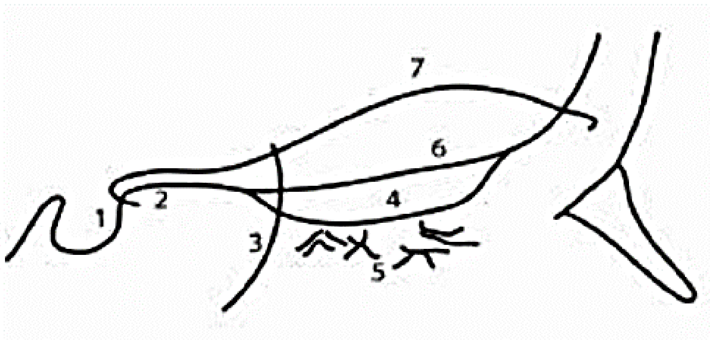


Figure 3 Stable structures of the anterior cranial base utilized for superimposition

4. Transferred the reference planes from the T1 film to the T2 film.

5. Changes of the soft tissue profile were expressed as changes in the x- and y- coordinates of each reference point as follows: (Figure 4)

1. Soft tissue nasion (N’)
2. Pronasale (Pr)
3. Columella (Cm)
4. Subnasale (Sn)
5. Superior labial sulcus (Sls)
6. Labrale superius (Ls)
7. Stomion superius (Ss)
8. Stomion inferius (Si)
9. Labrale inferius (Li)
10. Inferior labial sulcus (Ils)
11. Soft tissue pogonion (Pg’)
12. Soft tissue menton (Me’)

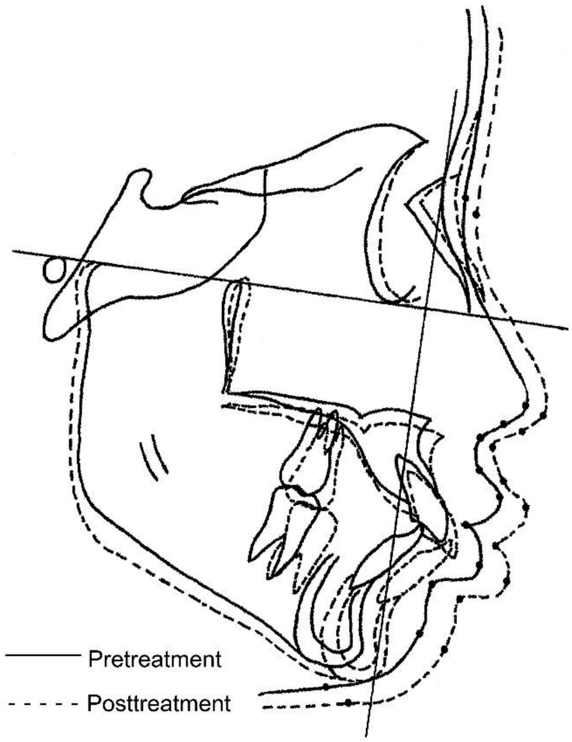


Figure 4 Changes of the soft tissue profile

6. Dento-skeleton and soft tissue morphology before and after treatments were also evaluated by linear and angular measurements to enable comparison with the available Thai norm (38). (Figure 5)

Skeletal morphology

1. SNA (degree)
2. SNB (degree)
3. ANB (degree)
4. SN-GoGn (degree)

Dental morphology

1. U1-NA (degree)
2. U1-NA (mm)
3. L1-NB (degree)
4. L1-NB (mm)

Soft tissue morphology

1. Nasolabial angle: NLA (degree)
2. Labiomental angle: LMA (degree)
3. Upper lip length (mm)
4. Lower lip length (mm)
5. Upper lip thickness (mm)
6. Lower lip thickness (mm)

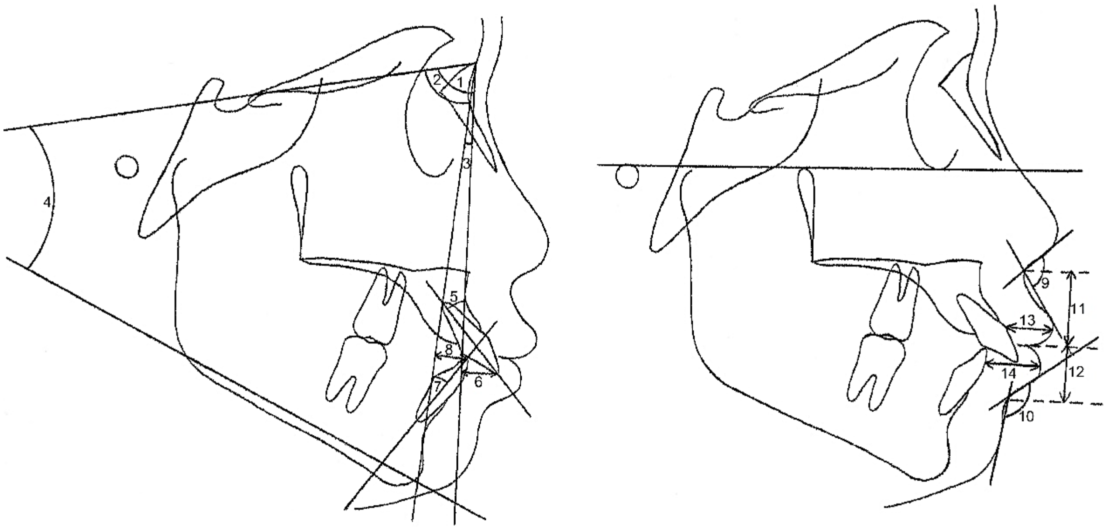


Figure 5 Angular and linear measurements utilized for evaluation of dento-skeleton and soft tissue morphology

1. SNA angle, 2. SNB angle, 3. ANB angle, 4. SN-GoGn angle, 5. U1-NA (angle), 6. U1-NA (linear), 7. L1-NB (angle), 8. L1-NB (linear), 9. Nasolabial angle (Cm-Sn-Ls angle), 10. Labiomental angle (Li-Ils-Pg’ angle), 11. Upper lip length (Sn-Ss) 12. Lower lip length (Ils-Si), 13. Upper lip thickness (The most labial point of the maxillary central incisor to Ls point), 14. Lower lip thickness (The most labial point of the mandibular central incisor to Li point)

7. To prevent error from examiner's fatique, the lateral cephalograms were not analyzed more than 8 sets per day.

8. Pretreatment and posttreatment radiographs of 10 patients were randomly selected to retrace and measure all variables for two times with at least 2 week interval after the first measurement.

Statistical Analysis

1. For intraexaminer reliability evaluation, method errors were estimated by Dahlberg's formula (39):

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between the first and second measurements and n is the number of duplicated measurements.

2. Normal distributions of all variables were verified by the Kolmogorov-Smirnov test.

3. For evaluation of the soft tissue profile changes following treatment with the three orthodontic modalities, significant differences of each measurement within and between groups were evaluated by paired t-test and one-way ANOVA respectively at 0.05 significant level.

4. For evaluation of the factors influencing soft tissue profile changes, correlations among significant soft tissue changes and independent variables comprising age, sex, treatment modality, pretreatment skeletal, dental and soft tissue morphology were evaluated by stepwise multiple regression analysis at 0.05 significant level.

Ethical Considerations

This research was approved by the ethical committee of Faculty of Dentistry Chulalongkorn University on April 7, 2015 (HREC-DCU 2015-009).

CHAPTER 4
RESULTS

Intraexaminer Reliability

Pretreatment and posttreatment radiographs of 10 patients were randomly selected to retrace and measure all variables at least 2 weeks interval after the first measurement. The method errors of the variables evaluated by means of linear and angular measurements ranged from 0.22 mm – 0.69 mm and 0.35 degree – 1.24 degree, except the nasolabial angle and the labiomental angle that ranged from 2.14 degree – 2.64 degree (Table 14 in appendix). The method errors of the variables evaluated by means of x-y coordinate system ranged from 0.16 mm – 1.23 mm and 0.32 mm – 1.34 mm, respectively (Table 15 in appendix).

Pretreatment Characteristics of the Subjects

The characteristics of the overall patients before treatment indicated that they presented not only Class II Division 1 malocclusion but also skeletal Class II malocclusion when compared with the Thai norms (38) (Table 3). All patients had skeletal Class II malocclusion (ANB = 5.34±2.12 degrees) due to mandibular retrusion (SNB = 77.82±3.65 degrees) with remarkable dental compensation of the lower incisors. The upper and lower incisors were proclined (U1-NA = 31.17±7.98 degrees, 7.99±2.94 mm and L1-NB = 32.30+5.48 degrees, 8.17+2.19 mm).

Table 3 Pretreatment dento-skeleton of the overall subject compared with Thai norm

	Thai norm		Overall subject		
	mean	s.d.	mean	s.d.	Sig
SNA (degree)	83	4	83.13	3.62	ns
SNB (degree)	79	3	77.82	3.65	*
ANB (degree)	4	2	5.34	2.12	*
SN-GoGn (degree)	34	6	32.40	5.31	*
U1-NA(degree)	28	4	31.17	7.98	*
U1-NA (mm)	6	2	7.99	2.94	*
L1-NB (degree)	28	4	32.30	5.48	*
L1-NB (mm)	6	2	8.17	2.19	*

Significant differences between groups * *p*-value ≤ 0.05, ns = non significance

Comparison between Treatment Groups

The subjects were divided into 3 groups regarding the treatment modalities as follows:

Group I: 30 patients (15 males, 15 females) age 8-13 years old (mean age 10.93±1.34 years old) were treated with cervical headgear and fixed appliance edgewise technique.

Group II: 30 patients (15 males, 15 females) age 10-16 years old (mean age 12.13±1.63 years old) were treated with Class II traction and fixed appliance edgewise technique.

Group III: 44 patients (20 males, 24 females) age 10-14 years old (mean age 11.73±1.15 years old) were treated as an extraction of the four first premolars and fixed appliance edgewise technique.

Kolmogorov-Smirnov test indicated that all variables of each group were normally distributed, therefore the parametric statistics was used for comparisons within and between groups (Table 16–18 in appendix).

The pretreatment characteristics of each group were presented in Table 4 indicating the initial ages of the headgear group were less than those of the remaining groups. Moreover, jaw positions of the three groups were similar when considered from the SNA and SNB angles except the ANB angle of the Class II traction and the extraction groups. The Class II traction group seemed to have more severe jaw discrepancy as the ANB angle was significantly larger than that of the extraction group. Regarding the dental position, the extraction group had more severe protrusion of both maxillary and mandibular incisors than those of the other groups. There were no significant differences of the soft tissue morphology between groups except the labiomental angle of the extraction group that was larger than those of the other groups.

Table 4 Pretreatment age, dento-skeleton and soft tissue morphology of the headgear, the Class II traction and the four first premolars extraction groups

	Headgear group (I) n=30		Class II traction group (II) n=30		Extraction group (III) n=44		
	mean	s.d.	mean	s.d.	mean	s.d.	Sig
Age (year)	10.93	1.34	12.13	1.63	11.73	1.15	I-II*
SNA (degree)	82.50	3.76	83.88	3.37	83.06	3.67	ns
SNB (degree)	76.95	3.97	77.82	3.20	78.41	3.67	ns
ANB (degree)	5.53	2.01	6.07	1.96	4.70	2.16	II-III*
SN-GoGn (degree)	31.43	4.81	31.32	6.08	33.81	4.86	ns
U1-NA(degree)	31.25	7.40	27.88	8.80	33.36	7.12	II-III*
U1-NA (mm)	7.80	2.66	6.30	2.99	9.27	2.48	II-III*
L1-NB (degree)	31.55	5.15	30.08	5.26	34.32	5.25	II-III*
L1-NB (mm)	7.62	1.66	7.37	1.91	9.09	2.38	I-III*, II-III*
NLA (degree)	93.53	10.59	93.32	11.96	95.39	11.29	ns
LMA (degree)	129.23	12.46	130.68	12.05	141.09	13.38	I-III*, II-III*
Upper lip length (mm)	22.72	2.11	23.45	2.19	23.63	2.09	ns
Lower lip length (mm)	13.30	1.74	13.98	1.92	14.19	2.01	ns
Upper lip thickness (mm)	13.10	1.59	12.98	1.94	12.50	1.41	ns
Lower lip thickness (mm)	16.15	2.05	15.90	1.95	16.10	2.08	ns

Significant differences between groups * *p*-value ≤ 0.05, ns = non significance

The pretreatment soft tissue profile evaluated by means of the coordinate system was presented in Table 5 indicating the three groups had similar soft tissue profile except the horizontal position of the lower lip when evaluated from the Si, Li and Ils points and the vertical positions of the N’ and Me’ points. The extraction group had more lower lip protrusion than those of the headgear group. The Class II traction group had more downward position of the N’ point than those of the other groups. Moreover, the headgear group had less downward position of the Me’ point than those of the extraction group.

At the end of treatment the headgear, the Class II traction and the extraction groups had similar overjet (2.73±0.70 mm, 2.83±0.87 mm and 2.89±2.89 mm, respectively) and overbite (2.73±0.83 mm, 2.75±0.93 mm and 3.13±0.82 mm, respectively). There were no significant differences of the mean treatment time among the headgear (2.57±0.94 years), the Class II traction (2.37±0.76 years) and the extraction groups (2.18±0.62 years).

Table 5 Pretreatment soft tissue profile evaluated by means of coordinate system of the headgear, the Class II traction and the four first premolars extraction groups

Landmark (mm)		Headgear group (I) (n=30)		Class II traction group (II) (n=30)		Extraction group (III) (n=44)		
		mean	s.d.	mean	s.d.	mean	s.d.	Sig
N’	(x)	5.48	0.99	5.20	1.26	5.64	0.89	ns
	(y)	-21.40	2.74	-25.43	4.42	-22.82	3.57	I-II*, II-III*
Pr	(x)	24.10	3.48	26.23	4.46	25.14	3.31	ns
	(y)	17.82	2.92	18.57	3.61	17.52	3.84	ns
Cm	(x)	20.00	3.55	21.68	4.56	20.64	3.32	ns
	(y)	23.60	2.84	24.60	3.43	23.63	3.65	ns
Sn	(x)	13.72	3.62	15.20	4.44	14.28	3.60	ns
	(y)	27.15	2.77	27.92	3.03	27.45	3.46	ns
Sls	(x)	16.03	3.70	16.92	4.46	17.23	3.26	ns
	(y)	34.58	2.93	35.35	3.12	35.40	3.56	ns
Ls	(x)	20.57	3.87	21.37	5.33	21.76	3.63	ns
	(y)	41.35	3.36	42.98	3.70	42.95	3.97	ns
Ss	(x)	13.50	3.83	13.85	4.81	15.03	3.62	ns
	(y)	49.87	3.30	51.37	3.13	51.08	4.04	ns
Si	(x)	10.42	5.73	12.28	5.13	13.60	4.67	I-III*
	(y)	51.10	2.81	51.93	2.71	52.06	4.37	ns
Li	(x)	15.65	5.92	16.32	5.54	18.68	5.05	I-III*
	(y)	58.02	2.93	58.73	3.35	58.73	4.63	ns
Ils	(x)	5.85	6.44	7.08	5.64	9.52	5.76	I-III*
	(y)	64.40	2.72	65.92	3.86	66.25	5.35	ns
Pg’	(x)	4.63	7.48	6.53	6.71	6.13	6.66	ns
	(y)	78.90	3.58	82.00	5.21	81.70	6.12	ns
Me’	(x)	-13.65	6.39	-11.80	6.45	-12.70	6.95	ns
	(y)	93.95	3.86	96.03	5.64	96.80	6.13	I-III*

Significant differences between groups * p-value ≤ 0.05, ns = non significance

(x): + = forward movement, - = backward movement

(y): + = downward movement, - = upward movement

Changes of dento-skeleton and soft tissue morphology after treatment studied by means of linear and angular measurements were presented in Table 6. There were significant differences of the maxillary position of the three groups. The maxilla was less retrusive in the extraction group than those of the other groups whereas the mandibular position (SNB and SN-GoGn angles) was similar among the three groups. The upper incisors were more retrusive in the extraction group than those of the other groups. This coincided with the lower incisor position meanwhile the lower incisors of the headgear and Class II traction groups were protrusive especially that of the Class II traction group. The soft tissue coverage at the upper and lower lip areas were similar except the upper lip thickness and the labiomental angle. The extraction group had the most upper lip thickness and decreased labiomental angle.

Table 6 Significant changes of dento-skeleton and soft tissue morphology between groups: the headgear, the Class II traction and the four first premolars extraction groups

	Headgear group (I) n=30		Class II traction group (II) n=30		Extraction group (III) n=44		
	mean	s.d.	mean	s.d.	mean	s.d.	Sig
SNA (degree)	-1.23	1.06	-1.10	1.97	-0.28	1.29	I-III*
SNB (degree)	0.08	1.26	-0.48	1.57	0.06	1.19	ns
ANB (degree)	-1.30	1.13	-0.62	1.47	-0.40	1.28	I-III*
SN-GoGn (degree)	0.97	1.87	1.15	2.07	0.48	1.38	ns
U1-NA(degree)	-8.83	7.06	-6.60	7.87	-15.77	6.49	I-III*,II-III*
U1-NA (mm)	-2.55	2.65	-1.63	2.43	-5.67	2.19	I-III*,II-III*
L1-NB (degree)	3.87	6.89	10.32	6.87	-7.23	7.66	I-II*, I-III*, II-III*
L1-NB (mm)	1.07	2.51	2.67	2.15	-2.53	2.53	I-II*, I-III*, II-III*
NLA (degree)	4.08	6.69	4.22	7.96	4.09	5.89	ns
LMA (degree)	8.42	9.37	5.93	10.88	-0.57	9.78	I-III*,II-III*
Upper lip length (mm)	0.60	1.86	0.97	1.93	0.67	1.68	ns
Lower lip length(mm)	2.48	2.22	2.17	2.74	1.94	1.90	ns
Upper lip thickness (mm)	0.95	1.52	0.82	1.48	1.81	1.37	I-III*,II-III*
Lower lip thickness (mm)	0.10	2.26	0.58	1.21	0.01	2.43	ns

Significant differences between groups * *p*-value ≤ 0.05, ns = non significance

The soft tissue profile changes evaluated by means of the x-y coordinate system within group were presented in Table 7 and between groups were presented in Table 8 and Figure 6. The result (Table 7) indicated that there were significant changes of the soft tissue profile in each group except the horizontal positions of the Sls point that showed no significant differences in all groups. There were significant differences of soft tissue profile changes between groups on the vertical positions of the Cm and Sn points and the horizontal positions of the Ss, Si and Li points (Table 8).

At the nasal area, the nose exhibited significantly forward and downward movements in all groups (Table 7). The headgear group exhibited greater downward movement of the Cm and Sn points than those of the extraction group (Table 8).

