ASSESSING TREATMENT OUTCOMES FROM THE POSTGRADUATE ORTHODONTIC PROGRAM, CHULALONGKORN UNIVERSITY

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A Thesis Submitted in Partial Fulfillment of the Requirements
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การประเมินผลการรักษาจากหลักสูตรหลังปริญญา ภาควิชาทันตกรรมจัดฟัน จุฬาลงกรณ์มหาวิทยาลัย

น.ส.ธัญภัค คงบุญวิจิตร์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Field of Study	Orthodontics
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ธัญภัค คงบุญวิจิตร : การประเมินผลการรักษาจากหลักสูตรหลังปริญญา ภาควิชาทันตกรรมจัดฟัน จุฬาลงกรณ์มหาวิทยาลัย. (ASSESSING TREATMENT OUTCOMES FROM THE POSTGRADUATE ORTHODONTIC PROGRAM, CHULALONGKORN UNIVERSITY) อ.ที่ปรึกษาหลัก : อ.ทญ. ดร.สิริโฉม สาตราวาหะ

วัตถุประสงค์การศึกษาเพื่อประเมินคุณภาพของผลการรักษาทางทันตกรรมจัดฟันโดยใช้ดัชนีพาร์แอ็ซเซสเม็นทเรตติ้ง (พาร์) ดัชนีอเมริกันบอร์ดออฟออร์โทดอนทิคออบเจคทีพเกรดดิงซีซเท็ม (เอบีโอ-โอจีเอส) และการวิเคราะห์ภาพรังสีกะโหลกศีรษะด้านข้างในผู้ป่วยที่ได้รับการรักษาเสร็จสิ้นจากคลินิกหลักสูตรหลังปริญญา ภาควิชาทันตกรรมจัดฟัน จุฬาลงกรณ์มหาวิทยาลัย และเพื่อประเมินปัจจัยต่างๆ ที่อาจมีความสัมพันธ์ต่อผลการรักษาทางทันต-กรรมจัดฟัน

วัสดุและวิธีการ เก็บข้อมูลผู้ป่วยจำนวน 100 คนที่ได้รับการรักษาทางทันตกรรมจัดฟันเสร็จสิ้นตั้งแต่ปีค.ศ. 2017 เป็นต้นไป ซึ่งได้รับการรักษาโดยทันตกรรมจัดฟันแบบติดแน่นทั้งฟันบนและฟันล่างและมีประวัติการรักษาที่ครบถ้วน ไม่รวมผู้ป่วยที่มีความผิดปกติของกระดูกกะโหลกและใบหน้าหรือถอดเครื่องมือจัดฟันก่อนการรักษาเสร็จสิ้น ผู้วิจัยที่ได้รับการปรับมาตรฐานการวัดเพียงผู้เดียวจะเป็นผู้ทำการประเมินโดยวัดดัชนีดีไอ ดัชนีพาร์และวิเคราะห์ภาพรังสีกะโหลกศีรษะด้านข้างก่อนการรักษา เพื่อประเมินผลของการรักษาผู้วิจัยจะประเมินดัชนีเอบีโอ-โอจีเอส ดัชนีพาร์และวิเคราะห์ภาพรังสีกะโหลกศีรษะด้านข้างภายหลังการรักษาเสร็จสิ้น มีการเก็บข้อมูลผู้ป่วย ได้แก่ อายุ เพศ ประเภทการสบฟันแบบแองเกิล วิธีการรักษา และระยะเวลาในการรักษาร่วมด้วย ความเชื่อมั่นและความเที่ยงตรงของการวัดจะถูกประเมินโดยใช้สัมประสิทธิ์สหสัมพันธ์ภายในชั้น (ไอซีซี) ข้อมูลจะถูกวิเคราะห์โดยใช้สถิติทดสอบวิลค็อกซันชนิดอันดับที่มีเครื่องหมาย สถิติทดสอบเพียรสันไคสแควร์ สหสัมพันธ์แบบสเปียร์แมน การวิเคราะห์ถดถอยเอกนามและการวิเคราะห์ถดถอยพหุนาม

ผลการศึกษา จากผู้ป่วยทั้งหมด 100 คน เพศหญิงร้อยละ 58 เพศชายร้อยละ 42 อายุเฉลี่ย 19.22±7.01 ปี มีลักษณะการสบฟันผิดปกติประเภทที่ 1 ร้อยละ 33 ประเภทที่ 2 ร้อยละ 33 และประเภทที่ 3 ร้อยละ 34 ผู้ป่วยที่ได้รับการรักษาทางทันตกรรมจัดฟันเพื่ออำพรางความผิดปกติของโครงสร้างกระดูกร้อยละ 47 จัดฟันร่วมกับการผ่าตัดขากรรไกรร้อยละ 19 และจัดฟันสองระยะร้อยละ 5 ระยะเวลาการรักษาเฉลี่ย 36.28±8.21 เดือน ช่วงตั้งแต่ 14-57 เดือน ความน่าเชื่อถือภายในผู้สังเกตและความน่าเชื่อถือระหว่างผู้สังเกตกับผู้เชี่ยวชาญอยู่ในระดับดีมาก ผลการวิเคราะห์พบว่าค่าเฉลี่ยคะแนนดัชนีดีไอเท่ากับ 25.69±16.12 คะแนน ค่าเฉลี่ยคะแนนพาร์ก่อนและหลังการรักษาเท่ากับ 33.53±12.42 และ 0.48±0.67 คะแนน ตามลำดับ อยู่ในกลุ่มดีขึ้นอย่างมากร้อยละ 77 และกลุ่มดีขึ้นร้อยละ 23 ค่าเฉลี่ยคะแนนเอบีโอ-โอจีเอสเท่ากับ 11.38±6.34 คะแนน อยู่ในกลุ่มผ่านเกณฑ์ร้อยละ 91 และกลุ่มยังไม่มีข้อสรุปร้อยละ 9 ภายหลังการรักษาค่าเอเอ็นบี ค่าวิทซ์ ระยะระหว่างฟันหน้าล่างต่อเส้นเอ็นบี มุมระหว่างฟันหน้าบนและฟันหน้าล่าง ระยะริมฝีปากบนต่ออีไลน์และมุมเอชแองเกิลดีขึ้นอย่างมีนัยสำคัญทางสถิติ (ระดับนัยสำคัญ<0.01) จากการวิเคราะห์สหสัมพันธ์แบบสเปียร์แมนและการวิเคราะห์ถดถอยไม่พบความสัมพันธ์อย่างมีนัยสำคัญทางสถิติระหว่างคะแนนดัชนีดีไอ คะแนนพาร์ก่อนการรักษา อายุ และเพศต่อคะแนนพาร์ภายหลังการรักษาและคะแนนเอบีโอ-โอจีเอส ในขณะที่ค่าเอฟเอ็มเอก่อนการรักษาและระยะเวลาในการรักษามีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติต่อคะแนนพาร์ภายหลังการรักษา (ระดับนัยสำคัญ<0.05) และพบความสัมพันธ์อย่างมีนัยสำคัญทางสถิติระหว่างประเภทการสบฟันของแองเกิล ค่าเอเอ็นบี ค่าวิทซ์ มุมระหว่างฟันหน้าล่างต่อเส้นเอ็นบี วิธีการรักษาและระยะเวลาในการรักษาต่อคะแนนเอบีโอ-โอจีเอส (ระดับนัยสำคัญ<0.05)

สรุปผลการศึกษา ผู้ป่วยส่วนใหญ่ที่ได้รับการรักษาทางทันตกรรมจัดฟันจากคลินิกหลักสูตรหลังปริญญา ภาควิชาทันตกรรมจัดฟัน จุฬาลงกรณ์มหาวิทยาลัยมีผลการรักษาที่ดี โดยความรุนแรงของความผิดปกติของขากรรไกรก่อนการรักษาและระยะเวลาในการรักษาส่งผลต่อคุณภาพของผลการรักษาอย่างมีนัยสำคัญทางสถิติ

สาขาวิชา	ทันตกรรมจัดฟัน	ลายมือชื่อนิสิต ....
ปีการศึกษา	2563	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6270025532 : MAJOR ORTHODONTICS

KEYWORD: TREATMENT OUTCOMES, AMERICAN BOARD OF ORTHODONTICS OBJECTIVE GRADING SYSTEM, PEER ASSESSMENT RATING INDEX, LATERAL CEPHALOMETRIC ANALYSIS, ANGLE'S CLASSIFICATION, ORTHOGNATHIC SURGERY, CAMOUFLAGE TREATMENT, 2-PHASE TREATMENT

Tanyapak Kongboonvijit : ASSESSING TREATMENT OUTCOMES FROM THE POSTGRADUATE ORTHODONTIC PROGRAM, CHULALONGKORN UNIVERSITY . Advisor: SIRICHOM SATRAWAHA, D.D.S., Ph.D.

Objective: To evaluate the quality of orthodontic treatment outcomes by using Peer Assessment Rating index (PAR), American Board of Orthodontics Objective Grading System (ABO-OGS) and lateral cephalometric analysis in the cases completed from the postgraduate orthodontic clinic, Chulalongkorn University. And to determine whether any contributing factors correlate with the orthodontic treatment outcomes.

Materials and Methods: 100 patients who had completed treatment since 2017 were included in this study. Inclusion criteria included patients with full upper and lower edgewise appliances and completed treatment records. Exclusion criteria included patients with craniofacial syndromes or debond before treatment completion. One calibrated examiner assessed DI, pretreatment PAR index and lateral cephalometric analysis. To evaluated treatment outcomes, ABO-OGS, posttreatment PAR index and lateral cephalometric analysis were assessed. Patient data included age, gender, Angle's classification, types of treatment and treatment duration were also collected. The reliability and validity of the measurements were evaluated using the intraclass correlation coefficient (ICC). Data were analyzed with Wilcoxon signed ranks test, Pearson Chi-square test, Spearman rank correlation, univariate and multivariate linear regression models.

Results: Of the 100 patients, 58% were females and 42% were males. The mean age of the sample was 19.22±7.01 years. The types of malocclusion were included: 33% Class I, 33% Class II, and 34% Class III. 47% were camouflaged, 19% were surgery and 5% received 2-phase treatment. The average treatment time was 36.28±8.21 months, with a range from 14 to 57 months. ICC showed very good intra-observer and inter-observer reliability in every index. The analysis showed that the average DI score was 25.69±16.12 points. The mean pretreatment and posttreatment PAR scores were 33.53±12.42 and 0.48±0.67 points respectively. 77% were greatly improved and 23% improved. The average score of ABO-OGS was 11.38±6.34 points. 91% were in the pass group and 9% undetermined. After treatment, there were statistically significant improvements in ANB, Wits, LI-NB (mm), UI-LI, upper lip to E-line and H-angle (*p*-value<0.01). Spearman rank correlation and linear regression models showed no statistically significant correlation between DI score, pretreatment PAR score, age and gender to posttreatment PAR score and ABO-OGS score. Meanwhile, pretreatment FMA and treatment duration were statistically significant correlated with posttreatment PAR score (*p*-value<0.05). There were statistically significant correlation between initial Angle's classification, pretreatment ANB, Wits, LI-NB angle, types of treatment and treatment duration with ABO-OGS score (*p*-value<0.05).

Conclusion: Most of the patients treated in the postgraduate orthodontic clinic, Chulalongkorn University had satisfactorily orthodontic treatment outcomes. Initial severity of skeletal discrepancy and duration of treatment were significantly associated with the quality of the final outcomes.

Field of Study:	Orthodontics	Student's Signature ....
Academic Year:	2020	Advisor's Signature ....

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Tanyapak Kongboonvijit

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1.1 Background and rationale

Evaluating treatment outcomes for an orthodontic program is essential for guaranteeing quality control. Identifying problems is important for developing strategies to effectively improve treatment outcomes. Formally, it had been assessed by only using the subjective opinions of experienced clinicians. To reduce subjectivity in the evaluation of orthodontic treatment, it can be achieved with the use of quantitative outcome assessments.

Up to the present time, many indices have been constructed and used for assessing the quality of orthodontic treatment outcomes. First, the occlusal index (1), objected to epidemiologic objectives, has been purposed to measure treatment outcomes (2, 3). Nevertheless, the occlusal index is more suitable for assessing pretreatment rather than posttreatment records (4). Later, Richmond et al (5) had been developed the Peer Assessment Rating (PAR) index, which is more reliable. The objective of this index is to evaluate treatment needs and assess malocclusion at pretreatment and posttreatment periods. Thus, many studies used this PAR index to assess the quality of orthodontic treatment results (6-15).

Then, in 1998, the American Board of Orthodontics (ABO) had set up the Discrepancy Index (DI) which is used to evaluate orthodontic treatment complexity (16). They also introduced Objective Grading System (OGS) which is one of the indices that extensively accepted and widely used nowadays (4). The goal of the American Board of Orthodontics (ABO) is to set up and sustain the highest standards of orthodontics treatment outcomes. This index is an instrument to reduce subjectivity when evaluating cases submitted to the ABO for examination. It is the measurement of board quality results and helps to elevate the quality of orthodontic treatment. The ABO-OGS has been considered reproducible relies on extensive inter-examiner and intra-examiner reliability testing by many investigators (17). Thus, various studies used the ABO-OGS measurement to assess orthodontic treatment outcomes (14, 18-39).