At the upper lip area, the Ss point of the Class II traction group moved less backward (0.33 mm) than those of the headgear (2.05 mm) and the extraction groups (2.18 mm). There was only significantly downward movement of the upper lip in the Class II traction group. Meanwhile, in the other two groups the upper lip exhibited significantly backward and downward movements.

At the lower lip area, the treatment responses among the three groups were significantly different when evaluated from the Si and Li points. The Si point moved backward 1.27 mm in the extraction group but moved slightly forward 0.55 mm in the headgear and 0.87 mm in the Class II traction groups. The Li point moved slightly backward 0.51 mm in the extraction group but moved forward 2.02 mm in the Class II traction group. Therefore, in the Class II traction group the lower lip moved forward and downward indicating protrusion of the lower lip after treatment, meanwhile in the headgear group the lower lip moved only downward and in the extraction the lower lip seemed to be more retrusive as it moved backward and downward.

At the chin area, there was no significantly forward movement of the chin in the Class II traction group when evaluated from the Pg’ point, but this point moved forward and downward in the headgear and the extraction groups. This coincided with the movement of the Me’ point of the extraction group. However, there were no significant differences between groups at the chin area (Table 8).

Table 7 Significant changes of the soft tissue profile evaluated by means of coordinate system within group: the headgear, the Class II traction and the four first premolars extraction groups

Landmark (mm)		Headgear group (n=30)					Class II traction group (n=30)					Extraction group (n=44)				
		Pretreatment		Posttreatment			Pretreatment		Posttreatment			Pretreatment		Posttreatment		
		mean	s.d.	mean	s.d.	Sig	mean	s.d.	mean	s.d.	Sig	mean	s.d.	mean	s.d.	Sig
N’	(x)	5.48	0.99	6.58	1.13	*	5.20	1.26	6.43	1.64	*	5.64	0.89	6.85	1.31	*
	(y)	-21.40	2.74	-20.42	2.66	*	-25.43	4.42	-24.08	4.28	*	-22.82	3.57	-22.40	3.95	ns
Pr	(x)	24.10	3.48	26.63	3.36	*	26.23	4.46	28.82	4.99	*	25.14	3.31	28.27	3.33	*
	(y)	17.82	2.92	21.87	4.25	*	18.57	3.61	21.55	4.91	*	17.52	3.84	20.06	4.31	*
Cm	(x)	20.00	3.55	21.57	3.67	*	21.68	4.56	23.73	5.18	*	20.64	3.32	22.81	3.43	*
	(y)	23.60	2.84	28.13	3.85	*	24.60	3.43	27.63	4.26	*	23.63	3.65	26.51	4.32	*
Sn	(x)	13.72	3.62	14.52	3.89	*	15.20	4.44	16.57	5.28	*	14.28	3.60	15.81	3.80	*
	(y)	27.15	2.77	31.47	3.68	*	27.92	3.03	30.93	3.88	*	27.45	3.46	30.34	4.07	*
Sls	(x)	16.03	3.70	15.63	3.96	ns	16.92	4.46	17.47	5.54	ns	17.23	3.26	17.28	3.63	ns
	(y)	34.58	2.93	39.23	3.83	*	35.35	3.12	38.73	4.10	*	35.40	3.56	38.64	4.32	*
Ls	(x)	20.57	3.87	19.73	4.40	*	21.37	5.33	21.72	6.36	ns	21.76	3.63	21.47	4.20	ns
	(y)	41.35	3.36	46.32	3.86	*	42.98	3.70	46.92	4.58	*	42.95	3.97	46.27	5.00	*
Ss	(x)	13.50	3.83	11.45	4.40	*	13.85	4.81	13.52	5.95	ns	15.03	3.62	12.85	4.11	*
	(y)	49.87	3.30	54.78	4.11	*	51.37	3.13	55.35	4.33	*	51.08	4.04	54.64	5.14	*

Significant difference within group * *p*-value ≤ 0.05, ns = non significance

(x): + = right on x-coordinate,   - = left on x-coordinate

(y): + = below on y-coordinate,   - = above on y-coordinate

Table 7 Significant changes of the soft tissue profile evaluated by means of coordinate system within group: the headgear, the Class II traction and the four first premolars extraction groups (Cont.)

Landmark (mm)		Headgear group (n=30)					Class II traction group (n=30)					Extraction group (n=44)				
		Pretreatment		Posttreatment			Pretreatment		Posttreatment			Pretreatment		Posttreatment		
		mean	s.d.	mean	s.d.	Sig	mean	s.d.	mean	s.d.	Sig	mean	s.d.	mean	s.d.	Sig
Si	(x)	10.42	5.73	10.97	4.55	ns	12.28	5.13	13.15	5.93	ns	13.60	4.67	12.33	4.48	*
	(y)	51.10	2.81	55.15	3.98	*	51.93	2.71	56.10	4.76	*	52.06	4.37	54.76	5.06	*
Li	(x)	15.65	5.92	16.43	4.94	ns	16.32	5.54	18.33	6.40	*	18.68	5.05	18.17	5.03	ns
	(y)	58.02	2.93	63.08	4.48	*	58.73	3.35	63.55	4.65	*	58.73	4.63	62.55	5.27	*
Ils	(x)	5.85	6.44	7.37	6.03	*	7.08	5.64	8.42	7.15	*	9.52	5.76	9.81	6.02	ns
	(y)	64.40	2.72	70.93	4.65	*	65.92	3.86	72.25	4.56	*	66.25	5.35	70.90	6.01	*
Pg’	(x)	4.63	7.48	5.73	7.61	*	6.53	6.71	7.22	8.92	ns	6.13	6.66	7.60	7.78	*
	(y)	78.90	3.58	85.62	4.96	*	82.00	5.21	87.73	6.01	*	81.70	6.12	88.43	6.96	*
Me’	(x)	-13.65	6.39	-12.75	7.42	ns	-11.80	6.45	-11.53	8.59	ns	-12.70	6.95	-11.19	8.25	*
	(y)	93.95	3.86	101.80	5.23	*	96.03	5.64	102.67	6.91	*	96.80	6.13	103.68	7.43	*

Significant difference within group * p-value ≤ 0.05, ns = non significance

(x): + = right on x-coordinate, - = left on x-coordinate

(y): + = below on y-coordinate, - = above on y-coordinate

Table 8 Significant changes of the soft tissue profile evaluated by means of coordinate system between groups: the headgear, the Class II traction and the four first premolars extraction groups

Landmark (mm)		Headgear group (I) n=30		Class II traction group (II) n=30		Extraction group (III) n=44		Sig
		mean	s.d.	mean	s.d.	mean	s.d.	
N’	(x)	1.10	0.81	1.23	1.59	1.22	1.17	ns
	(y)	0.98	2.29	1.35	2.71	0.42	1.69	ns
Pr	(x)	2.53	1.45	2.58	3.16	3.14	2.17	ns
	(y)	4.05	3.17	2.98	3.19	2.53	1.92	ns
Cm	(x)	1.57	1.48	2.05	2.92	2.17	1.84	ns
	(y)	4.53	2.95	3.03	3.03	2.89	2.11	I-III*
Sn	(x)	0.80	1.30	1.37	2.74	1.52	1.69	ns
	(y)	4.32	2.60	3.02	2.72	2.89	1.85	I-III*
Sls	(x)	-0.40	1.62	0.55	2.61	0.06	1.79	ns
	(y)	4.65	2.83	3.38	3.01	3.24	2.22	ns
Ls	(x)	-0.83	1.61	0.35	2.80	-0.30	2.07	ns
	(y)	4.97	3.44	3.93	3.46	3.32	2.67	ns
Ss	(x)	-2.05	2.19	-0.33	2.51	-2.18	2.16	I-II*, II-III*
	(y)	4.92	3.50	3.98	3.79	3.56	2.78	ns
Si	(x)	0.55	3.51	0.87	2.75	-1.27	2.45	I-III*, II-III*
	(y)	4.05	3.22	4.17	3.92	2.70	2.68	ns
Li	(x)	0.78	3.41	2.02	2.66	-0.51	2.46	II-III*
	(y)	5.07	3.62	4.82	4.16	3.82	2.61	ns
Ils	(x)	1.52	3.09	1.33	3.33	0.28	2.51	ns
	(y)	6.53	3.95	6.33	4.21	4.65	3.21	ns
Pg’	(x)	1.10	2.81	0.68	4.07	1.48	2.70	ns
	(y)	6.72	4.51	5.73	4.90	6.73	4.47	ns
Me’	(x)	0.90	2.56	0.27	4.00	1.51	2.50	ns
	(y)	7.85	4.02	6.63	4.71	6.89	3.63	ns

Significant differences between groups * *p*-value ≤ 0.05, ns = non significance

(x): + = forward movement, - = backward movement

(y): + = downward movement, - = upward movement

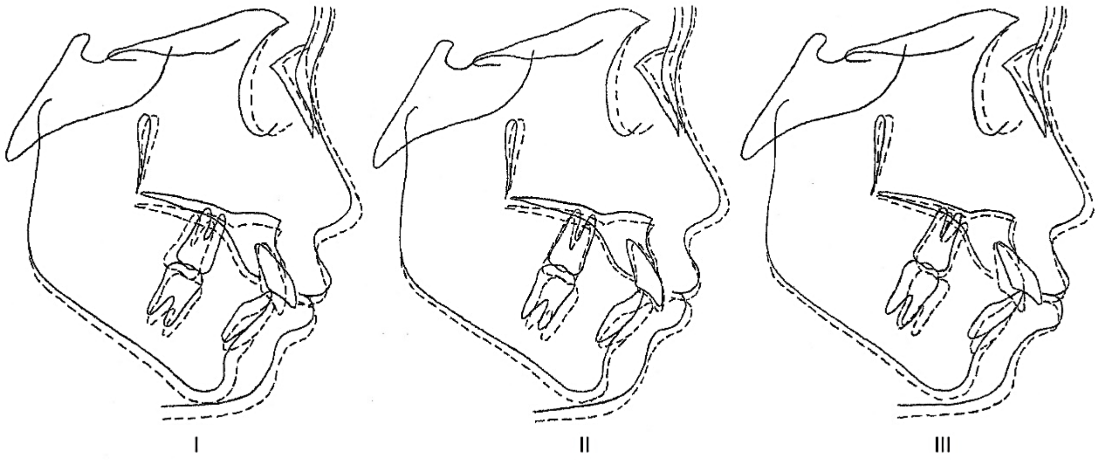


Figure 6 Soft tissue profile changes evaluated from superimposition along the anterior cranial base

I: The headgear group, II: The Class II traction group,

III: The four first premolars extraction group

Regression Analysis

Kolmogorov-Smirnov test showed that the variables of all subjects were normally distributed, therefore the parametric statistics could be used (Table 19 in appendix).

The soft tissue profile changes evaluated by means of the x-y coordinate system of all subjects were presented in Table 9 indicating the significant changes of the soft tissue profile in horizontal and vertical directions except the horizontal positions of the Sls, Ls and Si, points. At the nasal area, all reference points exhibited significantly forward and downward movements. At the upper lip area the Ss point moved backward and downward whereas the Sls and the Ls points only moved downward. At the lower lip area the Li and Ils points moved forward and downward whereas the Si point only moved downward. At the chin area there were significantly forward and downward movements of the Pg' and Me' points.

Table 9 Changes of the soft tissue profile by means of coordinate system of all subjects

Landmark (mm)		Pretreatment mean	Pretreatment s.d.	Posttreatment mean	Posttreatment s.d.	Difference mean	Difference s.d.	Sig
		All subjects (n=104)						
N’	(x)	5.47	1.04	6.65	1.37	1.19	1.21	*
	(y)	-23.16	3.92	-22.31	3.95	0.85	2.21	*
Pr	(x)	25.15	3.77	27.96	3.95	2.80	2.34	*
	(y)	17.91	3.52	21.01	4.51	3.10	2.76	*
Cm	(x)	20.75	3.80	22.72	4.12	1.96	2.12	*
	(y)	23.90	3.37	27.30	4.19	3.40	2.73	*
Sn	(x)	14.38	3.87	15.65	4.33	1.27	1.97	*
	(y)	27.50	3.13	30.84	3.90	3.34	2.41	*
Sls	(x)	16.79	3.76	16.86	4.38	0.07	2.03	ns
	(y)	35.15	3.25	38.84	4.09	3.69	2.69	*
Ls	(x)	21.30	4.24	21.04	4.99	-0.26	2.22	ns
	(y)	42.50	3.76	46.47	4.54	3.97	3.19	*
Ss	(x)	14.25	4.07	12.64	4.81	-1.61	2.40	*
	(y)	50.81	3.61	54.88	4.60	4.07	3.32	*
Si	(x)	12.30	5.24	12.17	4.98	-0.13	3.01	ns
	(y)	51.75	3.52	55.26	4.67	3.51	3.28	*
Li	(x)	17.13	5.57	17.72	5.44	0.59	2.99	*
	(y)	58.52	3.82	62.99	4.85	4.47	3.43	*
Ils	(x)	7.76	6.08	8.70	6.39	0.94	2.96	*
	(y)	65.62	4.34	71.30	5.23	5.68	3.81	*
Pg’	(x)	5.81	6.89	6.95	8.04	1.14	3.17	*
	(y)	80.98	5.35	87.42	6.22	6.44	4.59	*
Me’	(x)	-12.72	6.62	-11.74	8.07	0.98	3.04	*
	(y)	95.75	5.50	102.85	6.69	7.09	4.07	*

Significance within group * *p*-value ≤ 0.05, ns indicates not significance

(x): + = forward movement, - = backward movement

(y): + = downward movement, - = upward movement

In order to investigate factors influencing soft tissue profile changes after treatment, stepwise multiple regression analysis was performed to evaluate the correlations among the significant soft tissue changes and the independent variables so that the multiple regression equation could be obtained as the following formula:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k + e$$

Y = the dependent variable

β_0 = the constant or intercept

$B_{1, 2,\ldots, k}$ = the regression coefficient or slope of the regression line

$X_{1, 2,\ldots, k}$ = the independent variables

e = the difference between the observed Y value (Y) and the predicted Y value ($\hat{Y}$)

The assumptions of multiple regression analysis (40) were tested as follows:

1. The errors (e) were normally distributed. This assumption was checked with a histogram and P-P Plot that plotted the 45 degree line (Figure 7-26 in appendix).

2. The errors (e) had the constant variance. This assumption was checked with the scatter plot that the error terms along the regression line were equal (Figure 7-26 in appendix).

3. The errors (e) were independent of each other. This assumption was tested with the Durbin-Watson test. The values of 1.5 < Durbin-Watson < 2.5 show that there was no auto-correlation of the errors (Table 20 in appendix).

4. There was little or no multicollinearity in the data. The multicollinearity occurs when the independent variables are not independent from each other. The VIF values that were not greater than 10 and the tolerance values that were not less than 0.1 indicated that there was no multicollinearity in the data. (Table 20 in appendix).

Table 10-13 showed the correlations among significant soft tissue changes and independent variables comprised of age, sex, treatment modalities, pretreatment dento-skeleton and soft tissue morphology evaluated by the stepwise multiple regression analysis. The categorical variables comprising sex and treatment modalities were transformed to dummy variables with values 0 or 1.

At the nasal area (Table 10), the multiple regression equations utilized for prediction of the profile change at the nasal area were as follows:

- N' (x) = 4.278 + 0.805 (sex) – 0.230 (age)
  predictive power = 16.5%
- Pr (x) = 10.296 + 2.197 (sex) – 0.547 (age)
  predictive power = 31.5%
- Pr (y) = 22.886 – 0.222 (pretreatment SNB) – 0.638 (age) + 0.057 (pretreatment NLA) + 0.943 (sex)
  predictive power = 29.0%
- Cm (x) = 7.331 + 1.979 (sex) – 0.374 (age)
  predictive power = 26.4%
- Cm (y) = 22.338 – 0.803 (age) + 1.261 (sex) – 0.180 (pretreatment SNB) + 0.054 (pretreatment NLA)
  predictive power = 35.2%
- Sn (x) = 5.477 + 1.691 (sex) – 0.287 (age)
  predictive power = 21.0%
- Sn (y) = 19.108 – 0.681 (age) + 1.258 (sex) – 0.148 (pretreatment SNB) + 0.045 (pretreatment NLA)
  predictive power = 33.9%

The result indicated that horizontal change of all reference points (N', Pr, Cm and Sn) could be explained by age and sex. These two factors played around 16.5% - 31.5% of horizontal soft tissue change at the nasal area. Meanwhile, the vertical change of the Pr, Cm and Sn points could be explained by age, sex, pretreatment SNB and nasolabial angles that played around 29.0% - 35.2% of the vertical change at the nasal area.

At the upper lip area (Table 11), the multiple regression equations utilized for prediction of the profile change at the upper lip area were as follows:

- Sls (y) = 25.868 – 0.731 (age) + 1.612 (sex) – 0.165 (pretreatment SNB)
  predictive power = 32.7%
- Ls (y) = 31.546 – 0.855 (age) + 2.242 (sex) – 0.212 (pretreatment SNB)
  predictive power = 37.6%
- Ss (x) = -2.182 + 0.132 (tx1) + 1.848 (tx2)
  predictive power = 9.9%
- Ss (y) = 32.774 + 2.396 (sex) – 0.775 (age) – 0.237 (pretreatment SNB)
  predictive power = 35.6%

The result indicated that horizontal change of the Ss point could be explained 9.9% by the treatment modalities. The vertical changes of the Sls, Ls and Ss points could be explained by age, sex and pretreatment SNB angle that played around 32.7% - 37.6% of the vertical change at the upper lip area.

At the lower lip area (Table 12), the multiple regression equations utilized for prediction of the profile change at the lower lip area were as follows:

- Si (y) = 8.928 + 0.064 (pretreatment NLA) – 0.239 (pretreatment SNB) + 0.443 (pretreatment lower lip thickness)
  predictive power = 17.6%
- Li (x) = 19.543 - 0.210 (pretreatment L1 inclination) + 0.576 (pretreatment ANB) – 0.483 (pretreatment lower lip thickness) + 1.775 (sex) - 0.070 (pretreatment NLA)
  predictive power = 40.3%
- Li (y) = 17.103 + 0.473 (pretreatment lower lip thickness) – 0.663 (age) – 0.166 (pretreatment L1 inclination) + 0.076 (pretreatment NLA) – 0.184 (pretreatment SNB)
  predictive power = 27.2%

- Ils (x) = 15.966 – 0.063 (pretreatment LMA) + 1.849 (sex) – 0.078 (pretreatment NLA) + 0.316 (pretreatment ANB)

  predictive power = 33.2%
- Ils (y) = 30.769 + 2.305 (sex) – 0.817 (age) – 0.188 (pretreatment L1 inclination) + 0.065 (pretreatment NLA) – 0.186 (pretreatment SNB)

  predictive power = 31.9%

The result indicated that the vertical change of the Si point could be explained 17.6% by pretreatment nasolabial angle, SNB angle and lower lip thickness. The horizontal change of the Li point could be explained 40.3% by pretreatment lower incisor inclination, ANB angle and lower lip thickness, sex and pretreatment nasolabial angle, whereas the vertical change could be explained 27.2% by pretreatment lower lip thickness, age, pretreatment lower incisor inclination, nasolabial angle and SNB angle. The horizontal change of the Ils point could be explained 33.2% by pretreatment labiomental angle, sex, pretreatment nasolabial angle and ANB angle, whereas the vertical change could be explained 31.9% by sex, age, pretreatment lower incisor inclination, nasolabial angle and SNB angle.

At the chin area (Table 13), the multiple regression equations utilized for prediction of the profile change at the upper lip area were as follows:

- Pg' (x) = 13.052 + 2.277 (sex) – 0.165 (pretreatment SN-GoGn) – 0.464 (age)

  predictive power = 19.0%
- Pg' (y) = 9.020 + 2.276 (sex) – 0.862 (age) + 0.091 (pretreatment NLA)

  predictive power = 15.1%
- Me' (x) = 8.248 – 0.223 (pretreatment SN-GoGn) + 1.775 (sex) – 1.222 (tx1) – 1.881 (tx2)

  predictive power = 20.4%
- Me' (y) = 22.255 – 1.159 (age) + 3.269 (sex)

  predictive power = 30.9%

The result indicated that the horizontal change of the Pg’ point could be explained around 19.0% by sex, pretreatment mandibular plane angle and age, whereas the vertical change could be explained around 15.1% by sex, age and pretreatment nasolabial angle. The horizontal change of the Me’ point could be explained 20.4% by pretreatment mandibular plane angle, sex and treatment medalities, whereas the vertical change could be explained 30.9% by age and sex.

Table 10 The factors influencing soft tissue profile changes at the nasal area evaluated by stepwise multiple regression analysis

Dependent variables		Independent variables	Regression coefficient	std. error	t	Sig	Adjusted R^2
N'	(x)	(Constant)	4.278	.906	4.724	.000	0.165
		Sex	.805	.217	-3.708	.000	
		Age	-.230	.077	-3.002	.003	
	(y)	No variables were entered into the equation					
Pr	(x)	(Constant)	10.296	1.582	6.508	.000	0.315
		Sex	2.197	.379	-5.789	.000	
		Age	-.547	.134	-4.085	.000	
	(y)	(Constant)	22.886	5.306	4.313	.000	0.290
		Pretreatment SNB	-.222	.065	-3.392	.001	
		Age	-.638	.167	-3.822	.000	
		Pretreatment NLA	.057	.021	2.739	.007	
		Sex	.943	.469	-2.012	.047	
Cm	(x)	(Constant)	7.331	1.488	4.927	.000	0.264
		Sex	1.979	.357	-5.546	.000	
		Age	-.374	.126	-2.969	.004	
	(y)	(Constant)	22.338	4.999	4.468	.000	0.352
		Age	-.803	.157	-5.105	.000	
		Sex	1.261	.442	-2.856	.005	
		Pretreatment SNB	-.180	.062	-2.920	.004	
		Pretreatment NLA	.054	.020	2.729	.008	
Sn	(x)	(Constant)	5.477	1.433	3.822	.000	0.210
		Sex	1.691	0.344	-4.918	.000	
		Age	-.287	.121	-2.364	.020	
	(y)	(Constant)	19.108	4.472	4.273	.000	0.339
		Age	-.681	.141	-4.840	.000	
		Sex	1.258	.395	-3.185	.002	
		Pretreatment SNB	-.148	.055	-2.678	.009	
		Pretreatment NLA	.045	.018	2.583	.011	

Boy: Sex=1

Girl: Sex=0

Headgear group: Tx1=1, Tx2=0

Class II traction group: Tx1=0, Tx2=1

Extraction of four first premolars group: Tx1=0, Tx2=0

Table 11 The factors influencing soft tissue profile changes at the upper lip area evaluated by stepwise multiple regression analysis

Dependent variables		Independent variables	Regression coefficient	std. error	t	Sig	Adjusted R^2
Sls	(y)	(Constant)	25.868	4.756	5.440	.000	0.327
		Age	-.731	.156	-4.674	.000	
		Sex	1.612	.441	-3.653	.000	
		Pretreatment SNB	-.165	.062	-2.664	.009	
Ls	(y)	(Constant)	31.546	5.422	5.819	.000	0.376
		Age	-.855	.178	-4.795	.000	
		Sex	2.242	.503	-4.458	.000	
		Pretreatment SNB	-.212	.071	-2.996	.003	
Ss	(x)	(Constant)	-2.182	.343	-6.367	.000	0.099
		Tx1	.132	.538	.245	.807	
		Tx2	1.848	.538	3.434	.001	
	(y)	(Constant)	32.774	5.746	5.703	.000	0.356
		Sex	2.396	.533	-4.494	.000	
		Age	-.775	.189	-4.102	.000	
		Pretreatment SNB	-.237	.075	-3.165	.002	

Boy: Sex=1

Girl: Sex=0

Headgear group: Tx1=1, Tx2=0

Class II traction group: Tx1=0, Tx2=1

Extraction of four first premolars group: Tx1=0, Tx2=0

Table 12 The factors influencing soft tissue profile changes at the lower lip area evaluated by stepwise multiple regression analysis

Dependent variables		Independent variables	Regression coefficient	std. error	t	Sig	Adjusted R^2
Si	(y)	(Constant)	8.928	6.893	1.295	.198	0.176
		Pretreatment NLA	.064	.026	2.435	.017	
		Pretreatment SNB	-.239	.080	-2.965	.004	
		Pretreatment LL thickness	.443	.147	3.014	.003	
Li	(x)	(Constant)	19.543	2.943	6.641	.000	0.403
		Pretreatment L1 inclination	-.210	.044	-4.772	.000	
		Pretreatment ANB	.576	.114	5.043	.000	
		Pretreatment LL thickness	-.483	.122	-3.956	.000	
		Sex	1.775	.491	-3.615	.000	
		Pretreatment NLA	-.070	.021	-3.307	.001	
	(y)	(Constant)	17.103	6.986	2.448	.016	0.272
		Pretreatment LL thickness	.473	.145	3.252	.002	
		Age	-.663	.211	-3.145	.002	
		Pretreatment L1 inclination	-.166	.054	-3.089	.003	
		Pretreatment NLA	.076	.027	2.847	.005	
		Pretreatment SNB	-.184	.081	-2.278	.025	
Ils	(x)	(Constant)	15.966	2.767	5.771	.000	0.332
		Pretreatment LMA	-.063	.019	-3.372	.001	
		Sex	1.849	.497	-3.720	.000	
		Pretreatment NLA	-.078	.023	-3.438	.001	
		Pretreatment ANB	.316	.114	2.761	.007	
	(y)	(Constant)	30.769	7.332	4.197	.000	0.319
		Sex	2.305	.636	-3.623	.000	
		Age	-.817	.226	-3.610	.000	
		Pretreatment L1 inclination	-.188	.058	-3.263	.002	
		Pretreatment NLA	.065	.029	2.280	.025	
		Pretreatment SNB	-.186	.088	-2.107	.038	

Boy: Sex=1

Girl: Sex=0

Headgear group: Tx1=1, Tx2=0

Class II traction group: Tx1=0, Tx2=1

Extraction of four first premolars group: Tx1=0, Tx2=0

Table 13 The factors influencing soft tissue profile changes at the chin area evaluated by stepwise multiple regression analysis

Dependent variables		Independent variables	Regression coefficient	std. error	t	Sig	Adjusted R^2
Pg’	(x)	(Constant)	13.052	3.101	4.209	.000	0.190
		Sex	2.277	.563	-4.044	.000	
		Pretreatment SN-GoGn	-.165	.054	-3.079	.003	
		Age	-.464	.199	-2.332	.022	
	(y)	(Constant)	9.020	4.624	1.951	.054	0.151
		Sex	2.276	.836	-2.721	.008	
		Age	-.862	.297	-2.904	.005	
		Pretreatment NLA	.091	.038	2.410	.018	
Me’	(x)	(Constant)	8.248	1.793	4.601	.000	0.204
		Pretreatment SN-GoGn	-.223	.052	-4.296	.000	
		Sex	1.775	.536	3.313	.001	
		Tx1	-1.222	.654	-1.867	.065	
		Tx2	-1.881	.656	-2.869	.005	
	(y)	(Constant)	22.255	2.767	8.044	.000	0.309
		Age	-1.159	.234	-4.953	.000	
		Sex	3.269	.664	-4.926	.000	

Boy: Sex=1

Girl: Sex=0

Headgear group: Tx1=1, Tx2=0

Class II traction group: Tx1=0, Tx2=1

Extraction of four first premolars group: Tx1=0, Tx2=0

CHAPTER 5
DISCUSSION AND CONCLUSION

Discussion

The different orthodontic modalities had been prescribed for treatment of Class II Division 1 malocclusion in the subjects who had similar dental and skeletal malocclusions to test the research hypothesis that the soft tissue profile response to each treatment is different. The information obtained from this study will be beneficial for selection of the treatment modalities for Class II Division 1 malocclusion when improvement of facial esthetics is a major concern. However, there were differences of some pretreatment characteristics between groups because the treatment modality prescribed to the patients of this study was based upon development of dentition, site of jaw discrepancy, severity of malocclusion and clinical soft tissue profile evaluation. Prior to the treatment (Table 4 and 5), the headgear group had protrusive maxilla tendency with retrusive mandible. Moreover, the facial development of the headgear group had not pass the peak of pubertal growth therefore orthopedic treatment was prescribed. The Class II traction group seemed to have more severe skeletal discrepancy than those of the extraction group. They presented more protrusive maxilla and retrusive mandible so extraction of the four bicuspids was avoided and forward movement of the mandible was preferable. The extraction group had more incisor and lower lip protrusion than those of the other groups therefore extraction of the four first bicuspids was recommended.

The soft tissue profile and dentoskeletal changes found in this study could be the result of treatment as well as facial growth because all subjects were growing patients and there were no data of untreated Class II Division 1 malocclusion Thai subjects to differentiate between the effect of growth and treatment. Although there were no significant differences of the treatment time among the three groups, the profile changes of the headgear group could be influenced by facial growth more than those of the other groups because the subjects were in the prepubertal period and their initial age were the least as shown in Table 4.

The advantage of the study of profile change by means of the x-y coordinate system is that this measurement can demonstrate the changes in horizontal and vertical direction separately.

The result indicated that not only different treatment modalities but also other factors comprising age, sex, pretreatment dento-skeleton and soft tissue morphology seemed to be related to the profile changes. Although several studies (18, 41-44) had described the relationship of the incisal movement to the profile changes, most emphasized on the incisal position as well as the profile change after treatment. There was no document mention about the relations of the initial patient morphology such as skeletal pattern, incisal position and the soft tissue profile changes in term of regression analysis. Therefore, multiple regression analysis was used in this study as a tool to investigate the influence of treatment modalities, the initial patient morphology and other related factors on the soft tissue profile changes since this information can be obtained before treatment and are utilized for formulating the treatment planning. The prediction equation of the profile change based on initial patient morphology will enhance the decision making of the treatment modalities.

The result manifested the negative correlation between pretreatment age and the vertical change of the soft tissue profile for all variables. This supported the study of Hodges et al (45). Moreover, the boy had greater vertical changes than the girl due to more growth potential of the boy (46-49).

After treatment, the nose moved forward and downward significantly in all groups due to facial growth, this supported the study of Hoffelder et al (27) who concluded that the nose showed the greatest increases in height (8.65 mm) and length (13.71 mm) due to growth from 6 to 16 years. The Cm and Sn points of the headgear group had the greatest downward movement. This might be the orthopedic effect of the cervical headgear on redirection growth of the maxilla into more vertical direction as found from the study of Chaiyaraksa and Viteporn (9). The regression analysis (Table 10) showed the correlation between sex, age and the nasal growth since the boy and the younger patient had greater change. Moreover, the vertical change of the two points were correlated with the SNB and nasolabial angles. There was more vertical change in patients with less SNB and greater nasolabial angles indicating vertical growth pattern of the face.

At the upper lip area, both the headgear and extraction groups had similar effect on the upper lip retrusion. This result was consistent with the study by Janson et al (3) who found that the upper lip retrusion was similar in both headgear and the maxillary premolar extraction groups. Changes of dento-skeleton (Table 6) indicated that upper lip retrusion in the headgear group was the result of orthopedic effect of cervical headgear on the maxilla and upper incisor retraction. Meanwhile, upper lip retrusion in the extraction group was the result of dental effect only. Therefore, cervical headgear treatment without extraction in prepubertal patients with protrusion of upper incisor and the maxilla can improve upper lip protrusion in the same manner as orthodontic treatment with extraction of four first premolars in postpubertal patients. For the Class II traction group, there were no significant effect on horizontal position of the upper lip although there was slightly forward displacement of the Ls point. This was consistent with the study by Bishara et al (4) who found that the Ls point was more protrusive in patients treated with edgewise technique as a non-extraction case. The regression analysis (Table 11) showed that the treatment modalities was the major factor influencing upper lip retrusion evaluated from horizontal movement of the Ss point. None of the other variables produced a predictable regression. Anyhow the predictive power of the treatment modalities on the upper lip retrusion of this study was low (9.9%) and the result was contrast with the previous studies (18, 41-44) which concluded that the upper lip retraction was related with the upper incisor retraction, this due to the difference of the independent variable between the initial position of the upper incisor utilized in this study and the final position of the incisor from the previous studies. Change of the upper lip position in vertical direction was similar in all groups indicating significantly downward with increased nasolabial angle (Table 6, 7 and 8). The regression analysis showed that the age, sex and the SNB angle played important roles on downward movement of the upper lip. For instance the younger patient, the boy and the patient with less SNB angle had more vertical changes of the Sls, Ls and Ss points. These factors accounts around 32.7% - 37.6% predictive power of the three points.

At the lower lip area, the lower lip exhibited different responses in each group (Table 7 and 8). It moved moved forward in the Class II traction group and moved slightly forward in the headgear group but moved backward in the extraction group. The result was consistent with the study of Bishara et al (4) who found that the lower lip was more protrusive in the non-extraction group but more retrusive in the extraction group. The result also supported the study of Janson et al (3) who found that the treatment with the cervical headgear produced slightly lower lip protrusion but contrast with James' study (8) who concluded that the lower lip was slightly retrusive in the non-extraction group. In this study, after treatment with either the cervical headgear or the Class II traction the lower incisors were proclined. Meanwhile, the lower incisors were retroclined in the extraction group. Therefore, the lower incisors movement should play the major role for the lower lip position. Furthermore, the regression analysis (Table 12) showed that sex, the initial dento-skeleton and soft tissue morphology were correlated with the horizontal change of the lower lip evaluated at the Li, Ils points. The patients with less ANB angle had less lower lip protrusion after treatment, this was consistent with the study of Zierhut et al (29). Additionally, the patients with less lower incisor proclination before treatment seemed to have more the lower lip protrusion after treatment. Moreover, the patients with less nasolabial and labiomental angles had more lower lip protrusion after treatment. Thickness of the lower lip also played important role on the lower lip protrusion, this corresponded with the study of Oliver (16) who found strong correlation between osseous and soft tissue changes in patients with thin lips. Moreover, the boy had more lower lip protrusion than that of the girl.

Regarding vertical position of the lower lip, all groups presented significantly downward movement of the lower lip (Table 7). The correlated factors were similar to those of the horizontal changes. The patients with less SNB angle had more downward movement of the lower lip. The patients with less lower incisor proclination before treatment had more downward movement of the lower lip. Moreover, the patients with greater nasolabial angle had more downward movement of the lower lip. The patients with thick lower lip had more downward movement of the lower lip than the patients with thin lower lip. The younger patient had more downward movement of the lower lip because of growth potential. Although there were several factors involved with the vertical change of the lower lip the prediction power of these variables was low, they involved only 17.6% - 31.9% of the vertical changes at the Si, Li and Ils points.

At the chin area, the result (Table 7) indicated that the Class II traction had only significant effect on downward movement of the Pg' and Me' points. This should be the effect of Class II traction on extrusion of the mandibular molars and retroclination of the maxillary incisors causing backward rotation of the mandible (50). For the headgear and the extraction groups, the chin moved forward and downward. This might indicate that the two treatment modalities could enhance growth of the mandible. The result supported the previous studies concerning the effect of cervical headgear on mandibular position (9, 51-53). Moreover, although the patients in the extraction group were in postpubertal stage, the forward movement of the chin still be found due to the remaining facial growth. The regression analysis (Table 13) showed that horizontal changes of the chin at the Pg' and Me' points were different as the treatment modalities had no effect on the horizontal change of the Pg' point. For the Me' point the result indicated that not only the treatment modalities but also sex and the mandibular plane angle were correlated with the horizontal change of the Me'. The boy and the younger patient had more forward movement of the chin. The patient with steeper mandibular plane angle indicating the vertical growth pattern of the face had less forward movement of the chin. Regarding the vertical change of the chin, the regression analysis indicated that sex and age played an important role on vertical change of the Pg' and Me' points. The boy and the younger had more downward movement of the chin. Moreover the patient with greater nasolabial angle also had more downward movement of the chin.

The aforementioned results indicated the advantage of the headgear treatment in growing patients as it could improve the facial profile without extraction by upper lip retrusion and forward movement of the chin due to mandibular growth. The facial profile of the Class II traction group was mainly improved by lower lip protrusion as a result of the lower incisor proclination without effect on the upper lip position although the upper incisor protrusion had been corrected until acceptable overjet and overbite could be achieved. Therefore, the patients who had upper and lower lip protrusions due to severe protrusion of upper and lower incisors should not be treated by this modality, the extraction of four first premolars was preferable as the upper and lower lip positions could be improved.

The multiple regression analysis provided the prediction equations of the soft tissue profile changes from the related dento-skeleton and other factors. These prediction equations had been tested upon the assumptions of the regression analysis that focused upon nature of the error and the relations among the independent variables (Figure 7-26 and Table 20 in appendix). The result indicated that although the prediction equations of the soft tissue profile could be achieved, the feasibility of these equations should be considered as most of the predictive power of the independent variables were low (9.9% - 40.3%) and required several independent variables to explain the profile changes thus indicating that the nature of soft tissue profile changes were complicated and depended upon multiple factors. Last the independent variables that only relied on initial characteristics of the patient might be inadequate.

Suggestion

Further study should be undertaken to test the relation between hard and soft tissue changes after treatment and compare the predictive power of this study with the further study so that suitable prediction equation will be obtained. Moreover, evaluation of soft tissue profile changes and the influencing factors in adult patients should be studied to eliminate the result of growth.