Besides the dental cast and panoramic radiograph that are used to evaluate complexity and treatment outcomes in those indices mentioned above, lateral cephalogram is also an important instrument to diagnose the severity of malocclusion in each patient (10). This radiograph is a standard component of clinical records taken for orthodontic diagnosis and treatment planning. Using lateral cephalograms to assess pretreatment and posttreatment outcomes are essential. Thus, some studies used this radiograph to evaluate orthodontic treatment outcomes adjunct to dental cast (19, 30, 37, 38, 40).

Furthermore, various factors such as patient characteristics (27, 41, 42), treatment timing (43, 44), types of malocclusion (14, 24, 41, 43), extraction pattern (43) and association of orthognathic surgery (45) had also been studied to evaluate the association with the treatment outcomes, but the results remained controversial.

The purposes of this study are (1) to assess orthodontic treatment outcomes from the postgraduate orthodontic clinic, Chulalongkorn University by using PAR, ABO-OGS and lateral cephalometric evaluation, (2) to assess the contribution of various factors including age, gender, Angle's classification, types of treatment, treatment duration, DI score and pretreatment PAR score to the outcome scores (posttreatment PAR score and ABO-OGS score).

1.2 Research questions

1. What percentage of the acceptable case determined by ABO-OGS score in the cases completed from the postgraduate orthodontic clinic, Chulalongkorn University?

2. How much reduction in the mean PAR score in the cases completed from the postgraduate orthodontic clinic, Chulalongkorn University?

3. What percentage of the treated case that cephalometric parameters fall in a normal range?

4. What are the contributing factors that affect orthodontic treatment outcomes?

1.3 Research hypotheses

Ho_1: There are no statistically significant differences for any single component of the PAR score between the pretreatment and posttreatment periods.

Ha_1: There are statistically significant differences for any single component of the PAR score between the pretreatment and posttreatment periods.

Ho_2: There are no statistically significant differences for the percentage of treated cases that cephalometric parameters fall in a normal range between the pretreatment and posttreatment periods.

Ha_2: There are statistically significant differences for the percentage of treated cases that cephalometric parameters fall in a normal range between the pretreatment and posttreatment periods.

Ho_3: There are no statistically significant correlations between the contributing factors and orthodontic treatment outcomes.

Ha_3: There are statistically significant correlations between the contributing factors and orthodontic treatment outcomes.

1.4 Research objectives

1. To assess the PAR score and ABO-OGS score in the cases completed from the postgraduate orthodontic clinic, Chulalongkorn University.

2. To assess changes in the hard and soft tissue cephalometric parameters determined by ABO analysis in the cases completed from the postgraduate orthodontic clinic, Chulalongkorn University.

3. To determine whether any contributing factors (age, gender, Angle’s classification, types of treatment, treatment duration, DI score and pretreatment PAR score) correlate with the orthodontic treatment outcomes.

1.5 Benefits of this study

PAR, DI, ABO-OGS and lateral cephalogram analysis are the acceptable assessments used to evaluate the complexity of pretreatment malocclusion and orthodontic treatment outcomes. Using these assessments to evaluate treatment outcomes of orthodontic patients completed from the postgraduate orthodontic clinic, Chulalongkorn University helps set up and improve orthodontic treatment to reach ABO standard. Furthermore, determining factors influencing the successful treatment outcomes helps in treatment planning and predicting the treatment results.

1.6 Ethical consideration

This research was approved by the ethical committee of Faculty of Dentistry, Chulalongkorn University on December 4, 2020 (HREC-DCU 2020-115).

1.7 Conceptual framework

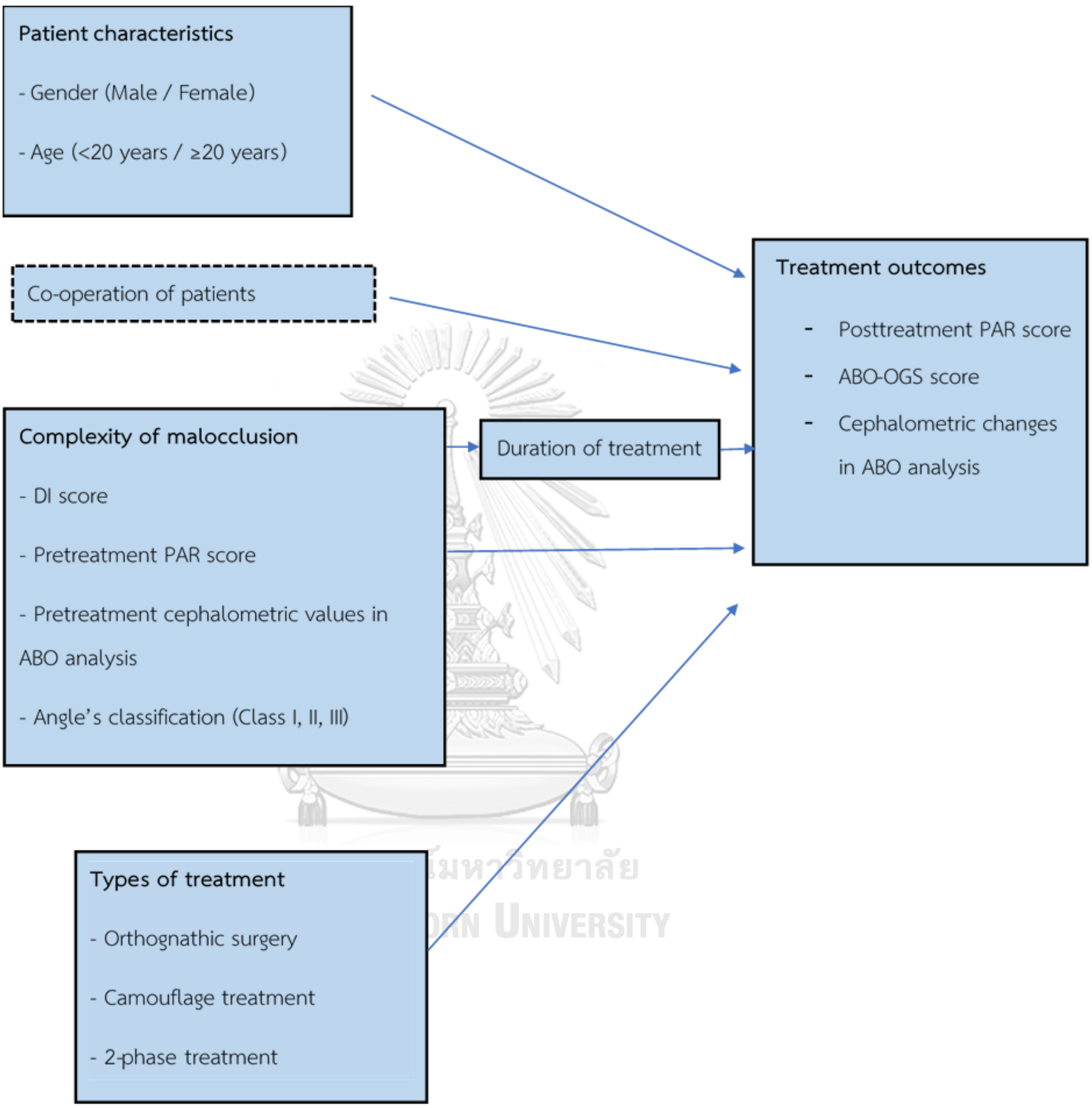

Figure 1 Conceptual framework

Chapter 2 Literature review

Over the years, many indices had been developed and used to evaluate the complexity of malocclusion and successfulness of orthodontic treatment outcomes. In the past, the clinicians had evaluated by using only the subjective opinions of experienced clinicians which were not up to standard. Thus, to reduce subjectivity in the evaluation of the complexity of cases and orthodontic treatment outcomes, nowadays it can be achieved with the use of quantitative outcome assessments.

2.1 Peer Assessment Rating (PAR index)

In 1987, the PAR index was invented by 10 experienced British orthodontists. They evaluated more than two hundred dental casts to stand for the results of the development of orthodontic treatment outcomes by assessing pretreatment and posttreatment phases (5).

The PAR index offers a sum of value from evaluating all the occlusal irregularities which are normally found in a malocclusion. The score gives an approximate of the deviation from ideal alignment and occlusion of cases. The difference in scores between the pretreatment and posttreatment periods can evaluate the degree of improvement. This PAR index measures discrepancies in anterior segment, right and left buccal segments, buccal occlusion, overjet, overbite and centreline (5).

Referring to Richmond et al (5), they defined the concept of normal occlusion as “all anatomical contact points being adjacent, with a good intercuspal mesh between upper and lower buccal teeth, non-excessive overjet and overbite”.

For buccal and anterior segments, they are divided into three segments including left buccal, right buccal and anterior part. Points are scored for both upper and lower arches. Buccal segments are recorded from the mesial anatomical contact point of the first molar to the distal anatomical contact point of the canine. For anterior segment, it is recorded from the mesial anatomical contact point of the canine on one side to the mesial anatomical contact point of the canine on the opposite side.

For the occlusal parts, crowding, spacing and impacted teeth are recorded. The shortest distance between contact points of adjacent teeth parallel to the occlusal plane is scored as displacement. The more values of the displacement, the more quantities of PAR scores. Because of the broad and extremely variable within the normal range, they exclude the displacements between first, second and third molars.

For an impacted tooth, it is recorded when the space for this tooth is less than or equal to 4 mm. Impacted canines are recorded in the anterior segment. Scores for the displacements and impactions are added, to sum up for an overall score for each segment.

For buccal occlusion, they are scored for both left and right sides, from the canine to the last molar. All irregularities in three planes of occlusion including the antero-posterior, vertical and transverse are recorded to sum for each buccal occlusion.

For overjet, it is recorded from the left to right lateral incisors. The most prominent aspect of any one incisor is recorded.

For overbite, it is also recorded from the left to right lateral incisors and the tooth which has the greatest overlap is recorded.

For centreline, it is defined by the discrepancy of centreline to the lower central incisors. The measurement is not recorded if there is a missing of a lower central incisor.

They considered a total PAR score of 10 or less to be acceptable alignment and occlusion and a PAR score of 5 or less to be an almost ideal occlusion. Furthermore, to improve the reliability and validity of this index, they assigned multipliers or 'weightings' to each component, including the overjet (x6), overbite (x2) and centreline (x4) and not included displacement measurements of the buccal segments to the total score. This method reflected relative importance and produced a new weighted PAR total score.

The degree of improvement and the success of treatment can be reflected by a reduction in PAR scores. The percentage reduction is assessed through the deduction of pretreatment and posttreatment scores divided by the pretreatment PAR score and multiplied by 100. The results of percentage reduction in PAR score can be categorized into 4 levels of improvement including "Great improvement" requiring 70% to 100% of percentage reduction, "Improvement" requiring 50% to 69% of percentage reduction, "Little improvement" requiring 30% to 49% of percentage reduction and "No improvement" requiring less than 30% of percentage reduction. Moreover, using the weighted version, it can be categorized into three groups for point and percentage reductions, including a score reduction of at least 22 points defined as 'Greatly improved', a reduction of at least 30% defined as 'Improved' and a reduction of less than 30% defined as 'Worse or no different' (46).

The PAR index was used in many studies to assess the improvement of orthodontic treatment outcomes (6-8, 10, 11, 14, 15). Referring to Zahran et al (15), to evaluate the efficiency and effectiveness of orthodontic treatment within United Kingdom secondary care, they used the PAR index to assess the improvement of 70 pretreatment and posttreatment outcomes. The result of this study found that the mean percentage PAR score reduction was 81.5%.

Dyken et al (7) compared 54 Board-accepted cases to 51 cases treated by orthodontic graduate students by using the PAR index. The results of this study showed no statistically significant difference in pretreatment and posttreatment PAR scores between the Board-accepted cases and the graduate student-treated cases. Nevertheless, the mean PAR score for the Board-accepted cases was significantly more reduced than the mean PAR score for the graduate student-treated cases.

Birkelane et al (6) used the PAR index to evaluate orthodontic treatment outcomes by collected 224 cases that were treated at the postgraduate, department of Orthodontics and Facial Orthopedics, University of Bergen. The cases included Angle class I, class II division 1 and division 2 and class III malocclusions. They measured in three points of time including pretreatment (T1), posttreatment (T2) and 5-year follow-up (T3). The results of this study showed a decrease in total PAR score from T1-T2 (77.8%) and T1-T3 (61.8%).

The PAR index can also be the tool to compare the effectiveness of each treatment approach and other various variables that might influence this score, for example, compared the outcomes of orthodontic treatment between cases that were completed by individual orthodontists and 2 orthodontists (26). Ponduri et al (12) compared the PAR score of posttreatment outcomes between orthodontic and orthognathic groups. Gu et al (9) compared the effectiveness and efficiency between the Invisalign system and conventional fixed appliances by using the PAR index.