Conclusion

Three treatment modalities: orthopedic treatment with cervical headgear, Class II traction and extraction of the first four premolars were prescribed to a group of Thai growing patients who presented with Class II Division 1 malocclusion. The result indicated there were significant changes of the soft tissue profile after treatment as follows:

- The nose exhibited forward and downward movements in all groups.

- In the headgear group, the upper lip moved downward and backward whereas the lower lip only moved downward and the chin moved forward and downward.

- In the Class II traction group, the upper lip moved downward whereas the lower lip moved forward and downward and the chin moved downward.

- In the extraction group, the upper and lower lips moved backward and downward whereas the chin moved forward and downward.

The soft tissue profile changes varied among different age, sex, treatment modalities, pretreatment skeletal, dental and soft tissue morphology. The prediction equations of the soft tissue profile changes from these factors could be obtained and should be beneficial for prediction of profile changes after treatment and orthodontic treatment planning of Class II Division 1 malocclusion.

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APPENDIX

Table 14 Method errors of the variables evaluated by means of linear and angular measurements

Variables	Pretreatment n=10	Posttreatment n=10
SNA (degree)	0.63	0.75
SNB (degree)	0.35	0.37
ANB (degree)	0.52	0.64
SN-GoGn (degree)	0.81	0.72
U1-NA (degree)	1.10	1.24
U1-NA (mm)	0.69	0.41
L1-NB (degree)	0.97	1.10
L1-NB (mm)	0.37	0.38
NLA (degree)	2.14	2.33
LMA (degree)	2.64	2.55
Upper lip length (mm)	0.30	0.45
Lower lip length (mm)	0.51	0.53
Upper lip thickness (mm)	0.25	0.22
Lower lip thickness (mm)	0.51	0.48

Table 15 Method errors of the variables evaluated by means of the coordinate system

Variables (mm)	Pretreatment n=10		Posttreatment n=10	
	x	y	x	y
N'	0.16	0.57	0.40	0.93
Pr	0.22	0.84	0.66	0.99
Cm	0.59	0.67	0.67	1.01
Sn	0.39	0.45	0.97	0.96
Sls	0.42	0.79	0.85	0.82
Ls	0.32	0.78	0.87	0.64
Ss	0.58	0.56	1.04	0.96
Si	0.52	0.50	1.22	1.13
Li	0.46	0.54	1.12	1.07
Ils	0.66	0.56	1.07	1.12
Pg'	0.61	0.92	1.14	1.34
Me'	1.07	0.32	1.23	0.56

Table 16 Normality test of the headgear group's variables

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_pre	30	5.4833	.98684	.797	.549
Pr_x_pre	30	24.1000	3.48247	.491	.969
Cm_x_pre	30	20.0000	3.55256	.658	.780
Sn_x_pre	30	13.717	3.6191	.884	.415
Sls_x_pre	30	16.0333	3.70213	.717	.682
Ls_x_pre	30	20.5667	3.87239	.681	.742
Ss_x_pre	30	13.5000	3.83496	.496	.966
Si_x_pre	30	10.4167	5.72816	.747	.632
Li_x_pre	30	15.6500	5.91630	.673	.755
Ils_x_pre	30	5.8500	6.43957	.613	.847
Pg'_x_pre	30	4.6333	7.48093	.707	.700
Me'_x_pre	30	-13.6500	6.39255	.497	.966
N'_y_pre	30	-21.4000	2.73672	.706	.701
Pr_y_pre	30	17.8167	2.91986	.599	.866
Cm_y_pre	30	23.6000	2.83573	.644	.801
Sn_y_pre	30	27.1500	2.76727	.509	.958
Sls_y_pre	30	34.5833	2.92752	.615	.844
Ls_y_pre	30	41.3500	3.36091	.490	.970
Ss_y_pre	30	49.8667	3.30343	.453	.986
Si_y_pre	30	51.1000	2.81131	.364	.999
Li_y_pre	30	58.0167	2.93164	.925	.359
Ils_y_pre	30	64.4000	2.71776	.530	.941
Pg'_y_pre	30	78.9000	3.57771	.585	.883
Me'_y_pre	30	93.9500	3.85592	.770	.593

Table 16 Normality test of the headgear group’s variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N’_x_post	30	6.5833	1.13018	1.256	.085
Pr_x_post	30	26.6333	3.35522	.685	.735
Cm_x_post	30	21.5667	3.66891	.733	.657
Sn_x_post	30	14.5167	3.88739	.729	.662
Sls_x_post	30	15.6333	3.95652	.750	.627
Ls_x_post	30	19.7333	4.39775	.621	.836
Ss_x_post	30	11.4500	4.39504	.638	.811
Si_x_post	30	10.9667	4.55036	.492	.969
Li_x_post	30	16.4333	4.93533	.524	.947
Ils_x_post	30	7.3667	6.02714	.597	.868
Pg’_x_post	30	5.7333	7.61094	.703	.707
Me’_x_post	30	-12.7500	7.41823	.693	.722
N’_y_post	30	-20.4167	2.65578	.619	.838
Pr_y_post	30	21.8667	4.25468	.472	.979
Cm_y_post	30	28.1333	3.85499	.555	.917
Sn_y_post	30	31.4667	3.67877	.672	.757
Sls_y_post	30	39.2333	3.82761	.568	.904
Ls_y_post	30	46.3167	3.86292	.528	.943
Ss_y_post	30	54.7833	4.10988	.640	.807
Si_y_post	30	55.1500	3.98305	.734	.654
Li_y_post	30	63.0833	4.47808	.572	.899
Ils_y_post	30	70.9333	4.64560	.963	.311
Pg’_y_post	30	85.6167	4.95616	.650	.792
Me’_y_post	30	101.8000	5.22857	.920	.365

Table 16 Normality test of the headgear group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_diff	30	1.1000	.81368	.816	.519
Pr_x_diff	30	2.5333	1.44993	.509	.958
Cm_x_diff	30	1.5667	1.48401	.815	.520
Sn_x_diff	30	.8000	1.29721	.883	.416
Sls_x_diff	30	-.4000	1.62098	.961	.314
Ls_x_diff	30	-.8333	1.60995	1.052	.218
Ss_x_diff	30	-2.0500	2.18675	.909	.380
Si_x_diff	30	.5500	3.50947	.706	.701
Li_x_diff	30	.7833	3.41064	.916	.371
Ils_x_diff	30	1.5167	3.08914	.755	.619
Pg'_x_diff	30	1.1000	2.81437	.650	.792
Me'_x_diff	30	.9000	2.55761	.573	.898
N'_y_diff	30	.9833	2.28746	.641	.806
Pr_y_diff	30	4.0500	3.17411	.527	.944
Cm_y_diff	30	4.5333	2.95347	.749	.629
Sn_y_diff	30	4.3167	2.60465	.694	.721
Sls_y_diff	30	4.6500	2.82584	.640	.807
Ls_y_diff	30	4.9667	3.43896	.712	.691
Ss_y_diff	30	4.9167	3.50144	.861	.449
Si_y_diff	30	4.0500	3.22263	.554	.919
Li_y_diff	30	5.0667	3.61923	.826	.503
Ils_y_diff	30	6.5333	3.95434	.387	.998
Pg'_y_diff	30	6.7167	4.51183	.573	.898
Me'_y_diff	30	7.8500	4.01538	.460	.984

Table 16 Normality test of the headgear group’s variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters Mean	Normal Parameters Std. Deviation	Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
SNA_pre	30	82.5000	3.76004	.533	.938
SNB_pre	30	76.9500	3.96613	.557	.916
ANB_pre	30	5.5333	2.00832	.868	.438
SN_GoGn_pre	30	31.4333	4.80792	.523	.947
U1_angular_pre	30	31.2500	7.39962	.624	.831
U1_linear_pre	30	7.8000	2.66394	.428	.993
L1_angular_pre	30	31.5500	5.14673	.611	.850
L1_linear_pre	30	7.6167	1.66445	.669	.762
NLA_pre	30	93.5333	10.59109	.542	.930
LMA_pre	30	129.2333	12.45802	.437	.991
UL_length_pre	30	22.7167	2.11188	.633	.818
LL_length_pre	30	13.3000	1.74494	.798	.548
UL_thickness_pre	30	13.1000	1.59417	.837	.485
LL_thickness_pre	30	16.1500	2.05170	.489	.970
SNA_post	30	81.2667	3.67595	.632	.819
SNB_post	30	77.0333	3.82806	.948	.330
ANB_post	30	4.2333	1.76525	.541	.932
SN_GoGn_post	30	32.4000	5.31653	.508	.959
U1_angular_post	30	22.4167	6.17292	.390	.998
U1_linear_post	30	5.2500	2.29974	.694	.721
L1_angular_post	30	35.4167	6.24787	.393	.998
L1_linear_post	30	8.6833	2.46522	.816	.519
NLA_post	30	97.6167	10.24164	.370	.999
LMA_post	30	137.6500	11.15653	.648	.795
UL_length_post	30	23.3167	1.73445	.987	.285
LL_length_post	30	15.7833	1.63835	.537	.935
UL_thickness_post	30	14.0500	1.78765	.791	.558
LL_thickness_post	30	16.2500	1.88346	.848	.469

Table 16 Normality test of the headgear group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
SNA_diff	30	-1.2333	1.06458	.846	.471
SNB_diff	30	.0833	1.26002	.914	.374
ANB_diff	30	-1.3000	1.13411	.875	.428
SN_GoGn_diff	30	.9667	1.87052	.540	.933
U1_angular_diff	30	-8.8333	7.06049	.516	.953
U1_linear_diff	30	-2.5500	2.64689	.616	.842
L1_angular_diff	30	3.8667	6.89444	.543	.930
L1_linear_diff	30	1.0667	2.51456	.668	.764
NLA_diff	30	4.0833	6.68772	.570	.901
LMA_diff	30	8.4167	9.37263	.501	.963
UL_length_diff	30	.6000	1.85881	.519	.951
LL_length_diff	30	2.4833	2.21859	.774	.587
UL_thickness_diff	30	.9500	1.51629	.658	.779
LL_thickness_diff	30	.1000	2.25679	.710	.694

Table 17 Normality test of the Class II traction group's variables

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters Mean	Normal Parameters Std. Deviation	Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
N'_x_pre	30	5.2000	1.25671	.711	.692
Pr_x_pre	30	26.2333	4.45617	.600	.865
Cm_x_pre	30	21.6833	4.55519	.706	.702
Sn_x_pre	30	15.200	4.4385	.704	.705
Sls_x_pre	30	16.9167	4.46265	.733	.656
Ls_x_pre	30	21.3667	5.33197	.606	.856
Ss_x_pre	30	13.8500	4.81046	.855	.457
Si_x_pre	30	12.2833	5.13219	.561	.912
Li_x_pre	30	16.3167	5.53902	.807	.533
Ils_x_pre	30	7.0833	5.63714	.580	.890
Pg'_x_pre	30	6.5333	6.70555	.587	.882
Me'_x_pre	30	-11.8000	6.45355	.615	.843
N'_y_pre	30	-25.4333	4.41926	.515	.954
Pr_y_pre	30	18.5667	3.60969	.537	.936
Cm_y_pre	30	24.6000	3.43009	.711	.693
Sn_y_pre	30	27.9167	3.03452	.697	.717
Sls_y_pre	30	35.3500	3.12429	.604	.859
Ls_y_pre	30	42.9833	3.69642	.434	.992
Ss_y_pre	30	51.3667	3.12921	.543	.930
Si_y_pre	30	51.9333	2.70929	.738	.647
Li_y_pre	30	58.7333	3.35470	.704	.704
Ils_y_pre	30	65.9167	3.85756	.777	.582
Pg'_y_pre	30	82.0000	5.20610	.819	.513
Me'_y_pre	30	96.0333	5.63844	.587	.881

Table 17 Normality test of the Class II traction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_post	30	6.4333	1.63861	.902	.390
Pr_x_post	30	28.8167	4.99048	.622	.834
Cm_x_post	30	23.7333	5.17909	.566	.905
Sn_x_post	30	16.5667	5.27965	.607	.855
Sls_x_post	30	17.4667	5.54283	.519	.950
Ls_x_post	30	21.7167	6.36353	.738	.648
Ss_x_post	30	13.5167	5.95310	.739	.645
Si_x_post	30	13.1500	5.92649	.674	.754
Li_x_post	30	18.3333	6.40492	.812	.525
Ils_x_post	30	8.4167	7.14877	.698	.715
Pg'_x_post	30	7.2167	8.91790	.722	.675
Me'_x_post	30	-11.5333	8.58521	.612	.849
N'_y_post	30	-24.0833	4.28325	.398	.997
Pr_y_post	30	21.5500	4.90663	.728	.664
Cm_y_post	30	27.6333	4.26480	.543	.930
Sn_y_post	30	30.9333	3.88128	.520	.949
Sls_y_post	30	38.7333	4.10158	.855	.458
Ls_y_post	30	46.9167	4.57897	.720	.678
Ss_y_post	30	55.3500	4.33142	.522	.948
Si_y_post	30	56.1000	4.75503	.547	.926
Li_y_post	30	63.5500	4.65231	.525	.946
Ils_y_post	30	72.2500	4.55758	.401	.997
Pg'_y_post	30	87.7333	6.01397	.512	.956
Me'_y_post	30	102.6667	6.90868	.475	.978

Table 17 Normality test of the Class II traction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_diff	30	1.2333	1.58513	.868	.438
Pr_x_diff	30	2.5833	3.15978	1.314	.063
Cm_x_diff	30	2.0500	2.91651	1.323	.061
Sn_x_diff	30	1.3667	2.74469	1.172	.128
Sls_x_diff	30	.5500	2.60752	.955	.322
Ls_x_diff	30	.3500	2.80440	.647	.796
Ss_x_diff	30	-.3333	2.50975	.655	.785
Si_x_diff	30	.8667	2.75097	.449	.988
Li_x_diff	30	2.0167	2.66032	.674	.754
Ils_x_diff	30	1.3333	3.32528	.781	.575
Pg'_x_diff	30	.6833	4.06729	.665	.769
Me'_x_diff	30	.2667	3.99943	.792	.558
N'_y_diff	30	1.3500	2.70743	.572	.899
Pr_y_diff	30	2.9833	3.18532	.901	.391
Cm_y_diff	30	3.0333	3.03410	1.095	.181
Sn_y_diff	30	3.0167	2.71802	.799	.546
Sls_y_diff	30	3.3833	3.01057	1.152	.140
Ls_y_diff	30	3.9333	3.45596	.766	.601
Ss_y_diff	30	3.9833	3.78856	.652	.790
Si_y_diff	30	4.1667	3.92018	.537	.936
Li_y_diff	30	4.8167	4.16364	.559	.914
Ils_y_diff	30	6.3333	4.21273	.863	.446
Pg'_y_diff	30	5.7333	4.90027	.667	.765
Me'_y_diff	30	6.6333	4.71413	.437	.991

Table 17 Normality test of the Class II traction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
SNA_pre	30	83.8833	3.36996	.790	.561
SNB_pre	30	77.8167	3.19613	.459	.984
ANB_pre	30	6.0667	1.95525	.656	.783
SN_GoGn_pre	30	31.3167	6.07636	.875	.429
U1_angular_pre	30	27.8833	8.79722	.696	.718
U1_linear_pre	30	6.3000	2.99021	.689	.729
L1_angular_pre	30	30.0833	5.25896	.513	.955
L1_linear_pre	30	7.3667	1.91155	.711	.693
NLA_pre	30	93.3167	11.96365	.603	.860
LMA_pre	30	130.6833	12.04767	.789	.562
UL_length_pre	30	23.4500	2.19463	.651	.791
LL_length_pre	30	13.9833	1.92302	.647	.796
UL_thickness_pre	30	12.9833	1.94086	1.086	.189
LL_thickness_pre	30	15.9000	1.95378	.809	.529
SNA_post	30	82.7833	3.23153	.663	.771
SNB_post	30	77.3333	3.44747	.700	.712
ANB_post	30	5.4500	1.71881	.784	.571
SN_GoGn_post	30	32.4667	7.17867	.997	.273
U1_angular_post	30	21.2833	4.87195	.436	.991
U1_linear_post	30	4.6667	1.96668	.727	.666
L1_angular_post	30	40.4000	6.38209	.426	.993
L1_linear_post	30	10.0333	2.50838	.644	.802
NLA_post	30	97.5333	10.19122	.465	.982
LMA_post	30	136.6167	14.45366	.682	.741
UL_length_post	30	24.4167	2.63950	.479	.976
LL_length_post	30	16.1500	1.97898	.756	.618
UL_thickness_post	30	13.8000	1.81754	.841	.479
LL_thickness_post	30	16.4833	1.45912	.821	.511

Table 17 Normality test of the Class II traction group’s variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters Mean	Normal Parameters Std. Deviation	Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
SNA_diff	30	-1.1000	1.97135	1.020	.249
SNB_diff	30	-.4833	1.57285	1.026	.243
ANB_diff	30	-.6167	1.46619	.922	.363
SN_GoGn_diff	30	1.1500	2.06844	.706	.701
U1_angular_diff	30	-6.6000	7.87226	.756	.618
U1_linear_diff	30	-1.6333	2.43159	.482	.974
L1_angular_diff	30	10.3167	6.87259	.723	.672
L1_linear_diff	30	2.6667	2.15492	.819	.514
NLA_diff	30	4.2167	7.96402	.843	.477
LMA_diff	30	5.9333	10.88477	.617	.842
UL_length_diff	30	.9667	1.92503	.692	.724
LL_length_diff	30	2.1667	2.73651	.780	.577
UL_thickness_diff	30	.8167	1.48256	.598	.867
LL_thickness_diff	30	.5833	1.21118	.920	.366

Table 18 Normality test of the four first premolars extraction group's variables

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_pre	44	5.6364	.88504	.858	.453
Pr_x_pre	44	25.1364	3.31024	.955	.321
Cm_x_pre	44	20.6364	3.31901	.952	.325
Sn_x_pre	44	14.284	3.5981	.808	.531
Sls_x_pre	44	17.2273	3.25550	.774	.587
Ls_x_pre	44	21.7614	3.62884	.781	.576
Ss_x_pre	44	15.0341	3.61746	.548	.925
Si_x_pre	44	13.6023	4.66753	.699	.713
Li_x_pre	44	18.6818	5.05331	.549	.924
Ils_x_pre	44	9.5227	5.75564	.556	.916
Pg'_x_pre	44	6.1250	6.65960	.495	.967
Me'_x_pre	44	-12.7045	6.94858	.565	.907
N'_y_pre	44	-22.8182	3.56516	.687	.733
Pr_y_pre	44	17.5227	3.83975	.665	.769
Cm_y_pre	44	23.6250	3.64903	.633	.818
Sn_y_pre	44	27.4545	3.45708	.966	.308
Sls_y_pre	44	35.3977	3.56106	1.110	.170
Ls_y_pre	44	42.9545	3.96763	.955	.322
Ss_y_pre	44	51.0795	4.04329	.957	.319
Si_y_pre	44	52.0568	4.36585	.789	.562
Li_y_pre	44	58.7273	4.62608	.513	.955
Ils_y_pre	44	66.2500	5.34888	.549	.924
Pg'_y_pre	44	81.7045	6.11928	1.014	.256
Me'_y_pre	44	96.7955	6.12972	.563	.909