As mentioned above, the PAR index is considered as an important assessment that can be used to evaluate orthodontic treatment outcomes. However, this index still has limitations (47), mainly due to the high weight assigned to overjet. Thus, there are difficulties to apply one weighting system to all malocclusions because occlusal features vary in different classes of malocclusion. Furthermore, if the initial scores of the PAR index are less than 22 points, it cannot become ‘greatly improved’ after treatment.

2.2 Discrepancy index (DI)

Initially in 1998, ABO had developed the Discrepancy Index (DI). The goal of assessing this index is to evaluate the complexity of cases for the ABO Phase III clinical examination by using standard pretreatment orthodontic records, including casts and cephalometric radiographs. First, there was a pilot study of the DI which was commenced to assess the complexity of cases treated by orthodontic residents to offer for board certification. The majority of these patients were adequately complicated to represent for the ABO Phase III examination, supporting the amount of the DI for choosing patients for board examinations (48).

This index is derived from measurements of overjet, overbite, anterior open bite, lateral open bite, crowding, occlusion, lingual posterior crossbite, buccal posterior crossbite, ANB angle, IMPA angle and SN-GoGn angle. The more scores of the DI, the more complex the case is (16).

According to Pulfer et al (49) who studied the relationship of the DI to the outcomes for routine malocclusions, they concluded that "the DI was a reliable and relatively stable index for measuring malocclusion complexity and it is an important indicator for estimating the difficulty expected in achieving an optimal result". Furthermore, this index can indicate the duration of orthodontic treatment (50, 51). The more scores of DI, the longer treatment time. Thus, the DI is a useful implement to expect orthodontic treatment time.

The DI is also found to be reliable for assessing malocclusion complexity. Not only the relatively, quickly and simply of the DI measurements, but this index also represents most disorders that have been treated by orthodontists. Thus, there are various studies that used the DI to evaluate the complexity of each pretreatment case (14, 18, 22, 31, 36, 52).

Referring to Deguchi et al (52), they compared the DI between the postgraduate orthodontic clinics at Okayama University (OU) and Indiana University (IU). They found that the mean of DI scores were 19 for OU and 17 for IU. OU patients scored significantly more DI points for crowding and mandibular plane angle compared with IU patients (p-value<0.05). On the contrary, they lost significantly fewer DI points for overbite and occlusion compared with IU patients (p-value<0.05). These results helped determine the severity of malocclusion in Asian patients.

2.3 American Board of Orthodontics Objective Grading System (ABO-OGS)

As mentioned before, the American Board of Orthodontics had invented two indices including Discrepancy Index (DI) and Objective Grading System (OGS). The DI is used to quantify the severity of a malocclusion whereas the ABO-OGS is used to assess the quality of orthodontic finishing. The ABO-OGS for scoring dental casts and panoramic radiographs include eight criteria: alignment, marginal ridges, buccolingual inclination, occlusal relationship, occlusal contacts, overjet, interproximal contacts and root angulation. The ABO-OGS provides a method for an objective assessment of the outcome and achievement of orthodontic treatment (4). According to this acceptable standard index, many studies used the ABO-OGS measurement to assess orthodontics treatment outcomes (18-24, 38). Some studies used this index to compare the outcomes from each orthodontic approach (27, 31, 33, 35-37) or other variables that they were interested in (14, 25, 26, 28, 29, 32, 34, 39), for example, compared the scores between cases that were completed from orthodontists and general dentists (25) or between university and private-practice orthodontic treatment outcomes (29, 34), etc.

Referring to Neoh et al (19), they used the ABO-OGS to compare orthodontic treatment outcomes between the passed, undetermined and failed groups divided by ABO-OGS score. By in the passed group, the score of ABO-OGS was 20 points or fewer, in the undetermined group, the score was 21-30 points and in the failed group, the score was more than 30 points. Their samples were collected from cases that were submitted for the Thai Board of Orthodontics examination. The total sample size was 194 samples. They found significant differences between these three groups in the mean of total ABO-OGS score and all ABO-OGS components except interproximal contacts and root angulation in maxilla. They also studied the correlations between ABO-OGS components with total ABO-OGS score and found that there were significant correlations at a moderate level for all variables except for interproximal contacts and maxillary root angulation.

Santiago et al (20) used the ABO-OGS to evaluate orthodontic treatment outcomes which were completed from the University of Puerto Rico's Orthodontic Graduate Program Clinic. The result was 53% of the completed cases at the university clinic obtained a potential passing score as per the ABO-OGS (<30 points).

Campbell et al (21) evaluated 399 patients which completed orthodontic treatment from the graduate orthodontics clinic at Indiana University School of Dentistry from 1998 to 2003. They reported that 46.1% of the cases which fit the ABO categories had ABO-OGS score less than 30 which mean passed and the most common deficiencies for ABO-OGS outcomes were lack of occlusal contacts.

Sunanta et al (43) assessed 100 cases which were selected from the posttreatment records of the Mahidol university postgraduate students submitted to the Thai Dental Board of Orthodontics certification to determine the quality of treatment outcome by using the ABO-OGS, they found that 62 cases (62%) received a passing score (≤ 20points), 35 cases (35%) received a borderline passing score (21-30 points) and the other 3 cases (3%) failed (> 30 points). By marginal ridges and buccolingual inclination were the most common deficiencies and interproximal contacts component was the least deductive points for ABO-OGS.

Furthermore, some researchers studied the relationship between the DI or the PAR index to ABO-OGS score. Referring to Campbell et al (21), they found that the ABO-OGS score was certainly correlated with the DI score, indicating that patients with higher DI score had more complicated malocclusion and were more difficult to finish.

Opposing to Cansunar et al (18) who studied the relationship between pretreatment case complexity and orthodontic treatment outcomes. They found no significant correlation between the total the DI and the total ABO-OGS score. Nevertheless, pretreatment overbite, lateral open bite, crowding, buccal posterior crossbite and other components affected the total ABO-OGS score significantly. They concluded that the complexity of each pretreatment case could affect the posttreatment clinical outcomes significantly.

Chalabi et al (53) evaluated orthodontic treatment outcomes by using the PAR index and the ABO-OGS. The results showed no statistically significant association between the ABO-OGS and the PAR index. Their conclusions were the PAR index could not replace the ABO-OGS for evaluating treatment outcomes and the ABO-OGS could not detect the improvement achieved in a treated case. Meanwhile, the PAR index could evaluate how improved cases were.

2.4 The validity and reliability of the DI, PAR and ABO-OGS assessments

Validity is used to explain how well the collected data covers the actual area of investigation. Thus, it simply means “measure what is intended to be measured”. While reliability concerns the extent to which a measurement of a phenomenon provides stable and consistent results. Reliability is also concerned with repeatability. For example, a scale or test is said to be reliable if repeat measurements made by it under constant conditions will give the same result (54).

Lui et al (55) showed the reliability of the DI and PAR Index. Both indices were calculated from measurements made on study casts and cephalometric radiographs. Ten randomly selected cases were used in preliminary calibration sessions. Each examiner individually evaluated each case three times within a five-day interval. Intraclass Correlation Coefficient (ICC) was used to test the intra-examiner and inter-examiner reliability. They repeated three calibration sessions until there was no category with an ICC value of less than 0.75. After 4 weeks of calibration, each examiner measured all patients in the final sample. They concluded that inter-examiner reliability of the DI and PAR index measured by the three residents with ICC value was excellent which were 0.990 and 0.964, respectively at p-value<0.001.

Referring to Richmond et al (5), they studied the reliability and validity of the PAR index. They found that this index had excellent reliability. The reliability was exhibited within and between examiners (ICC, r>0.91). For the validation of the PAR Index, it was carried out by a panel of 74 examiners to evaluate the extent to which the index could reflect current British orthodontic opinion by assessing 234 pretreatment and posttreatment study models. The results showed a high level of agreement between PAR and the panel's opinion. Furthermore, to reflect their significance, the validity of PAR index could improve by applying weightings (multipliers) to each component as mentioned before. The weighted component scores were then added together to give an overall total weighted PAR score. It showed that "the components of the PAR Index have been weighted to reflect current British dental opinion more closely". By the inter-examiner ICC of weighted version was 0.93, slight improvement over unweighted PAR (r=0.91). For the validation of weighted PAR index, it gave a statistically significant higher correlation with the mean deviation from normal occlusion than the unweighted PAR (p-value<0.001). By the correlation coefficient of weighted version was 0.85 compared to 0.74 of unweighted one. Thus, they concluded that the PAR Index was a uniform and standard assessment in evaluating orthodontic treatment outcomes.

Referring to Lieber et al (17), they randomly collected 36 posttreatment study casts from six different orthodontic offices to test the reliability of the study model-scoring system of the American Board of Orthodontists and used Spearman rank coefficient, Wilcoxon, Kruskal-Wallis and Mann-Whitney tests to calculated intra-examiner and inter-examiner reliability. They found that for the overall total ABO-OGS score, the average correlation was 0.77. The greatest intra-examiner correlation was occlusal relationship and the least was interproximal contact. Inter-examiner correlation for ABO score averaged *r*=0.85. The greatest correlation was buccolingual inclinations and the least was overjet.

2.5 Lateral cephalometric analysis

Not only assessment of occlusion, the changes of dental, skeletal patterns and soft tissue profile in cephalometric radiographs are also an important record for evaluating orthodontic treatment outcomes. Referring to Song et al (40), they studied the assessment of the reliability of experienced Chinese orthodontists in evaluating treatment outcomes by using three diagnostic orthodontic records including study casts, lateral cephalometric images and facial photographs. The results showed that study casts were the most significant predictive element. Furthermore, combined with lateral cephalometric films and facial photographs also aided in a more comprehensive evaluation.

For the reliability of the cephalometric analysis, according to Durão et al (56), they studied and evaluated the accuracy of two-dimensional (2D) cephalometric analysis compared to measurements on skulls. The result of this study showed statistically significant differences between cephalometric and direct craniometric measurements. However, for the inter-examiner reliability, no significant differences were observed between measurements by the two observers (*p*-value<0.05). Thus, they concluded that “radiographic linear measurements systematically overestimated the direct linear measurements performed on the skulls”. Nevertheless, the differences of those measurements were found most often less than 1 mm, which assumed that there was clinically acceptable.

Techalertpaisarn and Nilsuwankosit (57) compared cephalometric measurements between computerized and manual method. The computer program was developed by the investigators using an input device by a flatbed scanner and the image was saved in a GIF file. Used a mouse to locate the landmarks through the monitor then the program will calculate in ABO analysis, Rickett’s analysis and also analysis for orthognathic surgery patients. The results showed no statistically significant differences between these two methods (less than 0.5 mm and 0.5 deg) and also found high positive correlation in every cephalometric measurements.

Referring to Sorathesn (58), he collected 100 Thai facial profiles and developed lateral cephalometric norms for Thai males and females. The results showed not only the difference between Caucasians and Thais but also between gender.

Various studies also use lateral cephalometric images to evaluate orthodontic treatment outcomes combined with dental casts (19, 30, 37, 38). According to Tahir et al (38), they studied the changes in occlusion, cephalometric skeletal and dental variables, soft tissue variables and root resorption of the American Board of Orthodontics cases. Focusing on cephalometric hard and soft tissue relationships, 10 cephalometric radiographs were retraced and re-digitized twice with 7 days between trials. Matched pair t-tests were used to test for significant differences between these two trials. The result of this error test found no significant differences at *p*-value<0.05, indicating that cephalometric measurements were reproducible. This study used an acceptable range (AR) as a goal of treatment which was obtained from mean values and standard deviations from the Michigan Growth Study Standards for each variable, based on age and sex of each patient. They concluded that “in all the ABO cases, ideal overjet and overbite were attained. Cephalometrically, the mandibular plane and the Y-axis angle showed no significant change as a result of treatment. However, skeletal dysplasia (ANB) and skeletal convexity (Na-A-Po) showed improvement. Dentally, the maxillary incisor position and inclination, the interincisal angle and the lower incisor position ended within the acceptable range, whereas the lower incisors were proclined. Soft tissue variables also improved, lip balance and harmony, closure at rest and closure without strain all improved and for the nasolabial angle showed little change.

Daniels et al (30) studied posttreatment outcomes of severe Class II Division I malocclusion patients treated with surgical or non-surgical approaches by using occlusal outcomes (ABO-OGS) and cephalometric outcomes. For cephalometric variables, 10 radiographs were traced twice with two weeks between trials for intra-examiner reliability and a second examiner traced the same ten later to compare results for inter-examiner reliability and reported with >0.90 correlation found for both intra-examiner and inter-examiner reliability. They used ANB, FMIA, IMPA, U1-SN, overbite, overjet to compare the change of treatment outcomes. The results of this study showed that there was a significantly larger reduction in ANB angle and greater increased proclination of maxillary incisors in surgical group compared to non-surgical group (*p*-value=0.002) with no significant difference in ABO-OGS score.

Profit et al (37) compared treatment outcomes for skeletal Class II malocclusion between surgical and non-surgical groups determined by measuring cephalometric and dental cast changes. For cephalometric evaluation, 10 cephalometric radiographs were remeasured and found that the intraclass correlation was greater than 0.97 for all measurements. Pretreatment and posttreatment cephalometric radiographs were digitized and measured in two approaches which were whether the final value for a measurement criterion fell within the normal range and the quantitative amount of correction produced relative to an ideal value. They found that in surgical group, there were greater reduction of overjet and greater improvement in most cephalometric skeletal, dental and soft tissue criteria compared to non-surgical one.