Table 18 Normality test of the four first premolars extraction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_post	44	6.8523	1.30998	1.005	.265
Pr_x_post	44	28.2727	3.32617	.669	.762
Cm_x_post	44	22.8068	3.42904	.605	.858
Sn_x_post	44	15.8068	3.80058	.558	.915
Sls_x_post	44	17.2841	3.63350	.396	.998
Ls_x_post	44	21.4659	4.19634	.495	.967
Ss_x_post	44	12.8523	4.10697	.586	.883
Si_x_post	44	12.3295	4.47856	.663	.771
Li_x_post	44	18.1705	5.02776	.647	.796
Ils_x_post	44	9.8068	6.02149	.770	.594
Pg'_x_post	44	7.6023	7.77711	.487	.972
Me'_x_post	44	-11.1932	8.24566	.659	.779
N'_y_post	44	-22.3977	3.94965	.548	.925
Pr_y_post	44	20.0568	4.30956	.442	.990
Cm_y_post	44	26.5114	4.31936	.743	.639
Sn_y_post	44	30.3409	4.06884	.857	.454
Sls_y_post	44	38.6364	4.32053	.818	.516
Ls_y_post	44	46.2727	4.99588	.760	.610
Ss_y_post	44	54.6364	5.13692	.799	.545
Si_y_post	44	54.7614	5.05722	.763	.605
Li_y_post	44	62.5455	5.27149	.608	.854
Ils_y_post	44	70.8977	6.01411	.659	.778
Pg'_y_post	44	88.4318	6.96135	.390	.998
Me'_y_post	44	103.6818	7.42645	.766	.600

Table 18 Normality test of the four first premolars extraction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_diff	44	1.2159	1.16837	.637	.812
Pr_x_diff	44	3.1364	2.17374	.964	.311
Cm_x_diff	44	2.1705	1.83931	.703	.706
Sn_x_diff	44	1.5227	1.69113	.845	.473
Sls_x_diff	44	.0568	1.79215	.577	.893
Ls_x_diff	44	-.2955	2.06667	1.007	.263
Ss_x_diff	44	-2.1818	2.15959	.822	.509
Si_x_diff	44	-1.2727	2.45057	.669	.762
Li_x_diff	44	-.5114	2.46248	.534	.938
Ils_x_diff	44	.2841	2.51136	.544	.929
Pg'_x_diff	44	1.4773	2.70433	.827	.501
Me'_x_diff	44	1.5114	2.49997	.819	.513
N'_y_diff	44	.4205	1.69453	.741	.643
Pr_y_diff	44	2.5341	1.91808	.721	.676
Cm_y_diff	44	2.8864	2.10720	.577	.893
Sn_y_diff	44	2.8864	1.85480	.592	.875
Sls_y_diff	44	3.2386	2.21645	.895	.400
Ls_y_diff	44	3.3182	2.67219	.861	.449
Ss_y_diff	44	3.5568	2.77911	.959	.317
Si_y_diff	44	2.7045	2.67703	.668	.763
Li_y_diff	44	3.8182	2.61278	.734	.654
Ils_y_diff	44	4.6477	3.20534	.574	.897
Pg'_y_diff	44	6.7273	4.47403	.894	.402
Me'_y_diff	44	6.8864	3.62623	.550	.923

Table 18 Normality test of the four first premolars extraction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
SNA_pre	44	83.0568	3.67141	.887	.410
SNB_pre	44	78.4091	3.67467	.505	.961
ANB_pre	44	4.7045	2.15751	.590	.877
SN_GoGn_pre	44	33.8068	4.86231	.513	.955
U1_angular_pre	44	33.3636	7.12461	.470	.980
U1_linear_pre	44	9.2727	2.48122	.662	.772
L1_angular_pre	44	34.3182	5.24525	.660	.776
L1_linear_pre	44	9.0909	2.37544	.803	.539
NLA_pre	44	95.3864	11.29255	.744	.638
LMA_pre	44	141.0909	13.38268	.402	.997
UL_length_pre	44	23.6250	2.09130	.583	.886
LL_length_pre	44	14.1932	2.00933	.872	.432
UL_thickness_pre	44	12.5000	1.41010	1.041	.229
LL_thickness_pre	44	16.1023	2.08421	.653	.787
SNA_post	44	82.7727	3.49161	.704	.705
SNB_post	44	78.4659	3.70637	.579	.891
ANB_post	44	4.3068	2.13829	.978	.294
SN_GoGn_post	44	34.2841	5.11200	.453	.986
U1_angular_post	44	17.5909	5.96333	.588	.879
U1_linear_post	44	3.6023	2.05613	.773	.589
L1_angular_post	44	27.0909	7.25633	.810	.528
L1_linear_post	44	6.5568	2.55456	.758	.613
NLA_post	44	99.4773	10.52900	.618	.839
LMA_post	44	140.5227	10.60055	.733	.655
UL_length_post	44	24.2955	2.35589	.675	.752
LL_length_post	44	16.1364	1.82796	.791	.559
UL_thickness_post	44	14.3068	1.71253	.757	.615
LL_thickness_post	44	16.1136	2.44203	1.302	.067

Table 18 Normality test of the four first premolars extraction group's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
SNA_diff	44	-.2841	1.28677	.711	.693
SNB_diff	44	.0568	1.18722	.845	.472
ANB_diff	44	-.3977	1.28307	.746	.634
SNMP_diff	44	.4773	1.37652	.828	.500
U1_angular_diff	44	-15.7727	6.49459	.530	.942
U1_linear_diff	44	-5.6705	2.18862	.760	.610
L1_angular_diff	44	-7.2273	7.66330	.623	.833
L1_linear_diff	44	-2.5341	2.52752	.987	.284
NLA_diff	44	4.0909	5.88581	.789	.562
LMA_diff	44	-.5682	9.77811	.423	.994
UL_length_diff	44	.6705	1.68075	1.022	.247
LL_length_diff	44	1.9432	1.89619	.892	.404
UL_thickness_diff	44	1.8068	1.37340	.771	.593
LL_thickness_diff	44	.0114	2.43160	1.041	.229

Table 19 Normality test of all subjects's variables

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters		Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
		Mean	Std. Deviation		
N'_x_pre	104	5.4663	1.03873	1.175	.127
Pr_x_pre	104	25.1538	3.77400	.943	.336
Cm_x_pre	104	20.7548	3.79703	.841	.478
Sn_x_pre	104	14.3846	3.86874	.826	.502
Sls_x_pre	104	16.7933	3.76082	.685	.737
Ls_x_pre	104	21.3029	4.23945	.714	.688
Ss_x_pre	104	14.2500	4.07336	.794	.554
Si_x_pre	104	12.3029	5.24470	.648	.796
Li_x_pre	104	17.1250	5.56896	.701	.710
Ils_x_pre	104	7.7596	6.08076	.506	.960
Pg'_x_pre	104	5.8125	6.89420	.565	.908
Me'_x_pre	104	-12.7163	6.62474	.723	.673
N'_y_pre	104	-23.1635	3.92060	.702	.708
Pr_y_pre	104	17.9087	3.52368	.917	.370
Cm_y_pre	104	23.8990	3.36702	.882	.419
Sn_y_pre	104	27.5000	3.13452	1.165	.133
Sls_y_pre	104	35.1490	3.25374	.942	.337
Ls_y_pre	104	42.5000	3.76042	.675	.753
Ss_y_pre	104	50.8125	3.61039	.769	.595
Si_y_pre	104	51.7452	3.52453	.952	.325
Li_y_pre	104	58.5240	3.82466	.991	.280
Ils_y_pre	104	65.6202	4.34076	.942	.338
Pg'_y_pre	104	80.9808	5.35303	1.093	.183
Me'_y_pre	104	95.7548	5.50066	.777	.582

Table 19 Normality test of all subjects's variables (Cont.)

One-Sample Kolmogorov-Smirnov Test

Variables	N	Normal Parameters Mean	Normal Parameters Std. Deviation	Kolmogorov-Smirnov Z	Asymp. Sig. (2-tailed)
N'_x_post	104	6.6538	1.36545	1.340	.055
Pr_x_post	104	27.9567	3.94569	.740	.644
Cm_x_post	104	22.7163	4.11590	1.007	.263
Sn_x_post	104	15.6538	4.33157	.656	.783
Sls_x_post	104	16.8606	4.38081	.677	.749
Ls_x_post	104	21.0385	4.99062	.639	.809
Ss_x_post	104	12.6394	4.80769	.727	.665
Si_x_post	104	12.1731	4.98043	.786	.567
Li_x_post	104	17.7163	5.44423	.721	.676
Ils_x_post	104	8.7019	6.38890	1.048	.222
Pg'_x_post	104	6.9519	8.03648	.627	.827
Me'_x_post	104	-11.7404	8.06647	.555	.917
N'_y_post	104	-22.3125	3.95312	.640	.807
Pr_y_post	104	21.0096	4.50727	.640	.807
Cm_y_post	104	27.3029	4.19455	.521	.949
Sn_y_post	104	30.8365	3.89700	.691	.727
Sls_y_post	104	38.8365	4.08908	.743	.639
Ls_y_post	104	46.4712	4.53938	.704	.705
Ss_y_post	104	54.8846	4.59856	.656	.782
Si_y_post	104	55.2596	4.67174	.489	.970
Li_y_post	104	62.9904	4.84967	.611	.849
Ils_y_post	104	71.2981	5.23409	.563	.909
Pg'_y_post	104	87.4183	6.22441	.615	.844
Me'_y_post	104	102.8462	6.69229	.809	.529

Table 20 Assumption testing of multiple regression analysis

Dependent variables	Independent variables	Collinearity Statistics		
		Tolerance	VIF	Durbin-Watson
N’ (x)	(Constant)			
	Sex	1.000	1.000	
	Age	1.000	1.000	2.094
(y)	No variables were entered into the equation			
Pr (x)	(Constant)			
	Sex	1.000	1.000	
	Age	1.000	1.000	1.908
(y)	(Constant)			
	Pretreatment SNB	.924	1.082	
	Age	.931	1.074	
	Pretreatment NLA	.959	1.043	
	Sex	.950	1.053	2.112
Cm (x)	(Constant)			
	Sex	1.000	1.000	
	Age	1.000	1.000	1.713
(y)	(Constant)			
	Age	.931	1.074	
	Sex	.950	1.053	
	Pretreatment SNB	.924	1.082	
	Pretreatment NLA	.959	1.043	2.106
Sn (x)	(Constant)			
	Sex	1.000	1.000	
	Age	1.000	1.000	1.723
(y)	(Constant)			
	Age	.931	1.074	
	Sex	.950	1.053	
	Pretreatment SNB	.924	1.082	
	Pretreatment NLA	.959	1.043	2.209

Table 20 Assumption testing of multiple regression analysis (Cont.)

Dependent variables	Independent variables	Collinearity Statistics		Durbin-Watson
		Tolerance	VIF	
Sls (y)	(Constant)			
	Age	.955	1.047	
	Sex	.964	1.038	
	Pretreatment SNB	.924	1.082	2.152
Ls (y)	(Constant)			
	Age	.955	1.047	
	Sex	.964	1.038	
	Pretreatment SNB	.924	1.082	2.106
Ss (x)	(Constant)			
	Tx1	.489	2.046	
	Tx2	.489	2.046	1.790
(y)	(Constant)			
	Sex	.964	1.038	
	Age	.955	1.047	
	Pretreatment SNB	.924	1.082	2.021

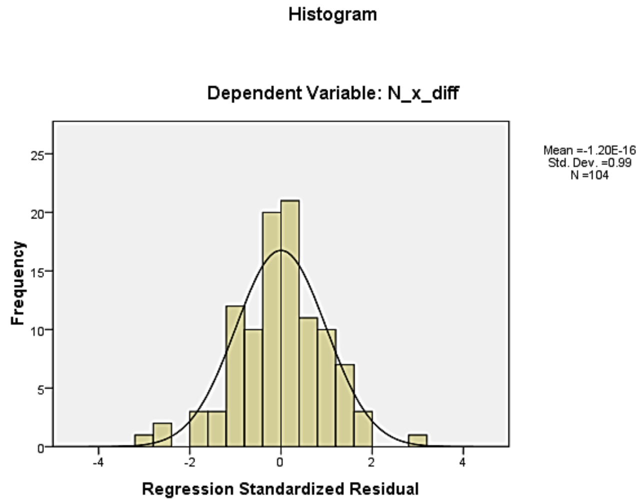
Table 20 Assumption testing of multiple regression analysis (Cont.)

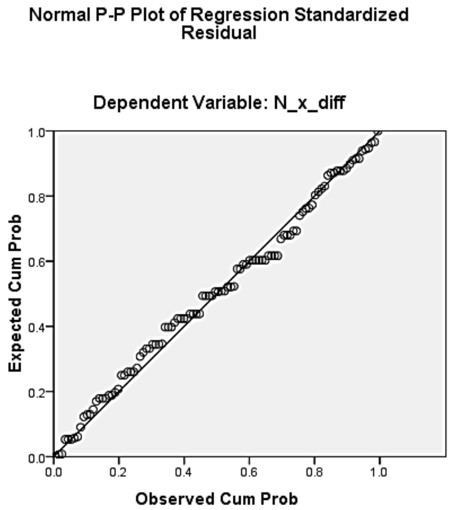
Dependent variables		Independent variables	Collinearity Statistics		Durbin-Watson
			Tolerance	VIF	
Si	(y)	(Constant)			
		Pretreatment NLA	.974	1.027	
		Pretreatment SNB	.995	1.005	
		Pretreatment LL thickness	.979	1.021	2.009
Li	(x)	(Constant)			
		Pretreatment L1 inclination	.885	1.130	
		Pretreatment ANB	.883	1.133	
		Pretreatment LL thickness	.928	1.078	
		Sex	.849	1.178	
		Pretreatment NLA	.851	1.176	1.616
	(y)	(Constant)			
		Pretreatment LL thickness	.961	1.041	
		Age	.923	1.084	
		Pretreatment L1 inclination	.960	1.042	
		Pretreatment NLA	.927	1.079	
		Pretreatment SNB	.953	1.049	2.340
Ils	(x)	(Constant)			
		Pretreatment LMA	.869	1.151	
		Sex	.912	1.096	
		Pretreatment NLA	.880	1.137	
		Pretreatment ANB	.965	1.036	2.321
	(y)	(Constant)			
		Sex	.939	1.065	
		Age	.923	1.083	
		Pretreatment L1 inclination	.960	1.042	
		Pretreatment NLA	.931	1.074	
		Pretreatment SNB	.924	1.083	2.194

Table 20 Assumption testing of multiple regression analysis (Cont.)

Dependent variables		Independent variables	Collinearity Statistics		Durbin-Watson
			Tolerance	VIF	
Pg’	(x)	(Constant)			
		Sex	.989	1.011	
		Pretreatment SN-GoGn	.976	1.025	
		Age	.985	1.015	1.641
	(y)	(Constant)			
		Sex	.984	1.016	
		Age	.974	1.027	
		Pretreatment NLA	.959	1.043	2.093
Me’	(x)	(Constant)			
		Pretreatment SN-GoGn	.781	1.281	
		Sex	.918	1.089	
		Tx1	.361	2.772	
		Tx2	.403	2.483	1.829
	(y)	(Constant)			
		Age	1.000	1.000	
		Sex	1.000	1.000	2.061

Figure 7 Assumption testing of multiple regression analysis: horizontal change of N’





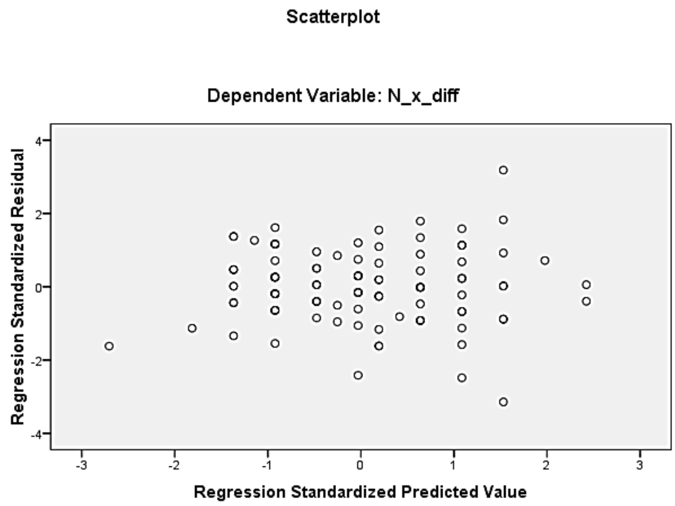
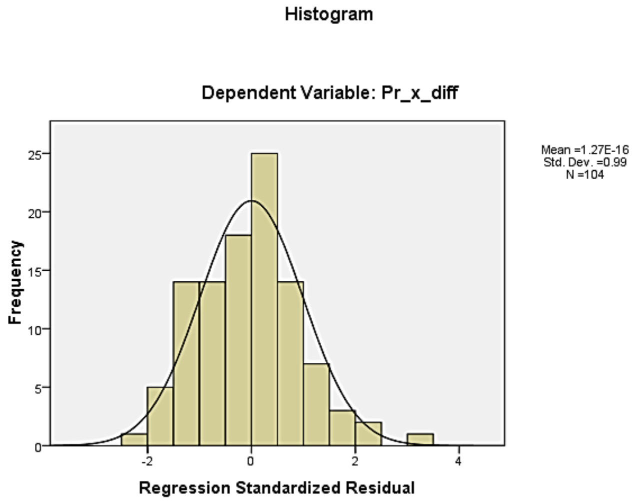
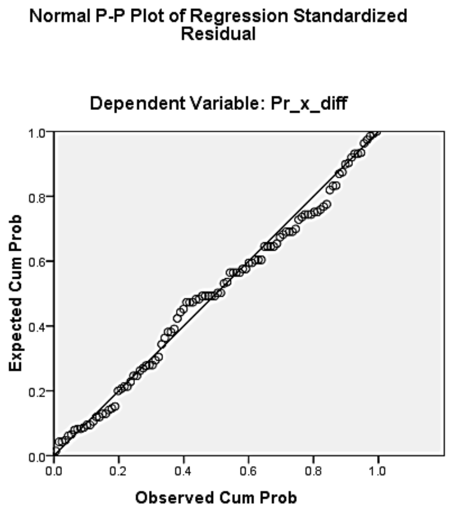


Figure 8 Assumption testing of multiple regression analysis: horizontal change of Pr