2.6 Factors influencing orthodontic treatment outcomes

Treatment outcomes can be affected by many factors, classified as patient factors, operator factors and appliance factors. Patient factors include patient compliance, gender, age, initial malocclusion and patient discomfort. Operator factors include number of operators, operator workplace and operator experience. While appliance factors include bracket design, archwires, bonding material, types of appliance, number of treatment phases and extraction or non-extraction treatment (59). Some studies had determined the correlation between these various factors to treatment outcomes (14, 24, 27, 41-43).

Referring to Quach et al (41) studied factors influencing orthodontic treatment outcomes in South East Wales. They assessed the correlations among age, gender, types of malocclusion and appliance type to posttreatment PAR score (≤5 points=high quality of outcome achieved) by using multivariate logistic regression. And used multiple linear regression to assess correlation among these predicting factors to the change in PAR score. The results showed no correlation between types of malocclusion and posttreatment PAR score (≤5 points) but initial malocclusion class II and class III gave a greater change in PAR score compared to class I, 2.83 and 5.66 points higher, respectively. For the appliance type, patients who used functional appliances before fixed appliances had achieved greater quality of treatment outcomes, defined by statistically significant of both posttreatment PAR score and change in PAR score. Whereas age and gender did not correlate with both posttreatment PAR score and change in PAR score.

Klaus et al (42) studied influencing factors that might affect treatment outcomes by comparing patients with excellent and unacceptable orthodontic treatment results. The samples were patients who completed treatment at the Department of Orthodontics of the Justus-Liebig-University Giessen, Germany between 1993 and 2009. They divided samples into 2 groups which are excellent or unacceptable groups according to the Ahlgren index (60). The excellent group was defined as patients with normal occlusion, as close to Angle's ideal occlusion as possible. While patients with remaining malocclusion at the end of treatment were categorized as an unacceptable group. Gender distribution was differed between the excellent and unacceptable groups by females had predominated in the excellent group (55.3%). Whereas the mean age at the start of treatment and Angle's classification differed insignificantly between groups. There are also no differences in transverse occlusion and overjet. On the contrary, overbite was significantly different between the excellent and unacceptable cases (*p*-value=0.005). By in the unacceptable group, 44.6% were patients with open bite or open bite tendency (overbite<2 mm) compared to 26.1% in the excellent group. While those with deep bite (overbite>3.5 mm) were slightly more frequent in the excellent group, 55.3% compared to 42.9% in the unacceptable group. Furthermore, the PAR index between these two groups was also compared and found statistically significant lower PAR score in the excellent group (*p*-value<0.001).

For the ABO-OGS, Anthopoulou et al (27) studied the association between ABO examination success and predictors including treatment modality, age and sex by using univariate and multivariate logistic regression analyses. They found that all predictors did not significantly correlate to this score, referring that these factors did not affect successful ABO examinations. Furthermore, according to malocclusion complexity, Struble and Huang (14) found that Class I malocclusion seemed to have some advantage for accomplishing passing ABO-OGS scores. Whereas Yang et al. (24)

and Sunanta et al (43) found no differences in ABO-OGS score among the Angle’s classification. Likewise, when comparing ABO-OGS score based on the level of DI scores (43).

Chapter 3 Research methodology

3.1 Study Design

Retrospective study

3.2 Study population

Patients completed orthodontic treatment from the postgraduate orthodontic program, Chulalongkorn University.

3.3 Sample size

According to the sample size estimation formula for testing infinite population proportion mentioned below:

$$n = \frac{z^2_{1-\frac{\alpha}{2}} p(1-p)}{d^2}$$

The sample size calculation from n4Studies: For estimating the infinite population proportion: Proportion (p) = 0.46, Error (d) = 0.10, Alpha (α) = 0.05, Z(0.975) = 1.959964

The proportion of cases that passed ABO-OGS scores from the study of Campbell et al (21) was calculated according to the formula above. The result indicated that the sample size was 96 subjects in total.

3.4 Study sample

The sample for this retrospective study was randomized by multistage stratified random sampling from the cases treated by orthodontic residents in the faculty of Dentistry, Chulalongkorn University since 2017 based on the inclusion and exclusion criteria. A total of 100 patients were collected. All markings that can identify the patients and the clinicians were removed from all the records.

3.5 Inclusion criteria

- Patients with full upper and lower edgewise appliances.
- Patients with availability of completed treatment records including dental casts, lateral cephalograms and panoramic radiographs.

3.6 Exclusion criteria

- Patients with craniofacial syndromes or cleft lip and palate.
- Patients who debond before treatment completion.

In total, 100 samples were collected divided by

- Gender: Male, Female
- Age: <20 years, ≥20 years
- Angle’s classification: Class I, II, III
- Types of treatment: Camouflage treatment, orthognathic surgery and 2-phase treatment

Furthermore, the duration of treatment was also collected.

3.7 Assessments

Clinical records of selected subjects were reviewed for data collection. This review included orthodontic treatment records, pretreatment and posttreatment orthodontic dental casts, panoramic radiographs and lateral cephalograms.

Pretreatment assessments included:

- Dental casts scored with DI and PAR index.
- Lateral cephalograms analyzed with ABO analysis.

Posttreatment assessments (day of debond) included:

- Dental casts scored with PAR index and ABO-OGS.

- Panoramic radiographs scored with ABO-OGS.
- Lateral cephalograms analyzed with ABO analysis.

Discrepancy Index (DI)

The elements chosen to bring up the DI were measurements of overjet, overbite, anterior open bite, lateral open bite, crowding, occlusion, lingual posterior crossbite, buccal posterior crossbite, ANB, IMPA and SN-GoGn angle. The methods to evaluate those elements are shown below:

Table 1 DI measurements

Overjet 0 mm (edge to edge) = 1 1-3 mm = 0 point 3.1-5 mm = 2 points 5.1-7 mm = 3 points 7.1-9 mm = 4 points >9 mm = 5 points Negative overjet (crossbite) 1 point per mm per tooth	**Occlusion** Class I to end on = 0 point End on class II or III = 2 points per side Full class II or III = 4 points per side Beyond class II or III = 1 point per mm additional
Overbite 0-3 mm = 0 point 3.1-5 mm = 2 points 5.1-7 mm = 3 points Impinging (100%) = 5 points	**Lingual posterior crossbite** 1 point per tooth
Anterior open bite 0 mm (edge to edge) = 1 Then 2 points per mm per tooth	**Buccal posterior crossbite** 2 points per tooth
Lateral open bite 2 points per mm per tooth	**Cephalometrics** ANB>5.5 deg or <-1.5 deg = 4 points Each additional degree = 1 point SN-GoGn 27-37 deg = 0 point

	Cephalometrics SN-GoGn>37 deg = 2 points per deg SN-GoGn<27 deg = 1 point per deg IMPA>98 deg = 1 point per deg
Crowding 0-3 mm = 1 point 3.1-5 mm = 2 points 5.1-7 mm = 4 points >7 mm = 7 points	**Other** 2 points Indicate problem: ______________________

According to Cansunar et al (18), the cases were divided into 3 groups including low, medium and high DI groups.

- The low DI group contained cases that score ≤7.
- The medium DI group contained cases that score 8–16.
- The high DI group contained cases that score ≥17.

Peer Assessment Rating (PAR index)

In this study, we assessed maxillary anterior segment alignment, mandibular anterior segment alignment, anteroposterior discrepancy, transverse discrepancy, vertical discrepancy, overjet, overbite and midline to obtain the total PAR score. The methods of measurements of each irregularity are mentioned below:

Table 2 PAR index measurements

Displacement measurements

Score	Discrepancy
0	0-1 mm
1	1.1-2 mm
2	2.1-4 mm

Score	Discrepancy
3	4.1-8 mm
4	Greater than 8 mm
5	Impacted teeth

If the space between the adjacent teeth was less than or equal to 4mm, a tooth was defined as impacted. For the mixed dentition case which had a chance for crowding, the space deficiency was calculated using average mesio-distal widths. If the remaining space for an unerupted tooth was 4 mm or less an impaction was recorded.

Buccal occlusion measurements

Score	Discrepancy
Antero-posterior	
0	Good interdigitation Class I, II and III
1	Less than half unit discrepancy
2	Half a unit discrepancy (cusp to cusp)
Vertical	
0	No discrepancy in intercuspation
1	Lateral open bite on at least two teeth greater than 2 mm
Transverse	
0	No crossbite
1	Crossbite tendency
Transverse	
2	Single tooth in crossbite
3	More than one tooth in crossbite
4	More than one tooth in scissor bite

Overjet measurements

Score	Discrepancy
Overjet	
0	0-3 mm
1	3.1-5 mm
2	5.1-7 mm
3	7.1-9 mm
4	Greater than 9 mm
Anterior cross-bites	
0	No discrepancy
1	One or more teeth edge to edge
2	One single tooth in crossbite
3	Two teeth in crossbite
4	More than two teeth in crossbite

Overbite measurements

Score	Discrepancy
Open bite	
0	No open bite
1	Open bite less than and equal to 1 mm
2	Open bite 1.1-2 mm
3	Open bite 2.1-3 mm
4	Open bite greater than or equal to 4 mm
Overbite	
0	Less than or equal to one third coverage of the lower incisor
1	Greater than one-third, but less than two-thirds coverage of the lower incisor
2	Greater than two-thirds coverage of the lower incisor
3	Greater than or equal to full tooth coverage

Centreline measurements

Score	Discrepancy
0	Coincident and up to one-quarter lower incisor width
1	One-quarter to one-half lower incisor width
2	Greater than one-half lower incisor width

The total score indicated the deviation from normal alignment and occlusion of each case. A zero-score referred to good alignment and higher scores implied increased levels of abnormality. The total scores were recorded on the pretreatment and posttreatment dental casts. The degree of improvement, as a result of orthodontic treatment, was confirmed by the difference between these scores.

For the weighted version of the PAR score, we added multipliers to each component, including the overjet (x6), overbite (x2) and centreline (x4). To assess the improvement level, pretreatment and posttreatment of PAR scores were calculated by using the formula indicated by Richmond et al (46).

- The worse group contained cases with less than 30% reduction in weighted PAR score.

- The improved group contained cases with at least a 30% reduction in weighted PAR score.

- The greatly improved group contained cases with either weighted PAR score reduction of 22 points or more.

American Board of Orthodontics Objective Grading System (ABO-OGS)

Scoring the ABO-OGS, all casts and panoramic radiographs were evaluated. For each case, eight measurements were assessed and the points were subtracted for any discrepancy from the ideal. The measurement criteria of the ABO-OGS were alignment, marginal ridges, buccolingual inclination, occlusal contacts, occlusal relationship, overjet, interproximal contacts and root angulation. The methods to evaluate those elements are shown below:

Table 3 ABO-OGS measurements

Alignment/Rotations 0.5-1 mm = 1 point for each tooth >1 mm = 2 points for each tooth	**Occlusal contacts** 0 mm = satisfactory ≤1 mm = 1 point for each posterior tooth out of contact >1 mm = 2 points for each posterior tooth out of contact *Do not score diminutive distolingual cusps of the maxillary 1^{st} and 2^{nd} molars, nor lingual cusps of the mandibular first premolars. Maximum of 2 points per tooth.
Marginal ridges 0.5-1 mm = 1 point for each proximal contact between posterior teeth >1 mm = 2 points for each proximal contact between posterior teeth *Do not include the canine-premolar contact. Do not include the distal of lower 1^{st} premolar.	**Occlusal relationship** <1 mm = satisfactory 1-2 mm = 1 point for each maxillary tooth from the canines to the 2^{nd} molars >2 mm = 2 points for each maxillary tooth from the canines to the 2^{nd} molars
Buccolingual inclination 0-1 mm = satisfactory 1.1-2 mm = 1 point for each posterior tooth >2 mm = 2 points for each posterior tooth *Do not score the mandibular 1^{st} premolars nor the distal cusps of the second molars.	**Interproximal contacts** 0.6-1 mm = 1 point for each interproximal contact >1 mm = 2 points for each interproximal contact
Overjet Anterior teeth must be contacting. 0 mm = satisfactory ≤1 mm = 1 point for each maxillary tooth >1 mm = 2 points for each maxillary tooth Transverse posterior teeth Mandibular buccal cusps are measured to the central fossa of the maxillary teeth.	**Root angulation** Parallel = satisfactory Not parallel = 1 point for each occurrence Root contacting adjacent root = 2 points for each occurrence *Do not score the maxillary and mandibular canines.
Third molars are not scored unless they substitute for the second molars. No tooth is scored more than 2 points per individual parameter.	