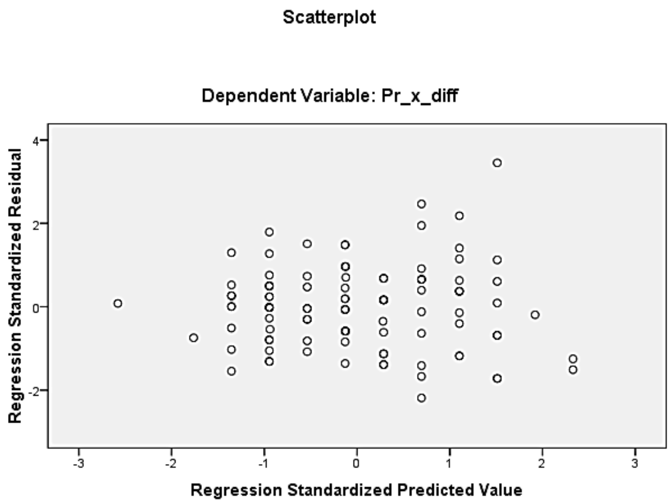
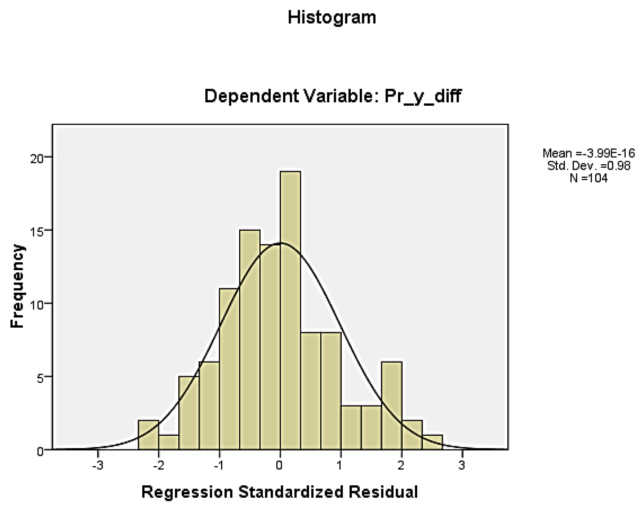
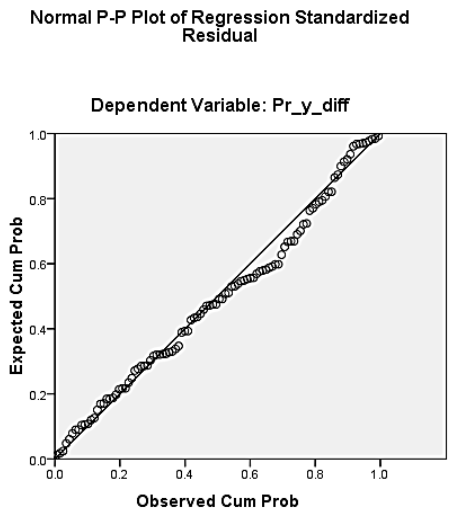


Figure 9 Assumption testing of multiple regression analysis: vertical change of Pr





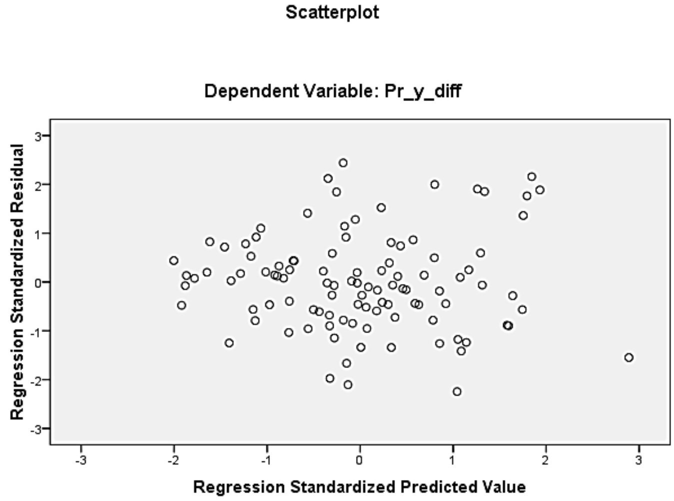


Figure 10 Assumption testing of multiple regression analysis: horizontal change of Cm

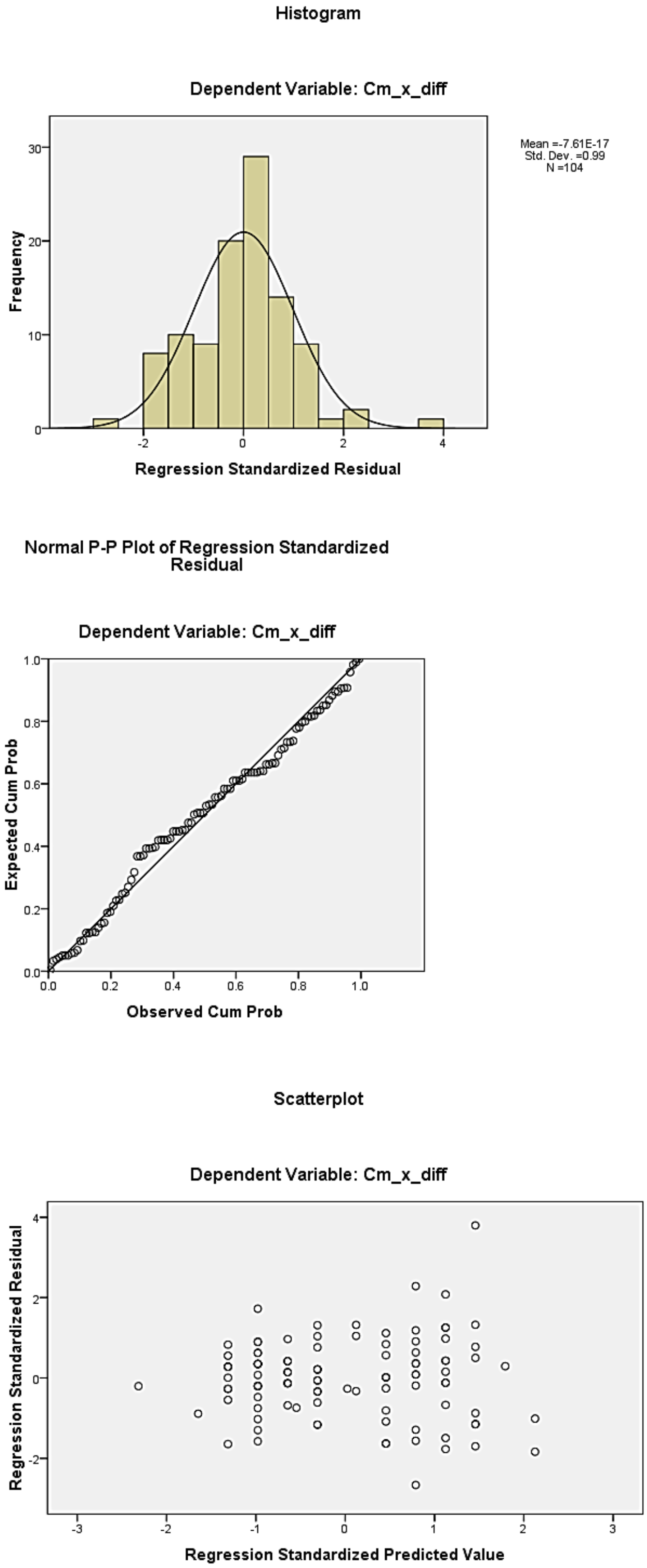


Figure 11 Assumption testing of multiple regression analysis: vertical change of Cm

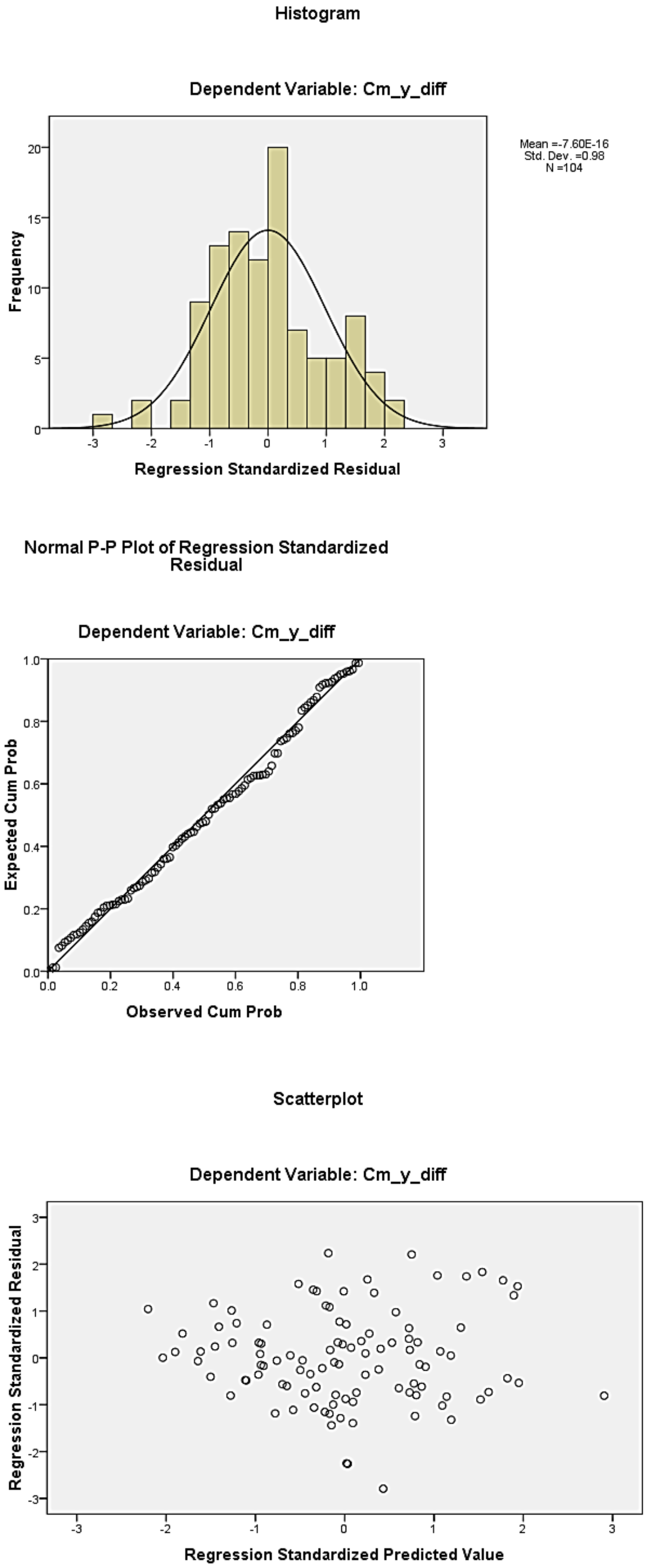
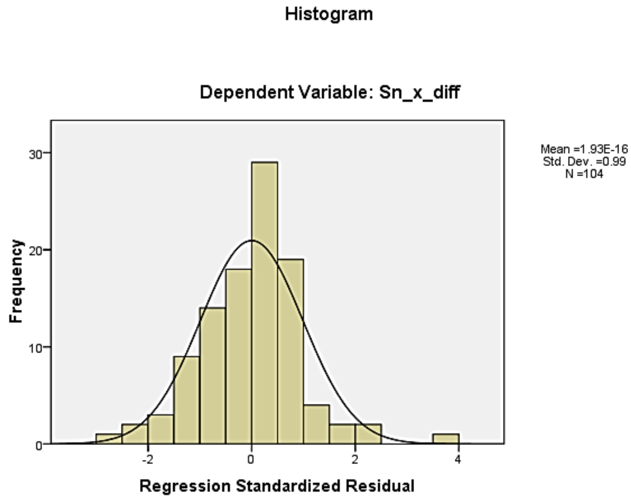
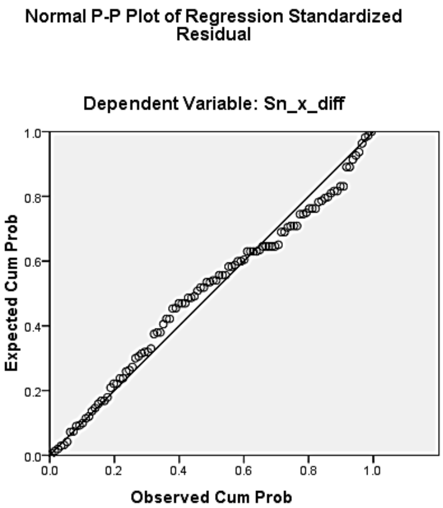


Figure 12 Assumption testing of multiple regression analysis: horizontal change of Sn





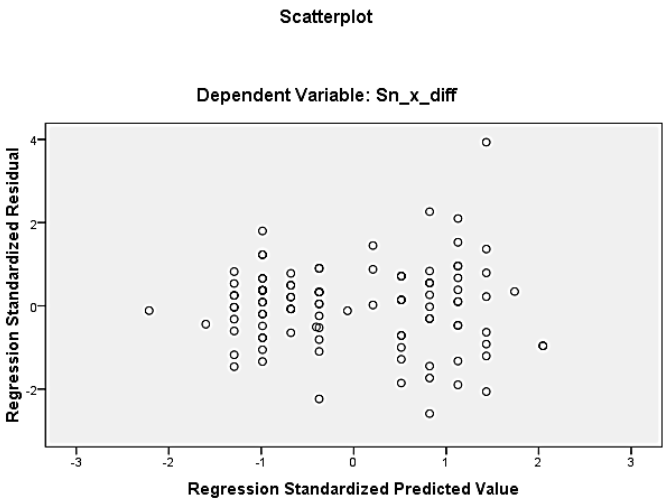
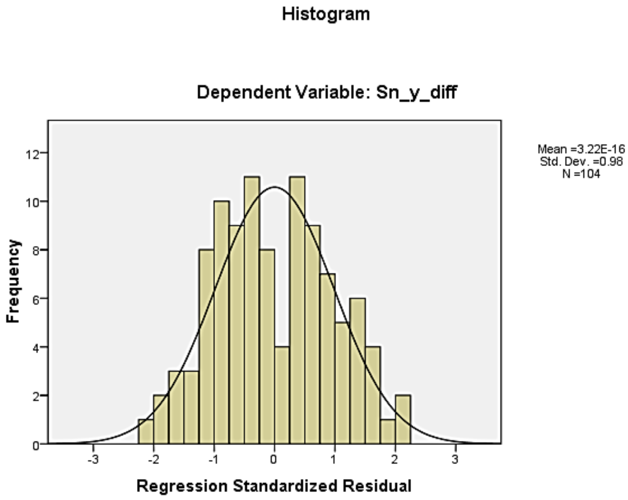
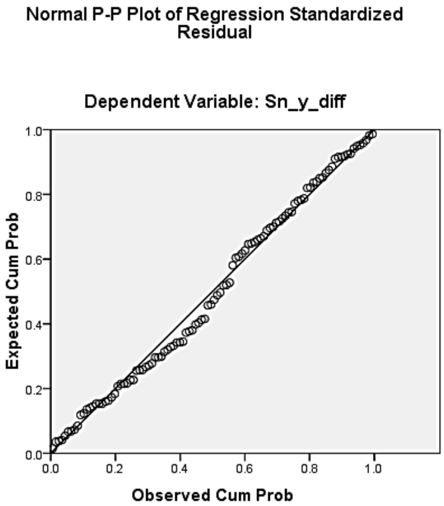


Figure 13 Assumption testing of multiple regression analysis: vertical change of Sn





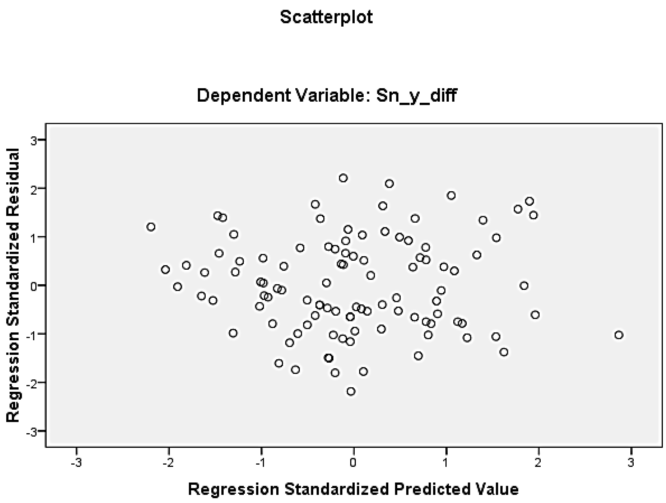
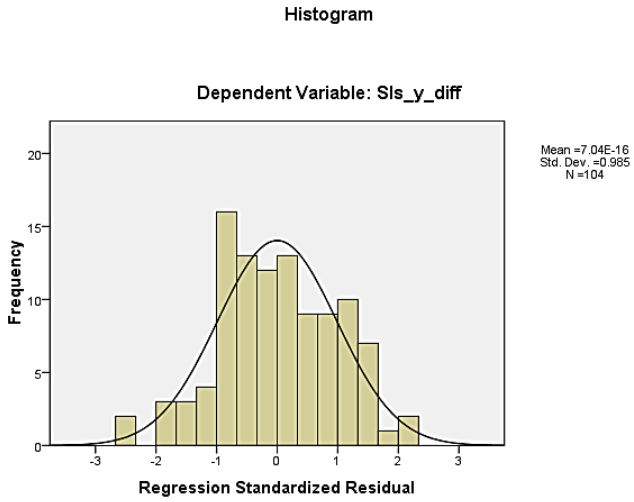
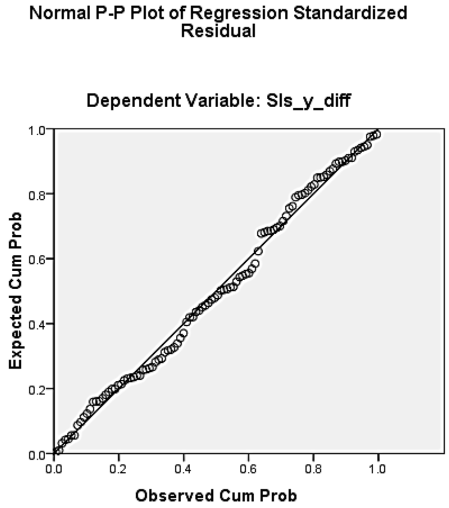


Figure 14 Assumption testing of multiple regression analysis: vertical change of Sls