To score the ABO-OGS, we used ABO measuring gauge which is consisted of 4 parts as shown in the figure below:

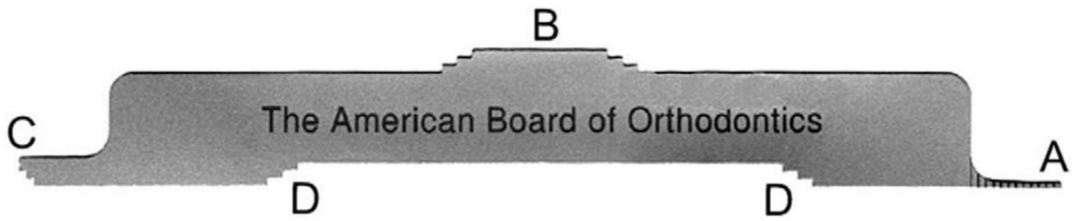

Figure 2 ABO measuring gauge

A is the part that used to measure discrepancies in alignment, overjet, occlusal contacts, interproximal contacts and occlusal relationship. This portion of the gauge is in 1 mm increments and the width of the gauge was 0.5 mm.

B is the part that used to measure discrepancies in mandibular posterior buccolingual inclination. This portion of the gauge is in 1 mm in each step height.

C is the part that was used to measure discrepancies in marginal ridges. This portion of the gauge is in 1 mm in each step height.

D is the part that was used to measure discrepancies in maxillary posterior buccolingual inclination. This portion of the gauge is in 1 mm in each step height.

Then all cases were further divided into three categories for the passed, undetermined or failed status according to the ABO-OGS scores as suggested by Casko et al (4).

An ideal score was 0.

- The passed group contained cases that score 20 points or fewer.
- The undetermined group contained cases that score 21-30.
- The failed group contained cases that score more than 30 points.

Lateral cephalometric analysis

For lateral cephalometric hard and soft tissue relationships: all lateral cephalograms were traced, computerized and analyzed in ABO analysis (57).

The parameters included skeletal measurements: SNA, SNB, ANB, FMA, Wits analysis, dental measurements: maxillary incisors: U1-NA (deg), U1-NA (mm), mandibular incisors: LI-NB (deg), LI-NB (mm), maxillary to mandibular incisor: UI-LI and soft tissue measurements: upper lip to E-line (mm), lower lip to E-line (mm), nasolabial angle (NLA), H-angle.

A normal range of each parameter was obtained from Thai adult norms (58, 61, 62). As suggested by Profit et al (37), treatment changes could occur in two potentially different ways:

- Acceptable: If at the end of treatment, the value of a measure fell within the normal range.

- Unacceptable: If at the end of treatment, the value of a measure fell out of the normal range.

Each parameter in ABO analysis was measured pretreatment and posttreatment periods. Then, the percentage of patients that posttreatment outcomes were in the normal range was calculated.

3.8 Examiner reliability

Inter-examiner and intra-examiner reliability analyses were performed by using Intraclass Correlation Coefficients (ICC).

For measuring DI, PAR index and ABO-OGS

- To assess intra-examiner reliability, one researcher scored pretreatment and posttreatment casts for 20 casts two times within a 1-week interval.

- To assess inter-examiner reliability, two different examiners (researcher and expert orthodontist) scored the same 20 cases independently.

For cephalometric tracing and ABO analysis

- To assess intra-examiner reliability, one researcher traced and analyzed 20 radiographs two times within a 1-week interval.

- To assess inter-examiner reliability, two different examiners (researcher and expert orthodontist) traced and analyzed the same 20 radiographs independently.

The correlation for both intra- examiner and inter-examiner reliability had to be >0.75, indicating good reliability (63).

3.9 Statistical analysis

All data were subjected to statistical analyses using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., Armonk, NY, USA).

Test of normality

Used the Kolmogorov Smirnov test to signify whether the PAR score, DI score and ABO-OGS score were normal distribution.

Descriptive statistics

Descriptive frequencies of patient characteristics (age and gender), Angle's classification (class I, II and III) and types of treatment (camouflage, surgery and 2-phase treatment) were collected.

For PAR index: Descriptive statistics were carried out to determine means and standard deviations for:

- The score of each component in pretreatment and posttreatment periods.
- The total score in pretreatment and posttreatment periods.
- The subcategories of improvement: worse, improved and greatly improved group and descriptive frequencies in each group.
- The subcategories of Angle's classification.

For DI: Descriptive statistics were carried out to determine means and standard deviations for:

- The score of each component and the total score.
- The subcategories of low, medium and high DI group and descriptive frequencies in each group.
- The subcategories of Angle's classification.

For ABO-OGS: Descriptive statistics were carried out to determine means and standard deviations for:

- The score of each component and the total score.
- The subcategories of passed, undetermined and failed group and descriptive frequencies in each group.
- The subcategories of Angle's classification.

For ABO analysis of lateral cephalograms: Descriptive frequencies of each parameter in ABO analysis in which posttreatment outcomes were in the normal range.

Comparative statistics

For PAR index: Comparisons of differences mean by using Wilcoxon signed ranks test between:

- The score of each component in pretreatment and posttreatment periods.
- Total score in pretreatment and posttreatment periods.

For ABO analysis of lateral cephalograms: Comparisons proportion of each lateral cephalometric parameter that fell in the normal range in ABO analysis by using Pearson chi-square test according to:

- Pretreatment and posttreatment periods.
- Treatment type.

Correlation statistics

Used Spearman's rank correlation to determine correlations between:

- Total pretreatment PAR score with total ABO-OGS score.

- Total DI score with total ABO-OGS score.

- Score of each component in ABO-OGS with total ABO-OGS score.

- Pretreatment cephalometric values (ANB, Wits, FMA, UI-NA and LI-NB) categorized by using acceptable range±0.5SD gradually (For example, score 0 indicated pretreatment cephalometric value was in normal range, score -1 and 1 indicated pretreatment cephalometric values were in normal range-0.5SD and normal range+0.5SD, respectively, score -2 and 2 indicated pretreatment cephalometric values were in normal range-(2*0.5)SD and normal range+(2*0.5)SD, respectively.) with total posttreatment PAR score and total ABO-OGS score.

The relationship between variables were generally considered strong when the correlation coefficient (*r* value) was larger than 0.7 (64).

Used univariate and multivariate linear regression analysis to determine correlations between:

- Contributing factors included patient characteristics (age and gender), Angle’s classification (class I, II and III), types of treatment (camouflage, surgery and 2-phase treatment) and treatment duration with total posttreatment PAR score and total ABO-OGS score.

The level of statistical significance for all analyses was set at α=0.05.

Chapter 4 Results

4.1 Demographic data

One hundred completed patient records ranged in age from 9 to 49 years were collected. The mean age of the entire sample was 19.22±7.01 years. The subjects consisted of 58 females and 42 males; 59 samples age under 20 years and 41 samples age 20 years and over; 33 samples had Class I malocclusion, 33 samples were Class II malocclusion and other 34 samples were Class III malocclusion; 47 samples received camouflage treatment, 19 samples received surgery and 5 samples received 2-phase treatment (table 4). The total average treatment duration was 36.28±8.21 months, with a range from 14 to 57 months.

Table 4 Demographic data

Variables		N	Percent
Gender	Female	58	58%
	Male	42	42%
Age	<20 years old	59	59%
	≥20 years old	41	41%
Angle's classification	Class I	33	33%
	Class II	33	33%
	Class III	34	34%
Type of treatments	Camouflage	47	47%
	Surgery	19	19%
	2-phase treatment	5	5%

N sample size

4.2 The scores and correlations of DI and ABO-OGS index.

Intraclass Correlation Coefficient showed very good intra-examiner and inter-examiner reliability in both indices ranged from 0.989 to 0.992. The average DI score for the entire sample was 25.69±16.12 points. The low DI group consisted of 6 patients (6% of cases, 5.50±1.76 points), the medium DI group consisted of 23 patients (23% of cases, 12.35±2.67 points) and the high DI group consisted of 71 patients (71% of cases, 31.72±12.33 points). The DI components that had the highest score were the cephalometrics component (7.93±7.19 points), followed by occlusion (4.72±4.56 points), while the lowest-scoring component was lateral open bite (0.14±0.51 points). Based on Angle's classification, the average DI scores were 15.12±7.05, 30.09±12.93 and 31.68±20.04 points for class I, II and III malocclusions respectively, Table 5, 6.

Table 5 Means and standard deviations of DI score and each component

Variables	Mean	SD	Min	Max
Total DI score	25.69	16.12	2.00	92.00
Overjet	4.56	5.69	.00	38.00
Overbite	1.46	1.92	.00	5.00
Anterior open bite	.95	4.21	.00	40.00
Lateral open bite	.14	.51	.00	2.00
Crowding	2.78	2.54	.00	7.00
Occlusion	4.72	4.56	.00	23.00
Lingual posterior crossbite	.55	1.10	.00	5.00
Buccal posterior crossbite	.60	1.49	.00	8.00
Cephalometrics	7.93	7.19	.00	31.00
Other	2.02	2.00	.00	8.00

SD standard deviation, Min minimum, Max maximum

Table 6 Means and standard deviations of DI score according to subcategories of DI and Angle's classification

DI	N	Mean	SD	Min	Max
Low	6	5.50	1.76	2	7
Medium	23	12.35	2.67	8	16
High	71	31.72	12.33	17	92
Class I	33	15.12	7.05	2	30
Class II	33	30.09	12.93	13	87
Class III	34	31.68	20.04	6	92

N sample size, SD standard deviation, Min minimum, Max maximum

The average ABO-OGS score for the entire sample was 11.38±6.34 points. The passed group consisted of 91 patients (91% of cases, 10.21±4.90 points), the undetermined group consisted of 9 patients (9% of cases, 23.22±7.31 points) and no sample was in the failed group. The ABO-OGS component that had the highest score was marginal ridges (2.39±1.65 points), followed by buccolingual inclination (2.18±1.73 points) and occlusal contacts (1.80±1.98 points), while the lowest-scoring component was interproximal contacts (0.06±0.31 points). Based on Angle's classification, the average ABO-OGS scores were 10.03±5.50, 8.58±4.12 and 15.41±6.94 points for class I, II and III malocclusions respectively, Table 7, 8.

Table 7 Means and standard deviations of ABO-OGS score and each component

Variables	Mean	SD	Min	Max
Total ABO-OGS score	11.38	6.34	2.00	29.00
Alignment	1.77	1.81	.00	8.00
Marginal ridges	2.39	1.65	.00	9.00
Buccolingual inclination	2.18	1.73	.00	8.00
Overjet	.64	1.28	.00	7.00
Occlusal contacts	1.80	1.98	.00	9.00
Occlusal relationship	1.19	1.75	.00	9.00
Interproximal contacts	.06	.31	.00	2.00
Root angulation	1.40	1.42	.00	6.00

SD standard deviation, Min minimum, Max maximum

Table 8 Means and standard deviations of ABO-OGS according to subcategories of ABO-OGS and Angle's classification

ABO-OGS	N	Mean	SD	Min	Max
Passed	91	10.21	4.90	2.00	20.00
Undetermined	9	23.22	7.31	5.00	29.00
Failed	0	-	-	-	-
Class I	33	10.03	5.50	2.00	25.00
Class II	33	8.58	4.12	2.00	17.00
Class III	34	15.41	6.94	5.00	29.00

N sample size, SD standard deviation, Min minimum, Max maximum

The correlation between DI and final total ABO-OGS score was explored with Spearman rank correlation. We found that the correlation was not found to be significant, Table 9. Meanwhile, we found statistically significant positive correlations between every component of ABO-OGS and total ABO-OGS score, Table 10.

Table 9 Spearman's correlation coefficients (*r*) between DI and total ABO-OGS score

	Total ABO-OGS score	
	r	*p*-value
Total DI	.080	.430

*r correlation coefficient, * p-value<0.05*

Table 10 Spearman's correlation coefficients (*r*) between components of ABO-OGS and total ABO-OGS score

	Total ABO-OGS score	
ABO-OGS components	*r*	*p*-value
Alignment	.606	<.001*
Marginal ridges	.671	<.001*
Buccolingual inclination	.316	.001*
Overjet	.569	<.001*
Occlusal contacts	.570	<.001*
Occlusal relationship	.524	<.001*
Interproximal contacts	.224	.025*
Root angulation	.486	<.001*

*r correlation coefficient, * p-value<0.05*

4.3 The score and comparison of PAR index according to treatment periods and correlation to ABO-OGS index.

Intraclass Correlation Coefficient showed very good intra-examiner and inter-examiner reliability in PAR index ranged from 0.889 to 0.993. The average pretreatment and posttreatment PAR scores for the entire sample were 33.53±12.42 and 0.48±0.67 points, respectively. Before treatment, the PAR component that had the highest score was overjet (15.18±9.04 points), followed by displacement (8.13±4.69 points), while the lowest-scoring component was overbite (2.82±2.45 points). After treatment, the PAR component that had the highest score was buccal occlusion (0.44±0.67 points), followed by centerline (0.03±0.17 points). Based on percentage improvement, 77% of the samples were in the greatly improved group, 23% were in the improved group and no sample was in the worse group and the percent improvement of the total sample was 98.57%. Based on Angle's classification, the average pretreatment PAR scores were 26.21±11.67, 36.55±11.98 and 37.71±10.52 points and the average posttreatment PAR scores were 0.36±0.70, 0.55±0.67 and 0.53±0.66 points for class I, II and III malocclusions respectively, Table 11, 12.