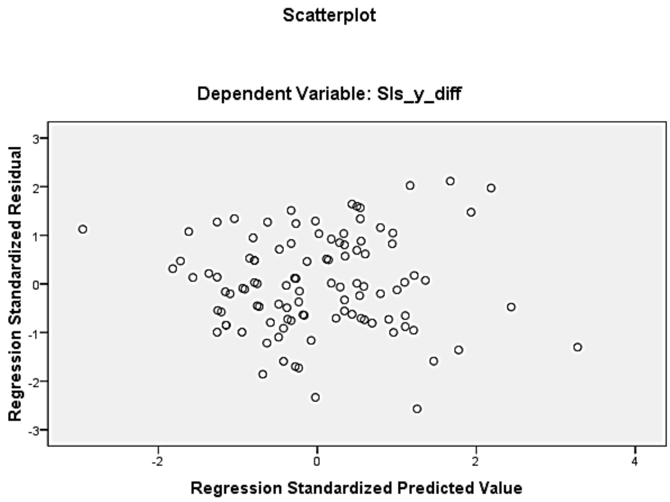
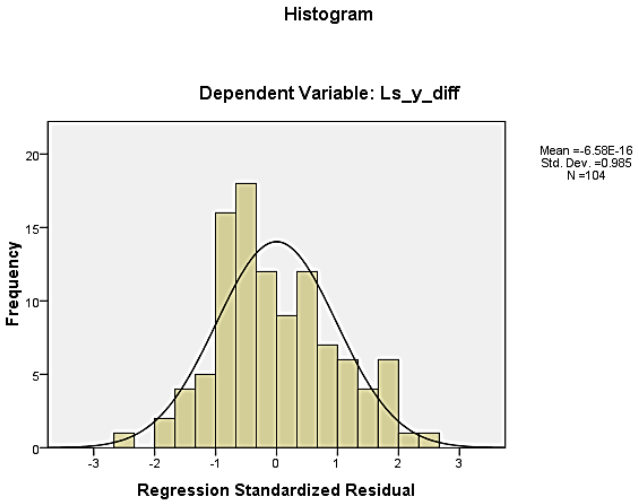
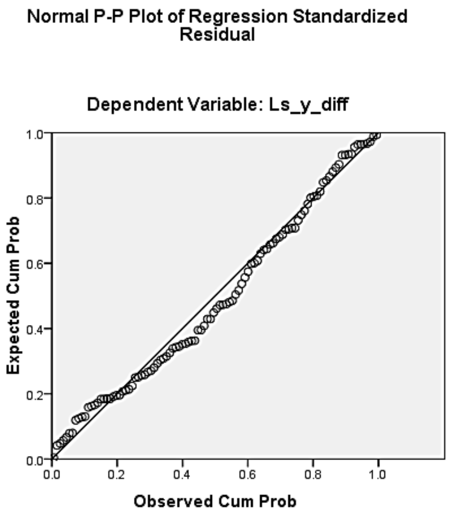


Figure 15 Assumption testing of multiple regression analysis: vertical change of Ls





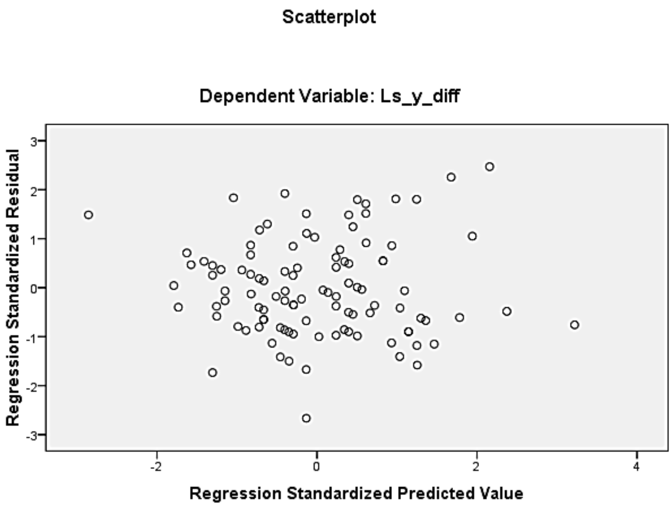
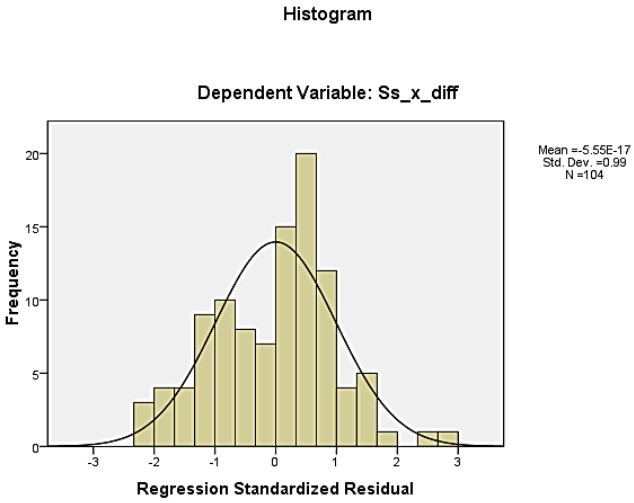
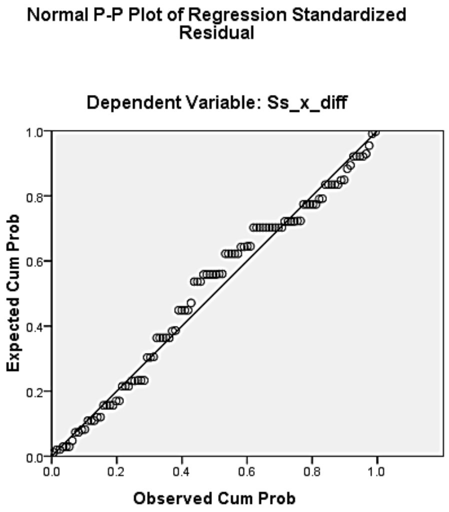


Figure 16 Assumption testing of multiple regression analysis: horizontal change of Ss





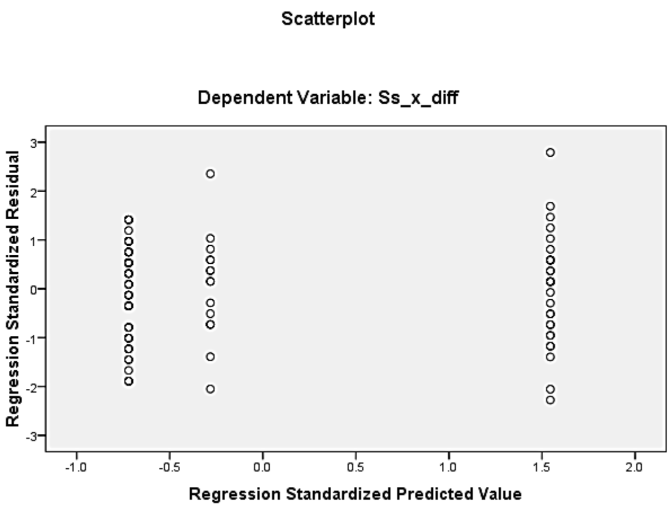
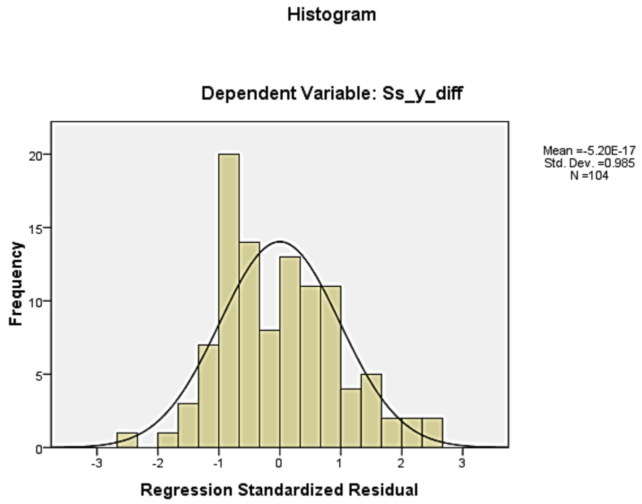
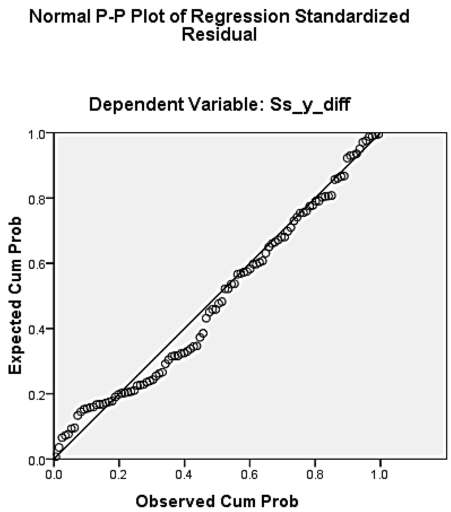


Figure 17 Assumption testing of multiple regression analysis: vertical change of Ss





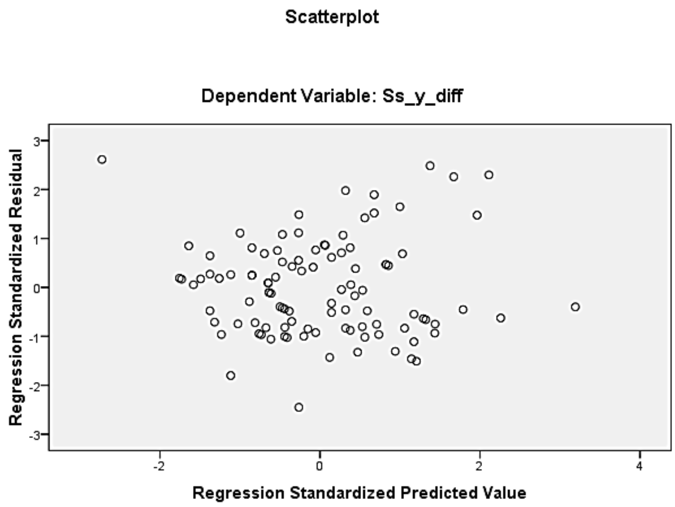
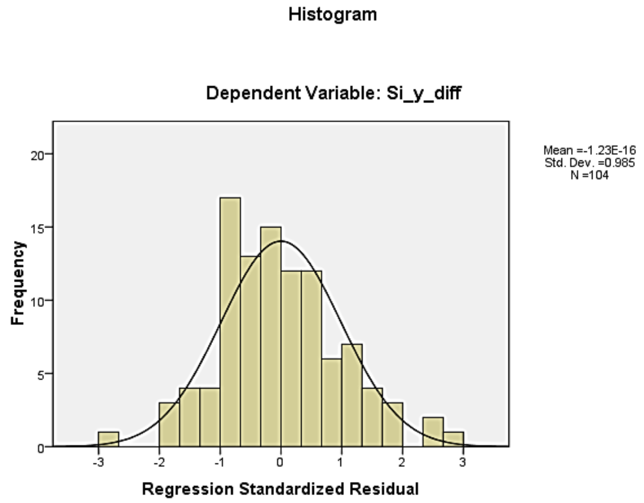
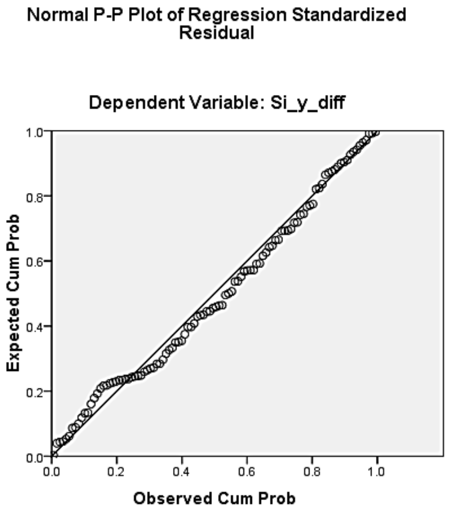


Figure 18 Assumption testing of multiple regression analysis: vertical change of Si





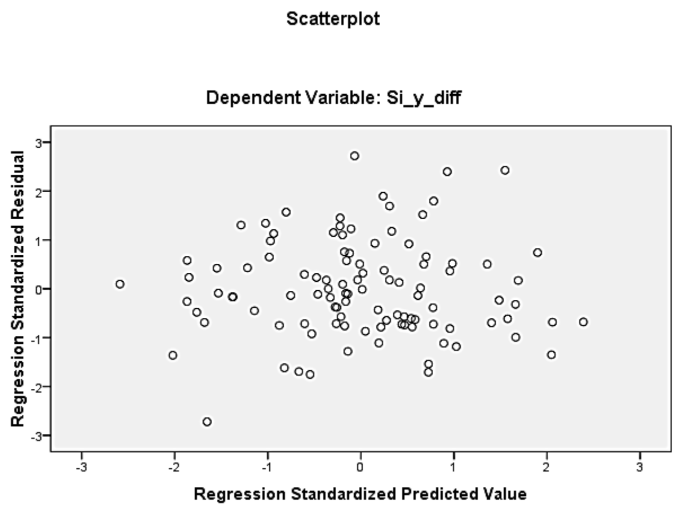
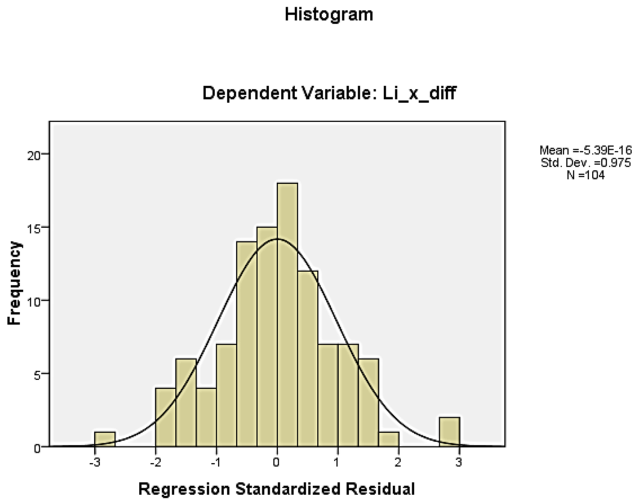
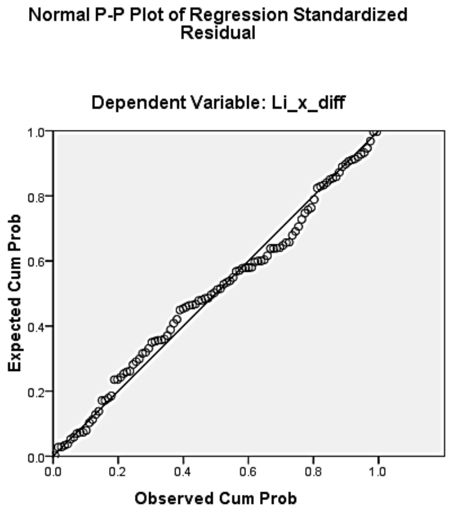


Figure 19 Assumption testing of multiple regression analysis: horizontal change of Li





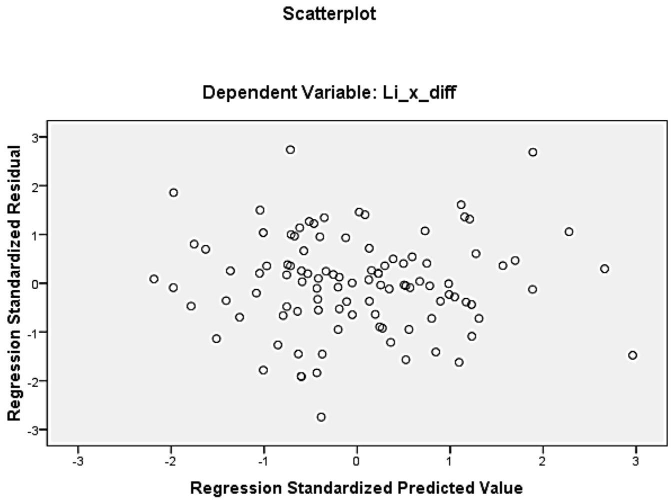


Figure 20 Assumption testing of multiple regression analysis: vertical change of Li

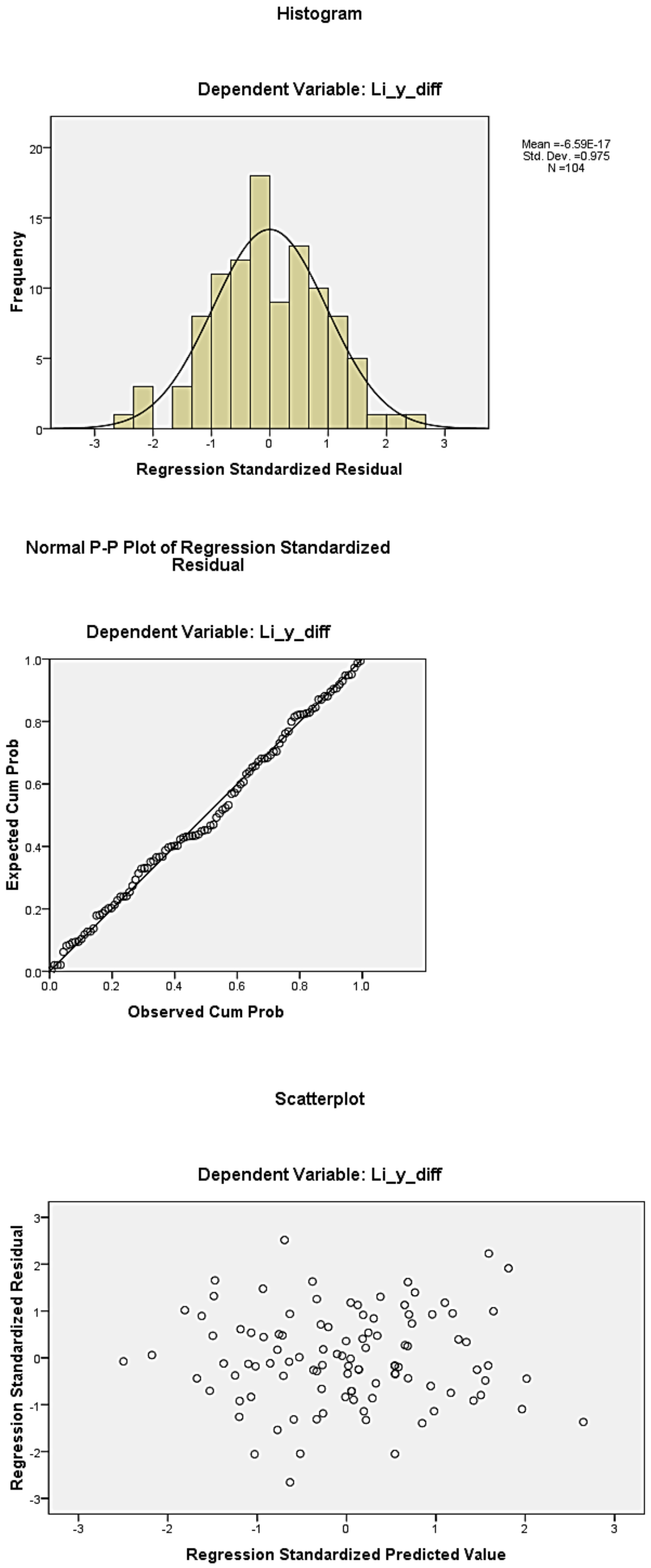
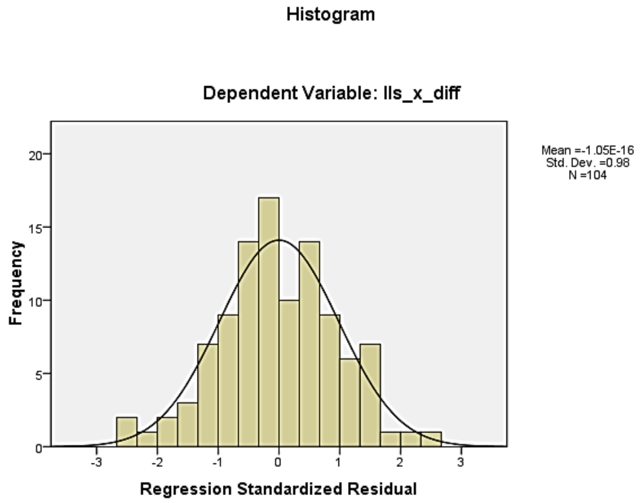
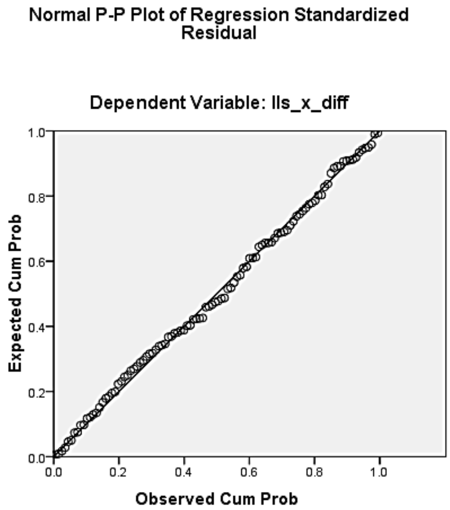