Table 11 Means and standard deviations of PAR score and each component

Variables		Mean	SD	Min	Max
Pretreatment PAR score	Total	33.53	12.42	5.00	64.00
	Displacement	8.13	4.69	.00	21.00
	Buccal occlusion	4.31	2.51	.00	10.00
	Overjet	15.18	9.04	.00	30.00
	Overbite	2.82	2.45	.00	8.00
	Centreline	3.32	3.01	.00	8.00
Posttreatment PAR score	Total	.48	.67	.00	2.00
	Displacement	.00	.00	.00	.00
	Buccal occlusion	.44	.67	.00	2.00
	Overjet	.00	.00	.00	.00
	Overbite	.00	.00	.00	.00
	Centreline	.03	.17	.00	1.00

SD standard deviation, Min minimum, Max maximum

Table 12 Means and standard deviations of PAR score according to subcategories of PAR and Angle's classification

PAR	Pretreatment					Posttreatment				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Worse	0	-	-	-	-	0	-	-	-	-
Improved	23	15.96	5.16	5.00	25.00	0	.48	.73	.00	2.00
Greatly improved	77	38.78	8.47	22.00	64.00	100	.48	.66	.00	2.00
Class I	33	26.21	11.67	7.00	45.00	33	.36	.70	.00	2.00
Class II	33	36.55	11.98	13.00	64.00	33	.55	.67	.00	2.00
Class III	34	37.71	10.52	5.00	56.00	34	.53	.66	.00	2.00

N sample size, SD standard deviation, Min minimum, Max maximum

The comparisons of total and each component of PAR scores were explored with Wilcoxon signed ranks test. We found that the scores were statistically significantly decreased in every component and total PAR score after treatment indicating the effectiveness of the orthodontic treatment (*p*-value<0.001), Table 13.

Table 13 Comparison between pretreatment and posttreatment PAR score

	PAR score				
	Pretreatment		Posttreatment		*p*-value
	Mean	SD	Mean	SD	
Total PAR score	33.53	12.42	.48	.67	<.001*
Displacement	8.13	4.69	.00	.00	<.001*
Buccal occlusion	4.31	2.51	.44	.67	<.001*
Overjet	15.18	9.04	.00	.00	<.001*
Overbite	2.82	2.45	.00	.00	<.001*
Centreline	3.32	3.01	.03	.17	<.001*

*SD standard deviation, * p-value<0.05*

The correlation between pretreatment PAR score and final total ABO-OGS score was explored with Spearman rank correlation. The result showed there was no relationship between the two variables, Table 14.

Table 14 Spearman's correlation coefficients (*r*) between pretreatment PAR and total ABO-OGS score

	Total ABO-OGS score	
	r	*p*-value
Total pretreatment PAR score	.190	.059

*r correlation coefficient, * p-value<0.05*

4.4 Interaction of contributing factors on treatment outcomes.

To study contributing factors that might affect the treatment outcomes, regression models were constructed. In the regression models, the posttreatment PAR score and total ABO-OGS score were the dependent variables (outcomes) and their predictors were age, gender, Angle's classification, types of treatment and treatment duration (independent variables). For the posttreatment PAR score, there was only treatment duration that was statistically significant correlated (*p*-value=0.028 and 0.045). The coefficients (**β**=0.018 and 0.017) were positive indicating patients with longer treatment times had poorer treatment outcomes. Other independent variables including age, gender, Angle's classification and types of treatment seemed to be unrelated to the posttreatment PAR score, Table 15.

For ABO-OGS score, univariate linear regression showed patients with Class III malocclusion and patients who received surgery were statistically significant correlated (*p*-value<0.001 and 0.040, respectively). The coefficients (**β**=5.381 and 3.532) were positive indicating that these patients were related to difficulty in getting to an ideal finish. Meanwhile, multivariate regression showed that Class II malocclusion, 2-phase treatment group and treatment duration were statistically significant (*p*-value=0.021, 0.001 and 0.032, respectively). The coefficients of patients with class II malocclusion and patients who received 2-phase treatment (**β**=-6.811 and -8.786) were negative indicating a more ideal finish in these two groups. Whereas the coefficient of treatment duration (**β**=0.177) was positive indicating patients with longer treatment times had poorer treatment outcomes corresponding to the correlation to posttreatment PAR score. Other independent variables including age and gender seemed to be unrelated to the final ABO-OGS score, Table 16.

Table 15 Linear regression analysis for the association between contributing factors to posttreatment PAR score

	Univariate		Multivariate	
Variables	**β** (SE.)	*p*-value	**β** (SE.)	*p*-value
age	.220 (.14)	.109	.071 (.18)	.685
gender	.117 (.14)	.396	.284 (.17)	.073
Angle's classification				
Class I	reference	-	reference	-
Class II	.182 (.17)	.277	-.468 (.36)	.198
Class III	.166 (.17)	.318	-.545 (.35)	.126
Types of treatment				
Camouflage	reference	-	reference	-
Surgery	.205 (.18)	.256	.219 (.20)	.270
2-phase	-.532 (.31)	.090	-.533 (.33)	.108
Treatment duration	.018 (.01)	.028*	.017 (.01)	.045*

Class I Angle's classification and camouflage was the reference group. β *regression coefficient, SE standard error, * p-value<0.05*

Table 16 Linear regression analysis for the association between contributing factors to ABO-OGS

	Univariate		Multivariate	
Variables	β (SE.)	*p*-value	β (SE.)	*p*-value
age	1.960 (1.28)	.129	-1.314 (1.40)	.352
gender	1.931 (1.28)	.133	2.182 (1.25)	.086
Angle's classification				
Class I	reference	-	reference	-
Class II	-1.455 (1.39)	.299	-6.811 (2.89)	.021*
Class III	5.381 (1.38)	<.001*	.743 (2.82)	.793
Types of treatment				
Camouflage	reference	-	reference	-
Surgery	3.532 (1.69)	.040*	.609 (1.58)	.701
2-phase	-5.468 (2.92)	.065	-8.786 (2.62)	.001*
Treatment duration	.138 (.08)	.074	.177 (.08)	.032*

Class I Angle's classification and camouflage was the reference group. β *regression coefficient, SE standard error, * p-value<0.05*

4.5 Lateral cephalometric analysis: comparison of the proportion of each parameter that fell in a normal range according to treatment periods and types of treatment.

For lateral cephalometric analysis, the proportion of each parameter that brought into a normal range was compared by using Pearson chi-square. According to treatment periods, after treatment, there were statistically significant improvements in ANB, Wits, LI-NB (mm), UI-LI, upper lip to E-line and H-angle (p-value<0.01). For other parameters, the majority of patients were also fell in a normal range but not significant, Table 17.

Table 17 Treatment efficacy according to pretreatment and posttreatment periods (percent values within normal range)

Cephalometric parameters		**Treatment periods**				
		Pretreatment		Posttreatment		*p*-value
	Normal range	N	%	N	%	
SNA	81-89	71	71	74	74	.635
SNB	79-85	42	42	50	50	.256
ANB	1-5	35	35	60	60	<.001*
Wits	(-5)-(-1)	26	26	51	51	<.001*
FMA	21-29	51	51	53	53	.777
UI-NA (deg)	24-32	44	44	46	46	.887
UI-NA (mm)	4-8	52	52	58	58	.394
LI-NB (deg)	26-38	61	61	70	70	.181
LI-NB (mm)	4-8	52	52	72	72	.004*
UI-LI	110-126	44	44	73	73	<.001*
E-line U.lip	(-3)-1	43	43	70	70	<.001*
E-line L.lip	0-4	54	54	67	67	.082
NLA	78-100	78	78	78	78	1
H-angle	10-18	55	55	77	77	.001*

*N sample size, * p-value<0.05*

Based on treatment type, after treatment, the results showed there were statistically significant differences in SNB, ANB, Wits and upper lip to E-line among these three groups (*p*-value<0.05). The majority of patients in the surgical group had greater percentages of normal SNB and Wits (84.2 and 78.9%, respectively). For ANB and upper lip to E-line, 80% and 100% of patients in the 2-phase treatment had normal values, meanwhile, patients in the surgical group also had greater percentages of these normal values compared to the camouflage group.

For dental parameters, there was no statistically significant difference among groups (*p*-value=0.065-0.504). The surgical group had a greater amount of normal inclination and position of the upper incisors and position of the lower incisors compared to the camouflage group. Whereas lower incisor inclination was more fell in a normal range in camouflage group. In the 2-phase treatment group, most of the patients had normal values of UI-NA (mm), LI-NB (deg), LI-NB (mm) and UI-LI.

For soft tissue parameters, there was a greater percentage of normal values of upper lip to E-line, lower lip to E-line and NLA in the surgical group compared to the camouflage group. Meanwhile, most of the patients who received 2-phase treatment had normal values of all soft tissue parameters, Table 18.

Table 18 Treatment efficacy according to treatment type (comparison of percent posttreatment values within normal range)

Variables		**Camouflage**				**Surgery**				**2-phase**				***p*-value**
	Normal range	Pretreatment		Posttreatment		Pretreatment		Posttreatment		Pretreatment		Posttreatment		
		N	%	N	%	N	%	N	%	N	%	N	%	
SNA	81-89	31	66	32	68.1	15	78.9	16	84.2	3	60	4	80	.383
SNB	79-85	15	31.9	17	36.2	8	42.1	16	84.2	4	80	2	40	.002*
ANB	1-5	6	12.8	16	34	1	5.3	12	63.2	1	20	4	80	.026*
Wits	(-5)-(-1)	7	14.9	15	31.9	1	5.3	15	78.9	1	20	3	60	.002*
FMA	21-29	22	46.8	21	44.7	12	63.2	14	73.7	2	40	2	40	.087
UI-NA (deg)	24-32	15	31.9	17	36.2	12	63.2	12	63.2	2	40	2	40	.065
UI-NA (mm)	4-8	21	44.7	23	48.9	10	52.6	12	63.2	4	80	4	80	.291
LI-NB (deg)	26-38	28	59.6	34	72.3	8	42.1	10	52.6	3	60	3	60	.295
LI-NB (mm)	4-8	24	51.1	29	61.7	11	57.9	12	63.2	4	80	5	100	.230
UI-LI	110-126	18	38.3	36	76.6	6	31.6	12	63.2	4	80	4	80	.504
E-line U.lip	(-3)-1	20	42.6	26	55.3	10	52.6	18	94.7	2	40	5	100	.002*
E-line L.lip	0-4	26	55.3	31	66	10	52.6	13	68.4	2	40	5	100	.293
NLA	78-100	37	78.7	34	72.3	14	73.7	15	78.9	4	80	4	80	.821
H-angle	10-18	28	59.6	38	80.9	4	21.1	12	63.2	2	40	5	100	.136

*N sample size, * p-value<0.05*

The correlation between pretreatment cephalometric values and posttreatment PAR score was explored with Spearman rank correlation. Only pretreatment FMA value was correlated to posttreatment PAR score significantly (*p*-value=0.029). However, it was just a weak positive relationship (*r*=0.218), Table 19.

Table 19 Spearman's correlation coefficients (*r*) between pretreatment cephalometric values and posttreatment PAR score

	Posttreatment PAR score	
Pretreatment cephalometric values	*r*	*p*-value
ANB	-.003	.976
Wits	-.106	.296
FMA	.218	.029*
UI-NA (deg)	.066	.512
UI-NA (mm)	.082	.415
LI-NB (deg)	-.047	.642
LI-NB (mm)	.150	.136

*r correlation coefficient, * p-value<0.05*

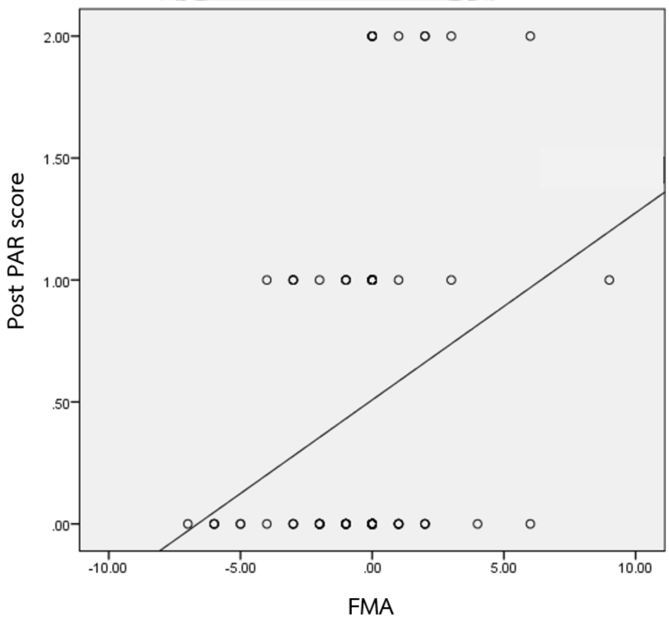

Figure 3 Scatter plot of posttreatment PAR score and FMA with correlation coefficient *r*=0.218

The correlation between pretreatment cephalometric values and total ABO-OGS score was explored with Spearman rank correlation. We found that pretreatment ANB, Wits and LI-NB (deg) values were correlated to total ABO-OGS score significantly (*p*-value=<0.001, <0.001 and 0.012, respectively). Their correlation coefficients were negative (*r*=-0.387, -0.453 and -0.251, respectively), Table 20.