Figure 21 Assumption testing of multiple regression analysis: horizontal change of Ils





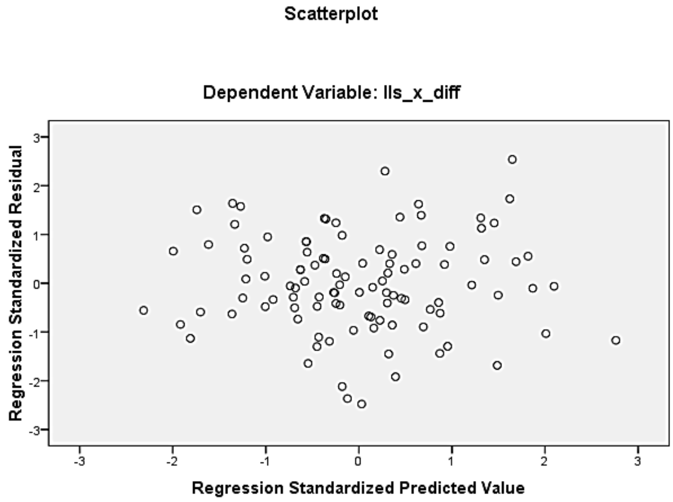
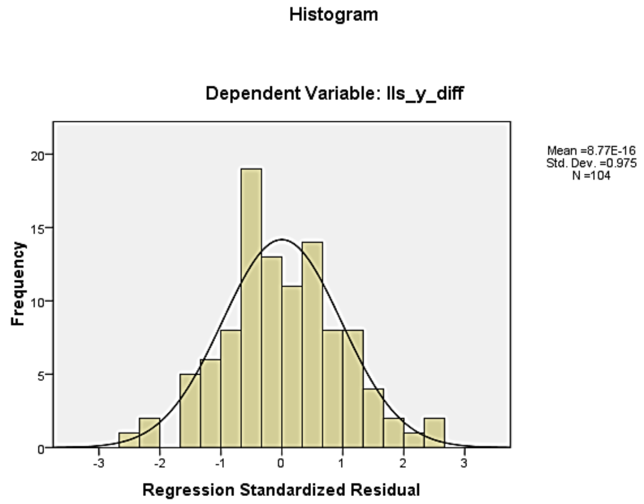
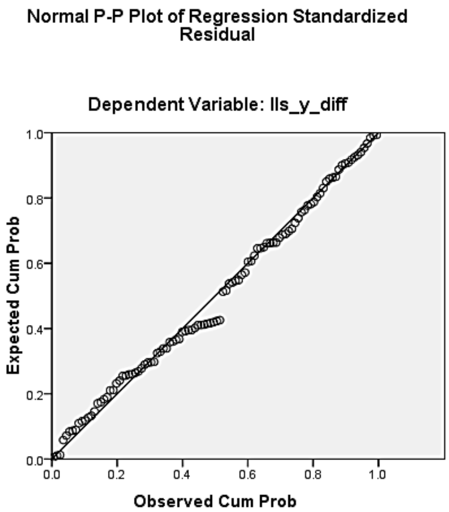


Figure 22 Assumption testing of multiple regression analysis: vertical change of Ils





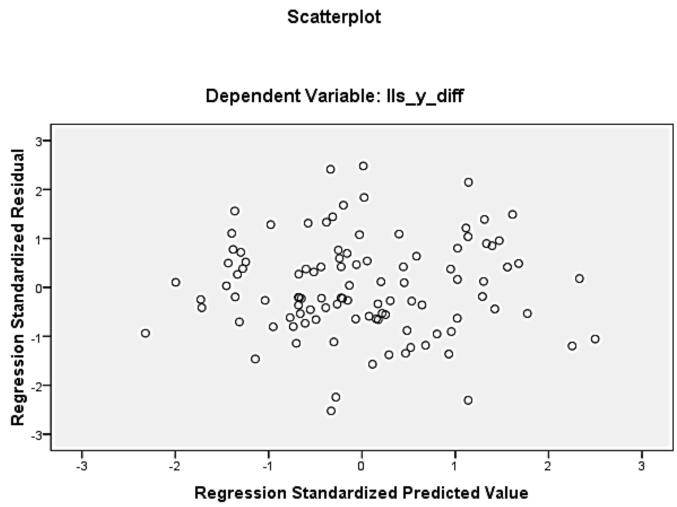


Figure 23 Assumption testing of multiple regression analysis: horizontal change of Pg’

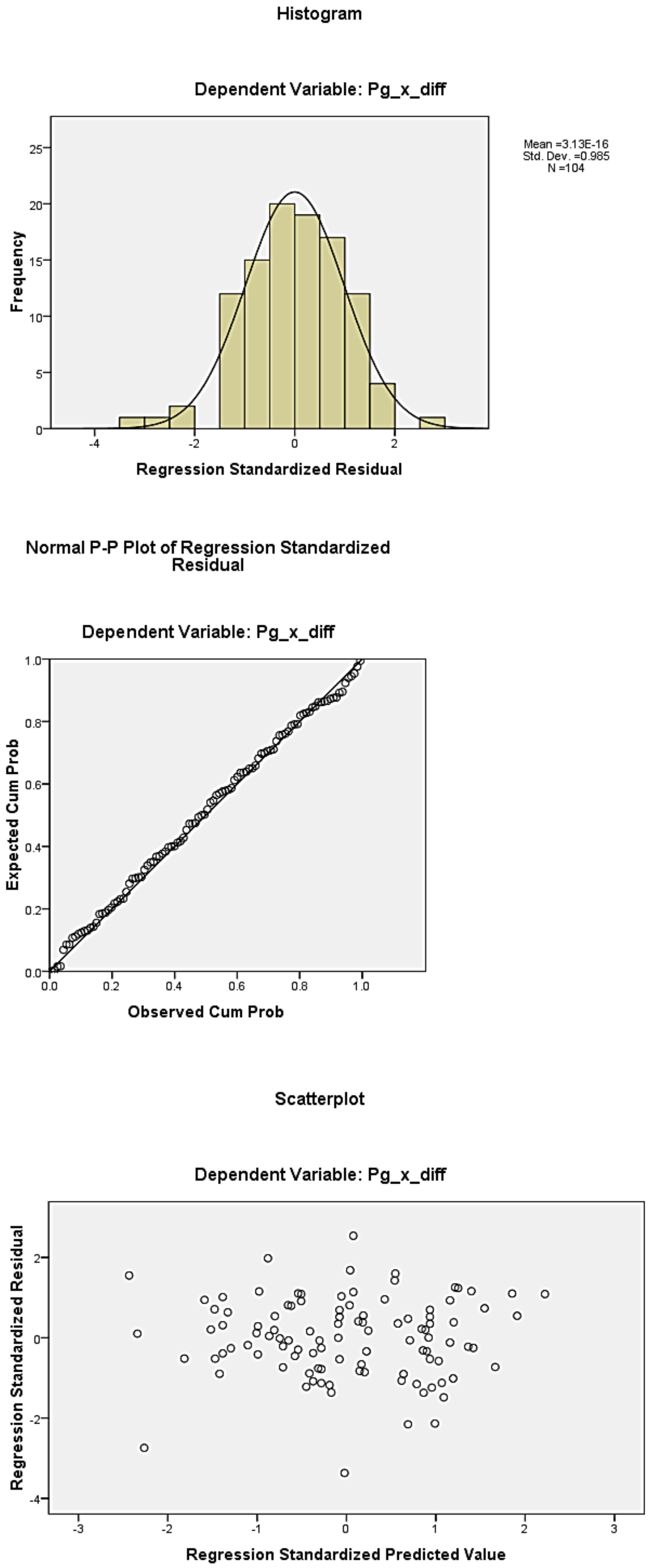
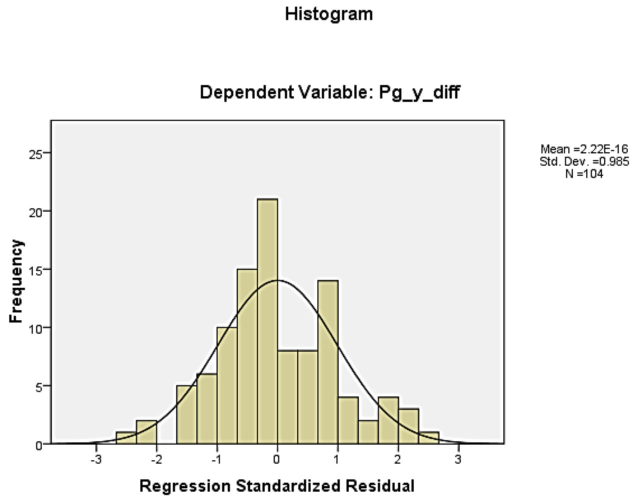
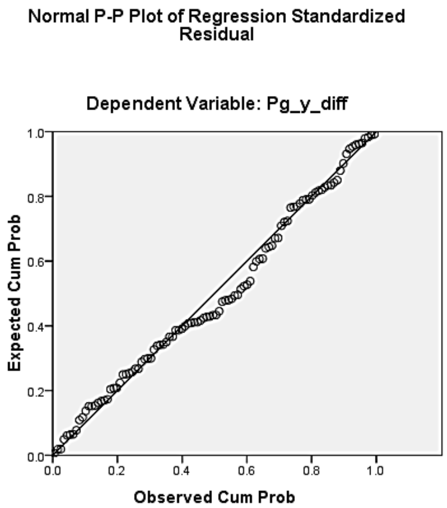


Figure 24 Assumption testing of multiple regression analysis: vertical change of Pg’





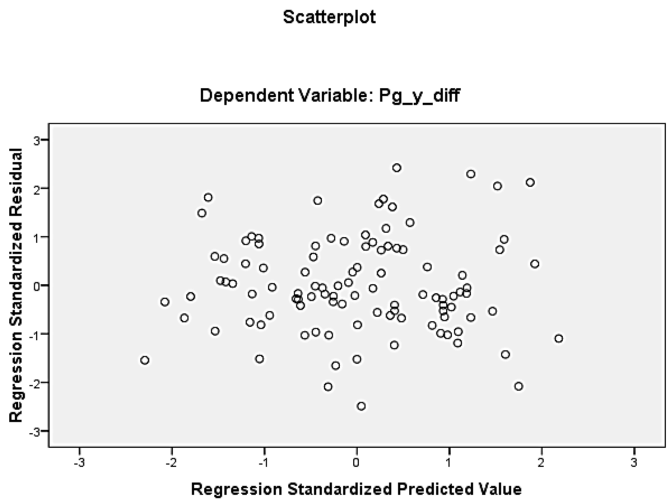
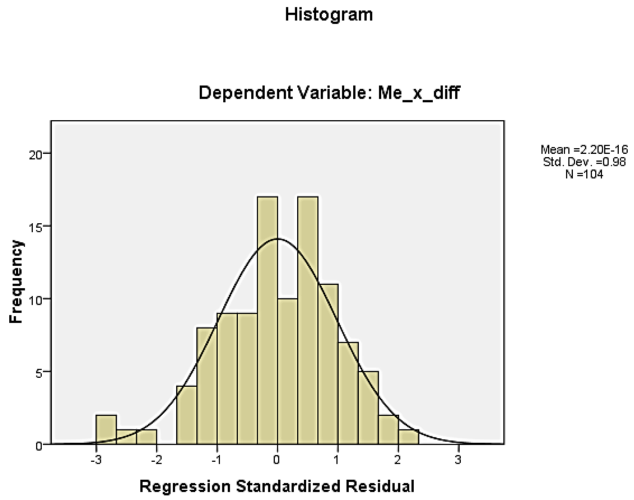
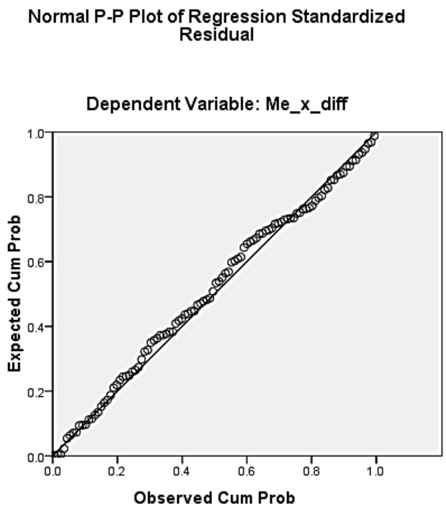


Figure 25 Assumption testing of multiple regression analysis: horizontal change of Me’





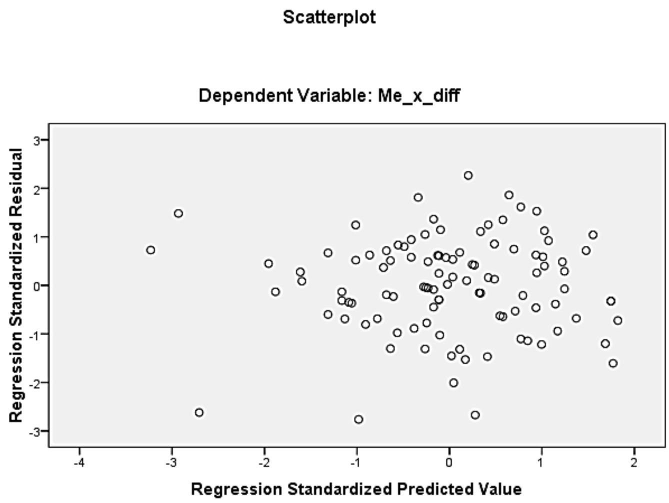
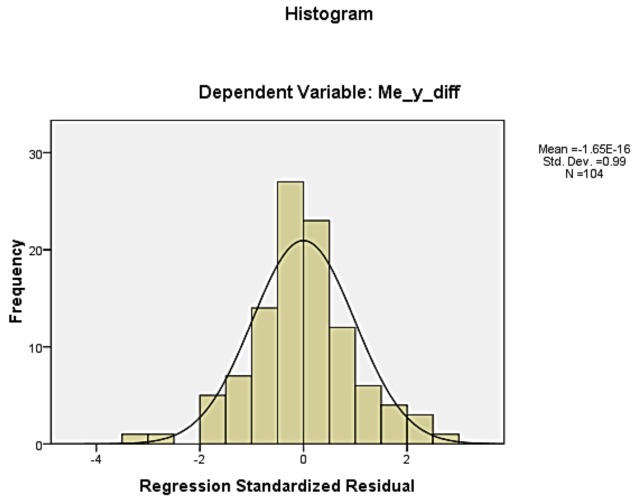
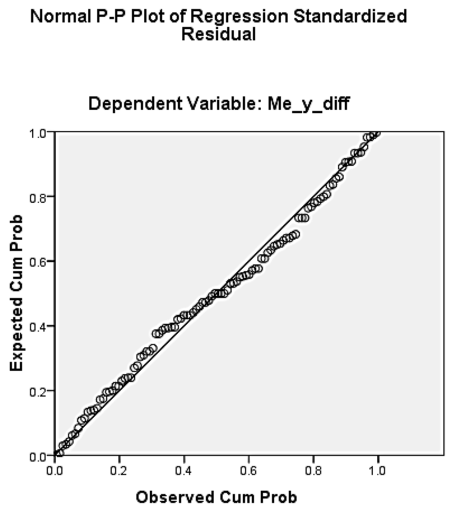
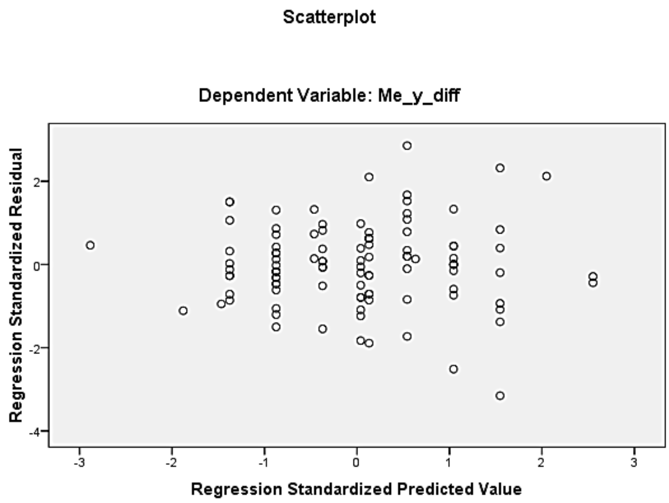


Figure 26 Assumption testing of multiple regression analysis: vertical change of Me’







VITA

Miss Suhatcha Maetevorakul was born on 4th January, 1985 in Bangkok. She received the Doctor of Dental Surgery (DDS) degree from Faculty of Dentistry, Chulalongkorn University in 2008. From 2009 to 2013, she worked as a general dentist at Wangmuangsatthum Hospital in Saraburi. Since 2014, she has studied the Master’s Degree of Science Program in Orthodontics at Department of Orthodontics, Faculty of Dentistry, Chulalongkorn University.