Table 20 Spearman's correlation coefficients (*r*) between pretreatment cephalometric values and total ABO-OGS score

	Total ABO-OGS score	
Pretreatment cephalometric values	*r*	*p*-value
ANB	-.387	<.001*
Wits	-.453	<.001*
FMA	-.023	.817
UI-NA (deg)	.009	.993
UI-NA (mm)	-.052	.607
LI-NB (deg)	-.251	.012*
LI-NB (mm)	-.188	.062

*r correlation coefficient, * p-value<0.05*

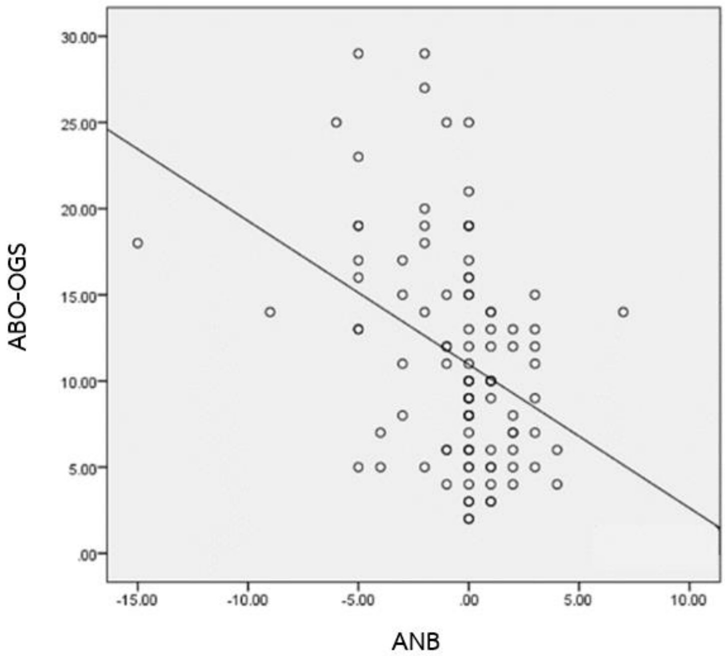

Figure 4 Scatter plot of ABO-OGS and ANB

with correlation coefficient *r*=-0.387

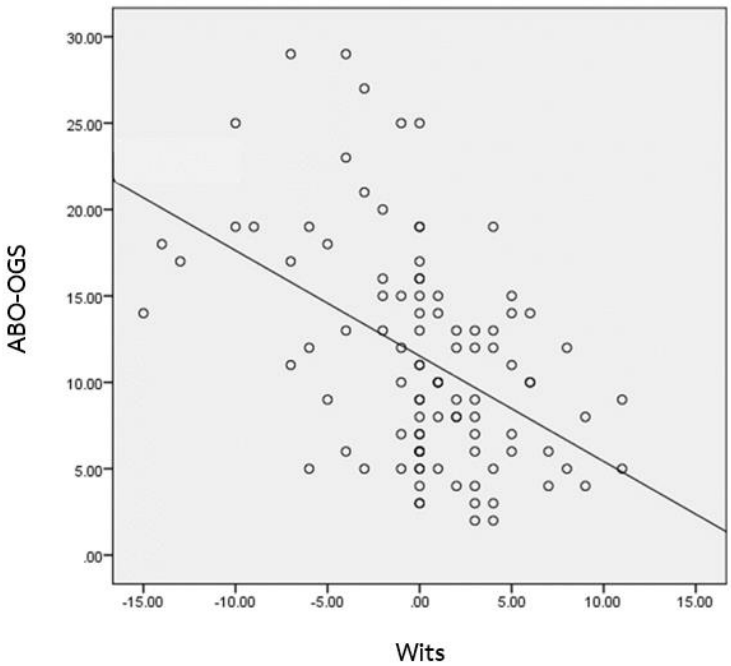

Figure 5 Scatter plot of ABO-OGS and Wits

with correlation coefficient *r*=-0.453

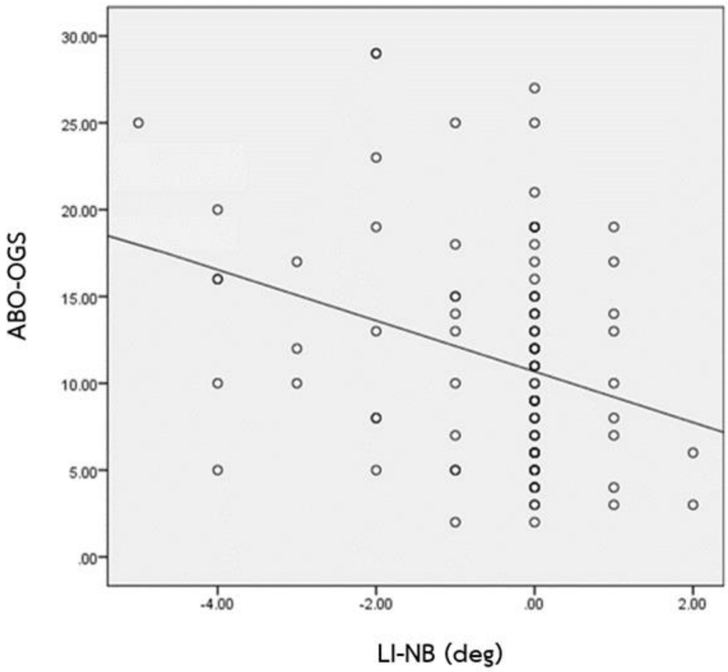

Figure 6 Scatter plot of ABO-OGS and LI-NB (deg) with correlation coefficient *r*=-0.251

Chapter 5 Discussion

We assessed the treatment outcomes of the completed cases treated by orthodontic residents in the faculty of Dentistry, Chulalongkorn University since 2017. Evaluating the quality of treatment outcomes can be used to improve the effectiveness of orthodontic treatment.

This retrospective study found that the average ABO-OGS score for the entire sample was 11.38±6.34 points. 91% of cases received a passing score of ABO-OGS. Only 9% were in the undetermined group and there was no sample in the failed group. These results indicate that the effectiveness of orthodontics treatment is the same quality as the American Board of orthodontic and there were better treatment outcomes compared to previous studies (21, 43). Referring to Sunanta et al (43), they assessed 100 cases treated in the postgraduate orthodontics clinic, Mahidol university using ABO-OGS. They reported 62% of the total cases were in the passed group, 35% were in the undetermined group and 3% were received a failed score. The average ABO-OGS score was 18.79±5.99 points. According to Campbell et al (21), they evaluated 382 patients who finished in the graduate orthodontics clinic at Indiana University School of Dentistry and found that the mean ABO-OGS score was 32.64±13.86 points. Focus on the components of ABO-OGS, the component that had the highest score was marginal ridges (2.39±1.65 points), followed by buccolingual inclination (2.18±1.73 points) and occlusal contacts (1.80±1.98 points) consistent with the results of the previous studies (21, 24, 43, 52). According to Casko et al (4), the marginal ridges of adjacent teeth should be at the same level to provide proper occlusal contacts. The most common problem area was between upper first and second molars. The proper buccolingual inclination of the posterior teeth also contributes to good occlusion. Referring to Durbin and Sadowsky (65), they studied changes in tooth contacts after active orthodontic treatment and found that the number of anterior and posterior teeth contacts were increased after 3 months of the retention period. Compared to Razdolsky et al (66), which found the settling of occlusion due to the biting force in a longer period, 21 months. For buccolingual inclination, it was the highest-scoring component in some previous studies (21, 24, 52). Because of the difficulty in identifying or correcting the problem, the buccal segments were found to insufficient in torque control. In the finishing period, some practitioners might be less careful in placing torque due to the use of the preadjusted appliances. Furthermore, the overcorrection of some appliance prescriptions might relate to improper buccolingual inclination at the end of the active phase (24). On the contrary, the lowest-scoring component was interproximal contacts. The result is the same with ABO field test and several previous studies (24, 25). Because of the ease to detect spacing and orthodontists have the potential to correct this problem. Thus, spacing is not a major problem. For the total ABO-OGS score, we found significant correlations of all ABO-OGS components to the final score agrees with Campbell et al (21).

Before treatment, the Discrepancy Index (DI) was used to evaluate malocclusion complexity. The more scores of the DI, the more complex the case was (16). The entire sample in this study was divided into low, medium and high DI groups. The average DI score was 25.69±16.12 points. Most of the samples (71%) were in the high DI group, 23% of cases were in the medium DI group and 6% of cases were in the low DI group. The DI component that had the highest score was the cephalometrics component (7.93±7.19 points), followed by occlusion (4.72±4.56 points) similar to Pulfer et al (49), while the lowest-scoring component was lateral open bite (0.14±0.51 points). According to Angle's classification, a Kruskal-Wallis test showed a statistically significant difference in the DI scores between class I and class II or class III malocclusion (*p*-value<0.001). Class III malocclusion received the highest average DI score (31.68±20.04 points), followed by class II malocclusion (30.09±12.93

points) and class I malocclusion (15.12±7.05 points). When compare the DI scores based on the result of ABO-OGS score divided into three groups including the passed, undetermined and failed groups, there were no statistically significant differences among these groups (p-value=0.416) as the same results to Sunanta et al (43). Consequently, any of the complexity of malocclusions in the present samples were of potential ABO quality.

For the PAR index, we evaluated both before and after treatment. In this study, the average pretreatment and posttreatment PAR scores for the entire sample were 33.53±12.42 and 0.48±0.67 points respectively. 77% of the samples were in the greatly improved group, 23% were in the improved group and no sample was in the worse group. According to the percentage improvement, the result of this study was 98.57%, which is better than Sohrabi's study (67). He assessed the PAR index in patients treated in the University of Washington Graduate Orthodontic Clinic. The results showed that of the entire patients treated, 48% were greatly improved, 46% improved and 6% of the patients were in the worse group. The average pretreatment PAR score was 26.7±11.7 points, a lower score compared to our study (33.53±12.42 points). Meanwhile, the average posttreatment PAR score was 4.3 ±4.6 points, a higher score compared to ours (0.48±0.67 points).

Another objective in this study was to assess if there were any contributing factors that might affect treatment outcomes. We evaluated the correlation between pretreatment complexity in terms of DI score and pretreatment PAR score to ABO-OGS score. We found that the associations were not found to be significant as the same results to Sunanta et al (43) and Cansunar et al (18) who found no association between the total DI score and the total ABO-OGS score. Meanwhile, Pulfer et al (49) reported weak positive relationships of the total DI score to ABO-OGS score. According to Sohrabi (67), he found a positive and significant (p-value=0.002) association between pretreatment PAR score and ABO-OGS score. It implied that the initial PAR score which indicated the pretreatment complexity of the patient is related to the difficulty of getting an ideal finish. Campbell et al (21) also found a significant association between DI score and ABO-OGS score (*p*-value<0.0001) and the correlation coefficient was 0.20. They indicated that for every 1 point increased in the DI, the ABO-OGS increased by 0.23±0.06 points. They included and evaluated the early debond cases that might promote the high average ABO-OGS score (32.64±13.86 points). The reason for early debonding was the extended treatment time. As stated by Al-Jewair et al (68), the more score of DI attribute to the longer treatment time results in early debond before an optimal result was achieved. Thus, the DI is an important indicator for assessing the difficulty and the more complex malocclusions are challenging to finish well. However, our study excluded the early deboned cases and before debonding cases were examined by the experienced orthodontist to be in the optimal treatment outcomes although they were difficult and complex cases.

For treatment duration, this study found there was statistically significant correlation to the posttreatment PAR score and ABO-OGS score (*p*-value=0.045 and 0.032, respectively). The coefficients (β=0.017 and 0.177) were positive indicating patients with longer treatment times had poorer treatment outcomes. According to Pinksaya et al (69), agreeing that ABO-OGS score showed a progressive diminished clinical outcome of finished cases that were associated with a treatment time increased from 28.9 to 39.3 months due to patient burn-out. More appointments and a significantly extended treatment duration might have been critical to accomplish the final occlusion result in a lesser quality of treatment outcomes (14). However, there was also a study that found no statistical difference in total treatment duration among ABO-OGS groups (43).

The association between Angle’s classification and treatment outcomes is still controversial. Previous research found no statistically significant differences in ABO-

OGS score according to different Angle's classification (14). As reported by Struble and Huang (14), they found that class I malocclusion tends to receive more percentages of patients with passing scores compare to other types of malocclusion. In contrast to our study, we found a statistically significant correlation between class II malocclusion and final ABO-OGS score (*p*-value=0.021). The coefficient was negative (β=-6.811) indicate that patients with class II malocclusion might have a lower final ABO-OGS score compared to class I malocclusion. Meanwhile from univariate linear regression found that in patients with class III malocclusion, there was a positive predictor of ABO-OGS score (β=5.381, *p*-value<0.001) indicate that patients with class III malocclusion seem to have higher final ABO-OGS score compared to class I malocclusion. To treat class III malocclusion is challenging and tends to be more complex and difficult because of genetic inheritance (70). For the correlation between Angle's classification and PAR index, this study found no statistically significant relation (*p*-value=0.198 and 0.126 for class II and class III malocclusions, respectively). In contrast to Birkelane et al (6) which indicated that after treatment, the PAR score displayed greater improvement in Angle's Class II division 1 than Angle's Class I (*p*-value<0.05).

Based on the types of treatment, there were no comparable studies measured by the ABO-OGS index are available. This study found the correlation to treatment outcomes of the surgical group was statistically significant (*p*-value=0.040). The coefficient (β=3.532) was positive indicates that these patients are related to difficulty in getting to an ideal finish. Meanwhile, multivariate regression showed 2-phase treatment group was statistically significant correlated to ABO-OGS (*p*-value=0.001). The coefficient of patients who received 2-phase treatment (β=-8.786) was negative indicates a lower final ABO-OGS score results in a more ideal finish in the 2-phase treatment group compared to the camouflage group. For the correlation between the types of treatment and posttreatment PAR score, this study found no statistically significant relationship (*p*-value=0.270 and 0.108 for surgery and 2-phase treatment, respectively). However, referring to Ponduri et al (12), they compared PAR index outcomes for camouflage and orthognathic surgery patients. The results showed that in the camouflage group, the mean percentage improvement in PAR score was 77% and 2.5% of patients were in the worse group. Meanwhile, the mean percentage improvement of the surgical group was 74% and no patients fell in the worst group. Corresponding to our study, which had the percentage improvement of the camouflage group (98.49%) higher than the surgical group (98.30%). Due to the mean pretreatment PAR score of the surgical group was higher than the camouflage group indicating the more complexity and severity of the surgical cases. This is possibly affected the posttreatment PAR score.

As for age and gender, we found no correlation to either the final PAR score or the ABO-OGS score (*p*-value>0.073). As the same results to Birkelane et al (6), they found that gender did not significantly affect the PAR score. Based on age, we divided the age at start into 2 groups including under 20 years and 20 years and older. The average age of the under 20 years group and the older group were 15.31±3.02 and 24.85±7.30 years, respectively. There were statistically significant intergroup differences (*p*-value<0.001). Agreeing with Sohrabi's study (67), the age of the patients at the start seemed to be unrelated to the final treatment outcomes (β=-0.13, *p*-value=0.18). On the other hand, Onyaeso et al (71) found that the PAR index was sensitive to the pretreatment age. Their results showed statistically significant associations between age at the beginning and the PAR index (*p*-value= 0.010), different from the ABO-OGS (*p*-value=0.926).

After treatment, all cephalometric parameters had a greater percentage of normal values indicates the good quality of the orthodontic treatment. There were statistically significant improvements in ANB, Wits, LI-NB (mm.), UI-LI, upper lip to E-line and H-angle. According to treatment type, our study consists of 47 samples in the camouflage group, 19 samples in the surgical group and 5 samples in the 2-phase treatment group. Due to the small sample size of patients with 2-phase treatment, the result might not have enough power to compare and evaluate the treatment efficacy. However, using Pearson chi-square we found statistically significant differences in the percentage of normal values of SNB, ANB, Wits and upper lip to E-line among these three groups. 80% and 100% of the patients with 2-phase treatment had normal values of ANB and upper lip to E-line, respectively. For the surgical group, the results showed there were greater percentages of patients with normal values of skeletal changes including SNA, SNB, ANB, Wits and FMA compared to the camouflage group. With surgical treatment focus on mandibular setback surgery in patients with class III malocclusion, mandibular advancement in patients with class II malocclusion, or two-jaw surgery, the skeletal relationship would be improved. For camouflage treatment, class II and class III intermaxillary elastics were used in most of the patients and their effects are primarily dentoalveolar. Using class II intermaxillary elastic results in lingual tipping, retrusion and extrusion of the maxillary incisors, labial tipping and intrusion of the mandibular incisors and mesialization and extrusion of the mandibular molars. The extruded maxillary incisors and mandibular molars cause clockwise rotation of the occlusal plane and the mandible (72). There were little effects to soft tissue referring to previous studies reported the increases of upper and lower lip thicknesses of 0.7 and 1.2 mm, respectively (73) and a reduction of the H-angle approximately 1.48 degree (74). For class III intermaxillary elastic, the effects were proclination of maxillary incisors, extrusion of maxillary molars, distal tipping of mandibular molars, extrusion of mandibular incisors result in clockwise rotation of the mandibular plane angle and increase in the lower anterior face height (75). There was one case that used temporary anchorage devices (TADs) for camouflaged class III malocclusion producing distal tipping and intrusion of the mandibular molars, bodily movement of the mandibular incisors and reduced mandibular plane angle. Thus, for patient selection, class III elastics are suitable for low-angle and short-face patients, while TADs are favored for high-angle and long-face patients (76). For dental evaluation, there was no statistically significant difference among groups (*p*-value=0.065-0.504). The surgical group had a greater amount of normal inclination and position of the upper incisors and position of the lower incisors compared to the camouflage group. Whereas lower incisor inclination was more fell in normal range in camouflage group that because before treatment, patients chosen for surgical treatment are prone to have more severe skeletal discrepancies and more compensated incisors than those chosen for camouflage treatment. Thus, the lower incisors in the surgical group might not adequately decompensate to acceptable values, 52.6% in norm. Furthermore, most of the patients in the camouflage group are class II malocclusion so the position of lower incisors was not as severe as in surgical group in pretreatment. Likewise, Troy et al (77) which compared incisor inclination in patients with Class III malocclusion treated with orthognathic surgery or orthodontic camouflage and found no statistically significant difference in incisor inclination and position between the Class III surgical and camouflage groups after treatment. For soft tissue evaluation, there were a greater percentage of acceptable values of upper lip to E-line, lower lip to E-line and NLA in the surgical group indicates better esthetics outcomes compared to the camouflage treatment likewise Georgalis and Woods' study (78). To sum up, these results illustrate that in the camouflage group, the skeletal changes were mostly considered by changes in the mandibular plane angle and changes in the anteroposterior relationship of the skeletal bases were not obvious. It is essential to emphasize that orthodontic camouflage treatment has limited results. Commonly, surgical treatment brings about better skeletal change, normalizing of the skeletal base relationship and a more favorable lips and chin contour. Therefore, surgical treatment is a better option for more severe cases.

Studying the associations between pretreatment cephalometric values and posttreatment PAR. One of the components of the PAR index was buccal occlusion which includes vertical consideration. Pretreatment FMA value was correlated to posttreatment PAR score significantly (*p*-value=0.029) and the correlation coefficient was positive (*r*=0.218). The result indicates that the more pretreatment FMA value, the more posttreatment PAR score. Thus, for the orthodontist, a skeletal anterior open bite is a challenging malocclusion due to the difficulty and instability of treatment (79). However, it was just a weak positive relationship. In respect of the correlation with the total ABO-OGS score, the results showed pretreatment ANB, Wits and LI-NB (deg) values were correlated to the total ABO-OGS score significantly (*p*-value=<0.001, <0.001 and 0.012, respectively). Their correlation coefficients were negative (*r*=-0.387, -0.453 and -0.251, respectively) indicate that patients with skeletal class III malocclusion (lower pretreatment ANB value), dental base class III (lower pretreatment Wits value) and retroclined lower incisors (lower pretreatment LI-NB (deg) value) which is the characteristic of class III malocclusion tend to have higher ABO-OGS score implied to the difficulty in finishing and deficient quality of treatment outcomes. As mentioned before, class III malocclusion had the highest ABO-OGS score (15.41±6.94 points) and there was a statistically significant positive correlation between class III malocclusion and ABO-OGS score (β=5.381, *p*-value<0.001) indicating the difficulty in getting to ideal outcomes for this malocclusion. Whereas Song et al (40) reported class II malocclusion had a slightly greater ABO-OGS score (20.56±8.40 points) than class III malocclusion (19.53±10.02 points). Due to the higher pretreatment severity of class III malocclusion in this retrospective study, this possibly impacts treatment outcomes.

Clinical application

Evaluating orthodontic treatment outcomes measurably and objectively is valuable for educational objectives. The assessments help to develop, maintain an ideal standard and guarantee quality control of the treatment in the postgraduate orthodontic clinic. Moreover, it can identify problems that usually remained after finished the treatment and guide clinicians to recognize, improve and be aware of the deficient specific areas. The ABO-OGS index is the efficient index to use for assessing treatment outcomes. It inclusively assesses all the fine details of dental occlusion and alignment. This index evaluates further the marginal ridge discrepancy, improper buccolingual inclination, spacing and also root angulation than the PAR index assesses. Concerning the factors that might affect the orthodontic treatment outcome is also beneficial. All of the factors mentioned above might have an effect on orthodontics treatment outcomes and should be one of the considerable things when evaluated each completed case. Different treatment type can result in different treatment outcomes. Commonly, surgical treatment brings about better skeletal change, normalizing of the skeletal base relationship and a more favorable lips and chin contour compared to the camouflage group. Therefore, surgical treatment is a better option for more severe cases. Likewise, treatment periods, longer treatment time can affect the quality of treatment outcomes. Thus, the orthodontic treatment outcomes would be better if clinicians can treat the patients in the proper period of time. Considering Angle’s classification, class III malocclusion is the challenging and complex malocclusion to finish with the ideal outcomes.

Limitations and suggestion

The limitation of this current retrospective study is the small amount of the entire sample size and some types of treatment group. Thus, we should further study with larger sample size. Moreover, appropriate other contributing factors including extraction consideration, different mechanics or treatment modalities would need further investigation to compare with orthodontic treatment outcomes. Patient cooperation, which is difficult to control and record, might also affect the results of orthodontic treatment. Furthermore, evaluation of the quality of long-term outcomes in the retention period should also be concerned.

Chapter 6 Conclusion

Based on PAR index and ABO-OGS index, most of the patients treated in the postgraduate orthodontic clinic, Chulalongkorn University had satisfactorily orthodontic treatment outcomes. 77% of the samples were in the greatly improved group of PAR index and 91% received a passing score of ABO-OGS. Focus on the components of ABO-OGS, the most concerning component that might be difficult to finish well were marginal ridges, buccolingual inclination and occlusal contacts. Furthermore, according to lateral cephalometric analysis, the majority of patients were also fell in an acceptable range of every cephalometric parameter after treatment confirmed the favorable quality of treatment outcomes and effectiveness of orthodontic treatment.

Initial Angle's classification, pretreatment values of ANB, Wits, FMA and LI-NB angle, types of treatment and treatment duration were significantly associated with final treatment outcomes. Class III malocclusion, decreased ANB, Wits and LI-NB angle, increased FMA values, patients with surgical treatment related to difficulty in getting to optimal occlusal outcomes. Furthermore, patients with longer treatment times had poorer treatment outcomes probably because of the more pretreatment complexity. Meanwhile, pretreatment complexity assessed by DI score, pretreatment PAR score, age and gender were not associated with the finished quality. From these points of view, we should take contributing factors that associate with the treatment outcomes into consideration for the effective treatment and ideal finish. We also observed that patients with surgical treatment had a greater improved skeletal change, normalizing of the skeletal base relationship and a more favorable esthetics profile.

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APPENDIX

Table 21 Normality test of each index

	N	Normal Parameters		Kolmogorov-smirnov	Asymp. Sig. (2-tailed)
		Mean	SD		
DI	100	25.69	16.12	.146	<.001*
Pretreatment PAR	100	33.53	12.42	.104	.010*
Posttreatment PAR	100	.48	.67	.380	<.001*
ABO-OGS	100	11.38	6.34	.098	.020*

**Normal distribution was rejected when p-value<0.05*

Table 22 Intraclass Correlation Coefficients (ICC) of each index

	Intraclass Correlation	95% Confidence Interval		F Test	
		Lower Bound	Upper Bound	Value	Sig
DI	0.992	.981	.997	133.124	<0.01**
Pretreatment PAR	0.993	.981	.997	134.030	<0.01**
Posttreatment PAR	0.889	.719	.956	9.000	<0.01**
ABO-OGS	0.989	.972	.996	91.289	<0.01**

***ICC was accepted at p-value<0.01*

Table 23 Intraclass Correlation Coefficients (ICC) of lateral cephalometric parameters

	Intraclass Correlation	95% Confidence Interval		F Test	
		Lower Bound	Upper Bound	Value	Sig
SNA	0.990	.975	.996	99.604	<0.01**
SNB	0.983	.956	.993	57.186	<0.01**
ANB	0.995	.987	.998	195.330	<0.01**
Wits	0.998	.994	.999	446.679	<0.01**
FMA	0.996	.991	.999	269.831	<0.01**
UI-NA (deg)	0.998	.996	.999	612.788	<0.01**
UI-NA (mm)	0.996	.989	.998	223.512	<0.01**
LI-NB (deg)	0.997	.992	.999	308.457	<0.01**
LI-NB (mm)	0.992	.981	.997	129.759	<0.01**
UI-LI	0.998	.994	.999	412.443	<0.01**
E-line U.lip	0.989	.972	.996	89.808	<0.01**
E-line L.lip	0.995	.986	.998	182.153	<0.01**
NLA	0.990	.976	.996	104.302	<0.01**
H-angle	0.988	.969	.995	81.063	<0.01**

**ICC was accepted at p-value<0.01

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